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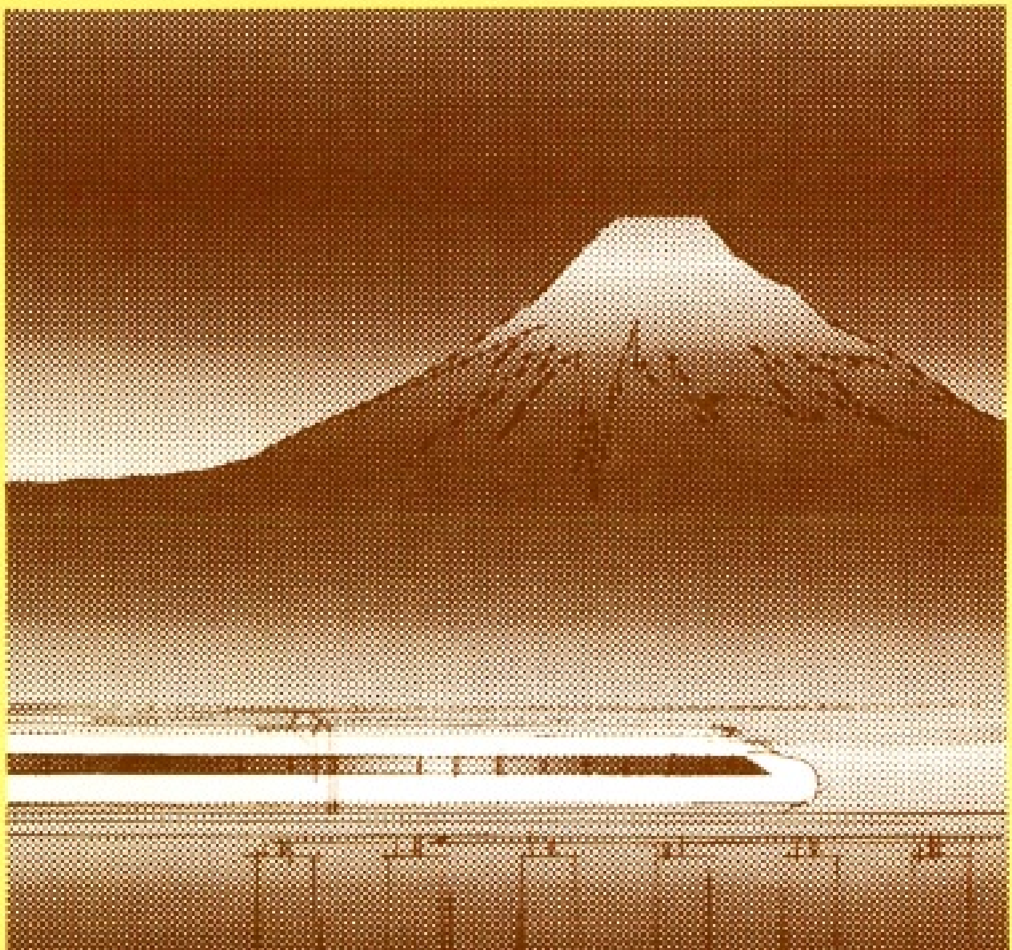
The Shinkansen High-Speed Rail Network of Japan

Proceedings of an IIASA Conference, June 27–30, 1977

A. Straszak and R. Tuch, Editors



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Volume 7

The Shinkansen High-Speed Rail Network of Japan

THE SHINKANSEN HIGH-SPEED RAIL NETWORK OF JAPAN

Proceedings of an IIASA Conference,
June 27-30, 1977

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and
Systems Research Institute
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Preface

The Management and Technology Area of IIASA has been studying large-scale planning programs since early 1975. A major research effort has been devoted in particular to national programs designed to lead to integrated regional development. The first two research efforts in this line dealt with the Tennessee Valley Authority in the United States and the Bratsk-Ilimsk Territorial Production Complex in the Soviet Union.

The general procedure followed was to organize an international conference on the program in question in order to present the basic techniques of the planning and management systems utilized, the organizational characteristics of the programs, and the application of mathematical models and computer systems.

The proceedings of the Shinkansen Conference presented in this volume represent the initial stage of research on the Shinkansen high-speed rail network of Japan and the impact that such a system has had on the mobility of the Japanese people and on the development of regions surrounding the Shinkansen system. The papers presented have served as a basis for more extensive study of the Shinkansen as a system and, together with the forthcoming results of an international field study team of IIASA scientists, should help to clarify both the internal and external effects of a highly efficient and rapid transportation system.

The proceedings focus on the Shinkansen as a planning program for the application of advanced technology in rail transport and its development into a safe, reliable and acceptable means of mass transport in Japan. Of special importance in these proceedings is a compilation of several attempts designed to determine the effect the Shinkansen has had, and will have, on regional and cross-regional development in Japan.

These proceedings present the Shinkansen as a total system of planning, organization and management. All too often transportation systems are examined only as transport systems — separate from the environment in which they operate. Subsequent effects are often not considered during the planning phase and only become evident after the transport system becomes operational. In this respect, the experience of the Japanese in anticipating and in planning for the subsequent effects of a modern transport system may be valuable for many countries considering the introduction of a technologically advanced mass transport system.

The editors wish to thank all of those people involved in both the preparations for the conference itself and for the processing of the proceedings for publication. This includes the secretarial staff of the Management and Technology Area — especially Ms Anna John and Eryl Ley, and the editorial and publication department of IIASA — Ms Jeanne Anderer, Barbara Lewis, and Anne Drew. Without their combined efforts, this volume would not have been possible.

Summary

The Shinkansen Conference was the third IIASA conference on large-scale planning projects. As a new concept of a high-speed, mass-transit railway system, the Shinkansen was originated by the Japanese National Railways (JNR) in the late 1950s, and was pushed through the Japanese governmental and legislative apparatus for approval and financial support in December 1958. Some of this financial support included a loan from the World Bank.

Construction of the first Shinkansen line between Tokyo and Osaka (515 km) commenced in August 1959 and was completed in June 1964. After an initial period for testing and training, the Tokaido Shinkansen was officially opened for commercial operation on 1 October 1964, closely coinciding with the opening of the Tokyo Olympic Games. The original time allocated for all phases of the Shinkansen — research, technological development, and construction — was only 5 years. This target was met with no more than a few months' delay.

The technical and economic success of the Tokaido Shinkansen induced further expansion of the Shinkansen system to include Okoyama, Hiroshima and Fukuoka — a total distance of 1069 km. The Japanese Government, realizing the broad nature of the effects of such a mass transport system as the Shinkansen, passed the Nationwide Shinkansen Law in 1970 — a recognition of regional as well as national demands. It has become evident, however, that the Shinkansen system as a transport technology has generated new environmental and societal problems. In response to these problems, the Japanese Shinkansen program has been debated on all levels of Japanese society and is still topical.

The Proceedings of the Shinkansen Conference concentrate on examining the Shinkansen as a system embedded in the Japanese socio-economic structure, and not as an isolated example of technological applications to rail transport. This technological aspect of the Shinkansen is, of course, included as part of the Conference material, but the main purpose of the Conference was to examine the effect of a system such as the Shinkansen on regional and national development and to determine or indicate how transport systems in general contribute to the growth of a region or nation.

The Conference material is divided into six main sections: general features of the Shinkansen; socio-economic impact: models and applications; environmental problems associated with the Shinkansen; implications of national development in Japan; planning and organization of the Shinkansen; high-speed operation, train safety, and operational management of the Shinkansen.

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ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE SHINKANSEN

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Introduction

1. *Welcoming Address*

R.E. LEVIEN

It is my great privilege to welcome all of you to the Institute for the next few days of discussion on the Shinkansen Project. I feel that this is one of the most interesting of the IIASA conferences scheduled for 1977, and represents the third in a series of conferences on retrospective development programs around the world. My role in introducing the Institute and in welcoming you to it is to provide a background in which the deliberations for the next few days can proceed.

IIASA stands for the International Institute for Applied Systems Analysis. We are a multidisciplinary, nongovernmental international East–West research institute, founded in October 1972 on the initiative of the academies of sciences or equivalent institutions in twelve countries. Current membership now includes scientific organizations from seventeen countries.

As stipulated in IIASA's Charter, "The Institute shall initiate and support collaborative and individual research in relation to problems of modern societies arising from scientific and technological development". There are two aspects of IIASA's research strategy. First, IIASA sponsors interdisciplinary studies of "global" issues, such as energy and food, that directly affect many nations and can be resolved only by their joint action, and of "universal" issues, such as regional development matters, that lie within the boundaries of single nations but which all nations share. Second, there are four research areas that provide the disciplinary base for these interdisciplinary studies. They are:

— Resources and Environment, concerned with the earth's natural endowment;
— Human Settlements and Services, concerned with the earth's human endowment;
— System and Decision Sciences, concerned with mathematical and computational methods of analyzing system and decision problems; and
— Management and Technology, concerned with man-made social, economic, and technological mechanisms.

The fourth research area, Management and Technology, is the sponsor of this Shinkansen Conference. I wish to extend a very warm and personal welcome to all of you for this third in our series of conferences on large-scale regional development, and the impact of major technologies on it. This has been an interesting and important series of activities at IIASA; beginning with our work on the Tennessee Valley Authority in the United States, then the Bratsk-Ilimsk Territorial Production Complex in the Soviet Union, and now choosing the Japanese example of Shinkansen development. I am personally looking forward to this conference and to what we shall learn from the Japanese scientists in their presentations concerning the development of this major transport system and its impact on the regions through which it passes.

2. *The Shinkansen as Part of the Management and Technology Area Studies on Large-Scale Planning Projects*

A. STRASZAK

Large-scale development programs play an increasingly important role in modern societies and economies. The fulfilment of current and future needs of existing societies requires a better utilization of all possible resources: minerals, energy, water, air, as well as labor and technology.

Management of development is a key management problem of today. The diversity of development areas is very broad and each development undertaking has its own nature and rules of the game. Nevertheless, some universal features of large-scale development programs can be found. Management of development must be more and more comprehensive and integrative, more advanced on technical, managerial, institutional and societal levels.

Programs arose as new tools for socio-economic or technological development only a few decades ago. The GOELRO program in the USSR began more than 50 years ago and the Tennessee Valley Authority (TVA) program in the U.S. more than 40 years ago. However, widespread implementation of the development program approach occurred only during the last 10 to 20 years as a result of modern economic and technological achievements and their increasing complexity. Change, progress, and planning are integral parts of our entire way of life and are crucial elements of our managerial process.

It was not by accident that the first major task of the Management and Technology Area has been concerned with large-scale development programs. Regional development carries universal attributes which can be considered by other countries where specific programs are being carried out or considered. Examination of individual regional development programs may permit better planning and management of such large projects — profiting from the experience of others.

It was not easy to choose the proper development programs for our studies. IIASA is a relatively new organization, both in its makeup and its approach to solving problems. We need strong support from scientists from the country in which research is to be undertaken. Previous subjects of our research have been the TVA in the U.S. and the Bratsk-Ilimsk Territorial Production Complex (BITPC) in the USSR. Scientists involved with these programs helped us considerably, both in the preparation of their respective conferences

[1,2] and in the subsequent field study. The present conference is also an example of the cooperation and willingness of Japanese scientists to assist IIASA's research efforts.

The TVA case study was recommended to IIASA by the U.S. National Academy of Sciences. It was to some extent a successful and world-famous program of regional development, unique in U.S. history, and has served as the predecessor of many U.S. regional and national development programs. In addition, specific aspects of this program have been emulated by other nations. The general concept of the TVA was designed by predecessors of today's policy engineers and, of course, it had the highest national policy support.

The BITPC case study was recommended to IIASA by the USSR State Committee for Science and Technology, and is another example of a successful program of large-scale regional development. The BITPC is the predecessor of many regional development programs in the USSR and is a world-famous concept designed for the fulfilment of this program. It has been generalized by Siberian scientists and is now being tested in other regions of Siberia. The Bratsk–Ilimsk program has also been carried out with the highest national policy support.

The methodology of our case studies was developed at IIASA by an international, interdisciplinary team of scientists from both East and West led by Professor Hans Knop, the previous leader of the IIASA Management and Technology Area.

The present case study, the Shinkansen, was recommended to us by the Japan Committee for IIASA. It is a successful program of transport development with an indirect influence on regional development. This is another world-famous example of development undertaking and has also been carried out with the highest national policy support.

The driving forces for the TVA and the BITPC programs were the utilization of water and mineral resources as well as the fulfilment of stated national goals. In the case of the Shinkansen we propose to consider the utilization of human and technical resources and the fulfilment of national goals as the driving force. This conference and the subsequent field study should help in understanding the goals of the Shinkansen.

All development programs considered by IIASA currently and in the future have achieved outstanding worldwide technical advances. For the TVA, technical advances have been made in electric power generation, flood control, fertilizer production, as well as in new agricultural techniques. The Bratsk-Ilimsk experience has led to new technical advances in the construction of industrial complexes such as the world's largest aluminum plant, huge timber complexes, hydroelectric power stations, and electrical generators.

The Shinkansen has also had its share of technical advances, and still represents the peak of technical development in railroad transport technology. This aspect of the Shinkansen will become evident as the presentations are studied.

All of these development programs have made significant contributions to the national and regional economies. The power generation capacity of the

TVA is over 23,000 MW, from hydroelectric and thermal power stations. The value of flood-damage prevention is estimated in excess of 1 billion dollars. These are only a few of the results of the TVA program. The BITPC complex has a power generation capacity of 12,500 MW from hydroelectric stations alone. The timber-processing capacity has reached the level of 7 million m^3 per year.

Both the TVA and the Bratsk–Ilimsk programs have contributed tremendously to national and regional economies in monetary terms. Both of these programs have contributed to national and regional economies in ways difficult to measure. The Shinkansen program is no different: it is well known that it is profitable, with total revenues received of approximately 7.5 billion U.S. dollars. Its extraneous effect on national and regional economies, however, is somewhat difficult to measure, and the problem of determining this is discussed in a separate section.

The TVA and the Bratsk–Ilimsk development programs are considered to be successful, but work on them is continuing. Shinkansen could be considered an exception if one only considers the initial phase of the project as seen in 1958, when only the construction of the Tokyo–Osaka line was proposed. Today, the Shinkansen is a development program with much more ambitious goals and is a topic of considerable debate in Japanese political and social spheres.

It is interesting to note that all of these three development programs considered for study by the Management and Technology Area have an internal goal-setting ability. These large-scale development programs are involved in real socio-economic structures and have their own "rules of the game" which can generate new problems and can even result in some conflicts. We have to consider development programs as a complex socio-economic and technical sub-system, having many interactions with other sub-systems, and its own dynamic and institutional mechanisms.

Our small team cannot yet carry out a full systems analysis of large-scale development programs. We do not have enough manpower, time, money or support; and, on another level, some methodological problems have to be solved.

Given these limitations, we have developed a multifocus and multifactor system of analysis, concentrating on the following aspects of a development program: goals and strategies, organization and planning, models and computer utilization, environmental management, use of technology, and resource management.

For each focus an analytical methodology is developed. This methodology is discussed in several papers by our team members in these Proceedings. It is also possible to consider the Shinkansen as a large-scale transport development program and as a growing large-scale transport system. In this context, the organizational capacity and the ability of the Japanese National Railway (JNR) and the Japanese Government has to be considered as one of the main reasons for the success of the Shinkansen.

If the Shinkansen is considered from a IIASA viewpoint of matrix interactions, as explained by Dr. Levien, our Director, the IIASA matrix structure could be used as a problem generator.

Let us consider, for example, the problem of mobility. The high mobility of the present Japanese population can be partly attributed to the success of the Shinkansen, but without the factor of potential mobility, the Shinkansen would most likely be a failure. Mobility is still increasing in Japan as well as in other countries, and is likely to continue to increase in the next few decades.

Mobility appears to be a function of economic growth, and if we agree with one of the optimistic versions of our future, mobility will increase far more than just up to 100 years. If we agree with the more pessimistic versions of our future, mobility should be limited very soon.

Relations between time, geographical distances and development is a subject of much research. The Shinkansen case study should enhance our knowledge along these lines.

Human settlement patterns also appear to be crucial to transport development. It is probably no coincidence that express motorways started in the Cologne–Bonn region and the Shinkansen in the Tokaido megalopolis. According to some modern researchers, however, Japan is not fully megalopolized. It is not certain that the megalopolis era will be a feature of our future, but the possibility cannot be excluded. It is also possible that the Shinkansen concept may become worldwide.

It is apparent that at this point in our research on the Shinkansen we have more questions than answers. This conference and the field study conducted in late 1977 should give us more answers than questions.

During the three days of this conference we shall have the opportunity to discuss all of these questions with the co-authors of the Shinkansen success and with Japanese experts who have already studied the impact of the Shinkansen.

I would like to thank all of our Japanese delegates for their work in preparation of the papers and for their valuable cooperation.

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General Features of the Shinkansen

3. *History of the Shinkansen*

M. NISHIDA

Introduction

When the Shinkansen started commercial operation between Tokyo and Osaka, a newspaper wrote: "The Shinkansen is a myth of modern times." Mr. Reisuke Ishida, the president of the Japanese National Railways (JNR), however, made the following statement (translation).

> The successful construction of the Shinkansen undoubtedly represents a permanent landmark in railway history, and this can be attributed to JNR's long experience and untiring efforts in technical development. It is by no means the result of chance. I cannot forget the very great hardships endured by those who participated in the work of construction. This can only be described as a desperate fight. When I look at the Shinkansen trains running lightly and smoothly, I am aware of the hopes and the personal dedication of the staff of the project. After five years' desperate fight, the Shinkansen has been brought to successful operation, and we can congratulate ourselves frankly and with pride.
>
> In recent years, the functions of the railway have been rediscovered and re-evaluated. In the U.S.A., railway construction plans, such as the Bay Area Rapid Transit (BART) and the high-speed railway between Boston and Washington, are reported to be making progress. It may well be that the success of the Shinkansen will provide the impetus for a bright future and that the railways of the world are entering a new age.
>
> However, we must not rest on our laurels. The Shinkansen is only one of the means chosen to augment JNR's carrying capacity in the most economic and efficient way. We should not talk about its technical superiority, but use it effectively for carrying passengers.
>
> The reason for constructing the Shinkansen was to increase the carrying capacity of the Tokaido Line, one of the most important conventional trunk lines in Japan, and to free its traffic congestion. About 34% of the total population and 60% of Japan's industrial products are concentrated in the area along this line. The area can well be considered the heart of Japanese industry and economy, and the Tokaido Line can be said to play the role of an artery connecting northern and western Japan. This line, although it was less than 3% of the total national route length, carried 25% of JNR's total volume of traffic. The threat to Japan's national life if this Tokaido Line should be blocked rendered construction of the Shinkansen a matter of extreme urgency. Thus, the Shinkansen was never meant to compete with

the airplane and the automobile in luxury and speed, but to meet the traffic demand, qualitatively and quantitatively. The Shinkansen adopted the standard gauge so that JNR's highly developed technology could be utilized in the new system.

The Shinkansen has proved to be an epoch-making means of transportation owing to its high speed, safety, comfort, punctuality, and frequency. Its advent can be considered a revolution in the history of the railway.

To achieve a technological innovation in the context of social development, such factors as demand, technical feasibility, and the technical skill and level of the work force are three basic prerequisites. However, I should like to add three more factors: organizing ability (ability to create new objectives and to organize manpower); economic power (ability to raise the necessary funds); and the determination and drive of top management.

Government backing and favorable public opinion are also desirable. Regrettably, these were not clearly seen in the early days of the project.

Transportation in Japan

Japan is situated in the western part of the Pacific Ocean and to the east of the Asian Continent, and consists of four main islands — Honshu, Hokkaido, Shikoku and Kyushu — and about 1000 small islands in the form of an arc.

The total area of this archipelago is approximately 370,000 km^2 and the population is 110 million. Most of the population is concentrated on the four main islands, especially on Honshu. Honshu is a long, narrow island extending from north to south, with mountain ranges running through its center and long, narrow plains along the coast.

The Pacific coast area is blessed with a milder climate than the Japan Sea coast area and, therefore, major cities such as Tokyo, Nagoya and Osaka are located on this side. Consequently, the principal means of transportation are also well developed along this side. The distribution of means of transportation in Japan is shown in Tables 3.1 and 3.2.

TABLE 3.1. *Distribution of means of transportation for passenger traffic (in 10^5 passenger-km)*

	1960	(%)	1965	(%)	1970	(%)	1975	(%)
JNR	1240	51	1740	45	1897	32	2153	30
Private railways	604	25	814	21	991	17	1085	15
Buses	440	18	802	21	1029	17	1101	16
Private cars and taxis	115	5	406	11	1814	31	2508	35
Airlines	7	-	29	1	93	2	191	3
Ships	27	1	34	1	48	1	66	1
Total	2433	100	3825	100	5872	100	7104	100

TABLE 3.2. *Distribution of means of transportation for freight traffic (in 10^5 t-km)*

	1960	%	1965	%	1970	%	1975	%
JNR	536	39	564	30	624	18	466	13
Private railways	9	1	9	1	10	-	8	-
Trucks	208	15	484	26	1359	39	1297	36
Domestic freighters	616	45	806	43	1512	43	1836	51
Total	1369	100	1863	100	3505	100	3607	100

Japanese National Railways

The first railway in Japan was opened by the State between Tokyo and Yokohama in 1872. Since then, the State Railways developed as a system operated by a government department until 1949, when the present Japanese National Railways (JNR) was established as a public corporation under the Japanese National Railways Law. With its capital wholly invested by the State, JNR is operated under the supervision of the Ministry of Transport.

The route length is about 21,000 km; roughly 28,000 trains run every day, and the number of employees is about 430,000. In recent years the revenue has been about 2000×10^9 yen, with expenditure exceeding this figure by about 30%. Measures to improve the financial situation are therefore being investigated, such as state subsidies and increased charges. However, the basic passenger and carload freight rates are determined by the National Diet in accordance with the provisions of the Japanese National Railways Tariff Law, and the Minister of Transport authorizes revisions of passenger and freight charges.

Of the total route length of 21,000 km, about 36% is electrified and approximately 26% is double or quadruple tracked. About 13,000 men are assigned to such work as electrification, double tracking and the construction of the Shinkansen, and about 800 are engaged in research and development work at the Railway Technical Research Institute.

Railway-Downfall Theory

The phrase "Railway-Downfall Theory" became popular some 25 years ago, when civil aviation reopened in Japan (1951) and super-highway construction plans began to be discussed.

The theory is that, just as horse-drawn carriages and sailing ships were superseded by trains and steamships early in the nineteenth century, the latter half of the twentieth century sees the supremacy of automobiles and airplanes, and the railway is now on the road to decline and extinction. About a quarter of a century ago, automobile production was gradually increasing and the construction of superhighways was about to start. Many people, impressed by the high speed of the airplane, concluded too hastily that the improved roads would render the railways useless. Many JNR personnel even took a negative view of the future of the railway.

The "High-Speed National Road Law" and "National Land Development Traversing Road Law" were passed in 1957 and construction of the national superhighway network began. The construction of Japan's first high-speed toll road started between Tokyo and Kobe through Nagoya: the Nagoya–Kobe section and the Tokyo–Nagoya section opened in 1962 and 1965, respectively.

Congestion on the Tokaido Line — Inability to Meet the Traffic Demand

The area along the Tokaido Line (590 km, from Tokyo to Kobe) is about 60,000 km^2, only 16% of the total area of Japan. This area, however, includes three of the four great industrial zones of Japan and seven of the ten large cities with a population of one million or more. In this area, the population density is 2.6 times that of the national average and accounts for 34% of the nation. The economy is therefore brisk, and the industrial output and national income produced in this region represents over 60% of the whole country. The volume of traffic on the Tokaido Line has therefore always been remarkably high, accounting for 25% of the passenger traffic and 24% of the freight traffic, and their large annual increment was also noticeable. In comparison with the annual national growth rate of 6.1% for passenger and 4.1% for freight, that of the Tokaido Line was 7.6% and 4.8%, respectively.

The Tokaido Line lies in the center of the JNR network, acting as the main artery of national transportation. Blockage of this line would paralyze the transport system of the entire nation. JNR made every effort to keep the traffic flowing by such measures as construction of additional tracks, electrification and other improvements, giving it priority over other lines. However, the maximum daily number of trains that could be operated one way on a double-tracked railway was 120, with passenger and freight trains operating together and trains of different speeds — limited express and express — operating simultaneously. The Tokaido line, in 1952, was approaching this upper limit.

Improvement Study

In May 1956 JNR set up the Tokaido Line Build-Up Investigation Commission and launched a comprehensive study, under the direction of the Vice President of Engineering, of the following: future traffic demands, quality transportation service, measures for increasing transport capacity, and type of motive power, rolling stock, repair system, etc., to adopt.

After a year of study, the forecast of traffic demand was completed and the need to increase transport capacity was agreed, but the decision to adopt narrow or standard gauge was not yet taken. In view of the enormous cost of the project, irrespective of the gauge chosen, the Commission concluded that the subject should be dealt with as an integral part of the Government's national transportation policy, in parallel with superhighway construction and other plans.

In July 1957 Mr. Shinji Sogo, then President of JNR, asked the Government to study improvements of the transport capacity of the Tokaido Line.

Technical Feasibility — 3 Hours from Tokyo to Osaka

A little earlier, in May 1957, a public lecture was given at the Railway Technical Research Institute to commemorate its 50th anniversary, and the subject was "The High-Speed Railway of the Future", based on studies undertaken at the Institute. The gist of the lecture was that results obtained from technological studies on rolling stock, track, electric facilities, etc., indicated that it was possible to cover the 550 km between Tokyo and Osaka in 3 hours by electric train, at a maximum speed of 250 km/h. This was an epoch-making announcement. I was then a young researcher, studying systems engineering at the Institute, and I certainly found the idea quite unbelievable. My main reasons were:

The maximum speed of any train in the world at that time was 160 km/h.

One year earlier, the French National Railways attained a maximum speed of 331 km/h in an experiment, but it was reported that sparks had quickly melted the trolley wire.

It was generally believed at that time that even if a speed of 200 km/h or more were possible, the repair of tracks and trolley wires, etc., would cost too much and the railway would not pay.

The Railway Technical Research Institute proposed to create a completely new technology and standards, for all the facilities — track, signal, trolley wire, safety devices, etc. — far from traditional railway concepts. Those responsible were fully confident in announcing an entirely new image of the railway and its technical possibilities.

The Government's Decision

The Minister of Transport, accepting JNR's request, established the JNR Trunk Line Investigation Commission in August 1957. The Commission, after 2 years of survey, made the following decisions at intervals as follows:

November 1957

A new Tokaido Line should be constructed and the start of construction work should be hastened, in view of the anticipated blockages on the existing Tokaido Line and the time required for construction.

March 1958

The new line should be standard gauged.

April 1958

The necessary funds would be 194,800 million yen, the expenditure being fully covered by future revenue.

The Government, from the findings of the JNR Trunk Line Investigation Commission, set up a Council of Ministers Concerned in Transportation in the Economic Planning Agency, but it was not until December 1958 that they decided to construct the Shinkansen.

The reason for this delay was to make sure that the investment in construction of the Shinkansen would not conflict with that for the superhighway from Tokyo to Kobe, which was already under way.

Narrow or Standard Gauge? — Resolution by Top Management

The first railways in Japan were narrow gauge and almost all subsequent railways were therefore constructed in narrow gauge, except for some private railways and subways in and around large cities. The JNR lines were constructed in narrow gauge without exception. There was, however, an argument for rebuilding them standard gauge to increase transport capacity. Within JNR the factions for and against standard gauge had been arguing some 60 years ago.

Since then, the JNR network had extended all over the country and reconstruction in standard gauge had become impracticable. In any case, after the war, JNR had to concentrate on restoring facilities devastated by the war or simply worn out. A new standard-gauge railway on a completely new system was out of the question. However, Mr. Shinji Sogo, then President of JNR, had been an advocate of the standard gauge all his life, and was waiting for the opportunity to adopt it.

As for measures to increase the transport capacity of the Tokaido Line, the first question was whether or not the new line should be built side by side with the existing line. There were 122 stations on the Tokaido Line between Tokyo and Osaka, each of them situated at the center of a city. It would therefore be difficult and costly to acquire the necessary land for a new line in the city areas along the existing line. Moreover, the Tokaido Line had level crossing over roads at 1100 places, which would impede high-speed trains. It was therefore decided to take a different route for the new line.

Next, the pros and cons of narrow and standard gauge were studied. Construction and rolling stock for narrow gauge is cheaper than for standard gauge. But when a new line is constructed in narrow gauge, it has to be connected at some places to the existing line; otherwise it would not make sense to make the line uniformly narrow gauge. It would then be necessary to construct connection facilities, and the cost would increase accordingly.

The AC system of electrification was ascertained to be more economic than the existing DC system. From an overall point of view the standard gauge was judged more advantageous for transport capacity, train speed, construction cost, etc. One disadvantage of the standard gauge, that it could not be connected to the existing narrow-gauge line to move rolling stock from one line to another, could be overcome by improving facilities for passenger transfer. Thus, the adoption of the standard gauge was decided.

However, many JNR personnel opposed the standard-gauge proposal on the grounds that the construction of the 500-km-long railway would cost a vast amount; that building the new narrow-gauge line parallel with the existing line would enable the work to advance gradually, in step with the amount of money available; and that the new line could be utilized immediately after completion of each section.

The selection of the new railway was one of the most important decisions for national transportation policy as well as for JNR management. If Mr. Sogo had not been the highest executive, the conclusion would have been quite different and the Shinkansen would probably never have been constructed. He convinced many opponents of the idea within JNR and outside; he pursued the bold course of constructing the Shinkansen in a difficult financial climate; and he achieved its realization. Now, he is much admired for his far-sightedness, and his achievement must be a supreme example of the importance of a top executive's judgement and courage based on long-term vision and firm management philosophy.

Five Years for Construction

JNR started construction of the Shinkansen in 1959, aiming at completion within 5 years. The predicted volume of traffic demanded completion at the earliest possible date, and a period of 5 years was estimated to be required for the construction of the Shin-Tanna Tunnel (7950 m) — the bottleneck of the whole line.

However, it would be an unprecedented achievement to complete a 500-km-long railway for a perfectly new system in such a short time, while simultaneously developing new technology. Five years was by no means a generous estimate since, for example, land purchase, civil engineering, work on the electric facility, signals and station facilities all had to be carried out in stages, even when the final details had been planned.

Just about that time I was transferred from the Railway Technical Research Institute to Tokyo Shinkansen Construction Division as a chief engineer. Frankly, I had no idea whether the project could be completed by the target date or whether the speed of 200 km/h would be possible after the construction had been completed.

To create something great, a long period of research is usually required before starting the actual work. But in this case construction work had to be started immediately. Therefore, the working schedule, limited to 5 years, was planned so that the research work would finish early enough to avoid delaying any construction work; and each phase of construction work was adjusted to finish within a minimum period so that the necessary time for research could be ensured.

When adopting new technologies, it is essential to make field tests to check safe operation, since the first duty of a railway is to operate with perfect safety.

The following progress was made between the survey and research stage and the start of commercial operation:

Survey and research started	April 1958
Purchase of land and construction started	August 1959
Model track completed and test run started	June 1962
A record of 256 km/h speed established	March 1963
Line completed and training operation started	June 1964
Commercial operation started	October 1964

All branches of the JNR — research, planning, execution, civil engineering, electrification, rolling stock, train operation, etc. — united their efforts, explored the unknown and created an entirely new railway. Tribute should be paid to their great efforts and pioneering spirit which accomplished the project, quite apart from the tremendous value of the railway itself.

Basic Study and Accumulation of Technology

Some part of the success of the Shinkansen was due to the body of basic study and technology on the existing narrow-gauge lines which had been amassed over many years.

The high speed of 200 km/h was expected to create many problems, in such areas as train-running resistance, vibration and brakes. Consequently, such fundamental problems as the contact relations between rail and wheel, pantograph and trolley wire had to be solved, and, of course, the structure of the track and rolling stock demanded special attention. Also, to ensure safety at high speed, an automatic brake control was required in order to avoid depending upon fallible human judgement. Certain basic studies initiated by JNR in 1945 were of great value in integrating comprehensive technologies. They comprised:

study of rolling stock for comfort;
development of AC electrification technology;
study of new track — concrete sleepers, long rails, etc.;
study of application of electronics.

One factor that contributed to the success of the Shinkansen's high speed and safety was that, on the basis of these studies, each technology was developed to the same level and harmoniously integrated into one system.

The Railway Technical Research Institute

The Railway Technical Research Institute's publication of its studies on the technical feasibility of linking Tokyo and Osaka in 3 hours encouraged the start of construction of the Shinkansen. This Institute played an important role in technical developments and in subsequent studies on the test track. If I remember correctly, the Institute then had over 1000 researchers and assistants. Frankly speaking, they were by no means well paid, owing to the difficult financial situation of JNR in those days. They were working in old and cramped buildings with antiquated research facilities, and suffered from scanty research funds.

Mr. Sogo made the important decision to increase research funds considerably and to construct a new Research Center on a large area in the suburbs of Tokyo. Researchers moved into the new facilities in October 1959 and started energetically to develop a new railway system in the well-equipped Research Center.

Raising the Construction Funds

The cost of constructing the Shinkansen was at first estimated at 194.8×10^9 yen and the whole sum had to be borrowed. The funds were raised in the form of government loan, railway bonds and a low-interest loan of $80 million from the World Bank.

Surveying, planning, study, technical development and construction all proceeded simultaneously, and the work schedule was limited to a short period of time. Consequently, the land-purchasing cost drastically increased. Moreover, owing to changes in construction plans and the sharp increase in domestic prices of commodities and wages, the total cost amounted to 380×10^9 yen, twice as much as originally planned. This increase in construction cost was met by additional borrowing.

The drastically increased cost coincided with a train collision in a suburb of Tokyo in which many passengers were killed or injured. Mr. Sogo consequently retired from the presidency of JNR after 8 years of service (two terms) with the Shinkansen very near completion. His retirement was much regretted by all who had been engaged in this project which he had done so much to promote.

The New System and the Operational Organization

The organization of a new system for management and safe operation of the Shinkansen was an epoch-making event in JNR's 100-year history.

The traditional car-inspection system, for example, had been to inspect the cars from top to bottom, one at a time. Under the new system, the bogie and the car body are separated and the bogie is thoroughly inspected and repaired, while the car body, after a somewhat simpler inspection, is mounted on a spare bogie which has already been inspected and repaired, and thus the car leaves the shed and returns into service without delay.

The traditional method of inspecting track and trolley wire depended on human hands and eyes. Under the new system, an inspection car is run continuously at high speed to check and accurately record the conditions of the facilities and, if anything is found wrong, it is repaired immediately by repair groups.

The Shinkansen is more than a high-speed railway; its special features are safety, comfort and punctuality, made possible by its method of operation, which combines new technologies and systems.

Conclusion

The creation of the Tokaido Shinkansen represents a revolution in land transportation which was brought about by the technology of JNR and the courage and hard work of its personnel. The successful operation of the Shinkansen has firmly established the importance of Japanese railway technology throughout the world.

After inauguration, the new railway was extended to 1000 km, and another 800 km are now under construction. About 1700 km are under survey and study; construction work and early completion are earnestly awaited by residents along the projected routes. In some districts, however, residents along the Shinkansen route are taking legal action against JNR on the grounds that their environment is being disrupted by the noise and vibration of speeding trains. JNR is therefore making efforts to develop methods to minimize such noise and vibration, and noise-proof walls are being installed along the line. In some cases houses are purchased outright by JNR, or compensation is paid.

In conclusion, I sincerely hope that the results of the experience obtained by Japan's Shinkansen will be of value to the studies of all concerned.

4. *Installations, Operation, and Management of the Shinkansen*

Y. OGURA and S. YAMANOUCHI

Organization for Control and Operation

Unlike the narrow-gauge lines, which are organized regionally, the Shinkansen, using standard gauge, is operated and controlled as a complete line, in order to make full use of its outstanding characteristics as a means of high-speed mass transport. However, the entire network of the Japanese National Railways (JNR) will be in ideal working condition only when the Shinkansen and the narrow-gauge lines are operated together. JNR is therefore coordinating the Shinkansen operation with the narrow-gauge lines. Moreover, to avoid duplicating passenger services between the two systems, such local operations as facilities for passengers at stations and relief and repair work are performed under the supervision of the Railway Operating Divisions in charge of the narrow-gauge lines.

The Shinkansen personnel alone number about 15,000 men, to run 275 trains a day covering a total distance of 180,000 km.

Transportation Plan and Train Diagram

TRANSPORTATION PLAN AT THE TIME OF CONSTRUCTION

Construction of the Shinkansen was planned on the basis of a traffic volume determined by the Trunk Line Investigation Committee set up within JNR in 1957. Passenger and freight traffic along the vitally important Tokaido Main Line had been steadily increasing (see Table 4.1), passenger traffic reaching 24% and freight 23% of the total domestic traffic. Train frequency was expected to reach the upper limit in the 1960s. Estimated traffic volume was 13,000 million passenger-km for the opening year 1964 and 20,000 million for 1975. Although the traffic did not reach the estimated figure during the first years, the rate of increase later rose far above the estimate, and in 1975 reached about twice the estimated figure for the Tokyo–Shin-Osaka Section.* The amazing growth of the national economy was undoubtedly responsible for this.

*Shin-Osaka is the name of the station in Osaka City.

TABLE 4.1. *Traffic on the Tokaido Main Line prior to opening the Shinkansen*

Fiscal year	Passenger traffic					Freight traffic							
	JNR (a)		Tokaido Main Line (b)		Ratio	JNR (a)		Tokaido Main Line (b)		Ratio	Number of down trains between Numazu and Shizuoka		
	Passenger-km (millions)	Index	Passenger-km (millions)	Index	(b/a) (%)	Ton-km (millions)	Index	Ton-km (millions)	Index	(b/a) (%)	Passenger trains	Freight trains	Total
1950	69,100	100	15,300	100	22.2	33,300	100	5900	100	17.7	31	27	58
1951	79,000	114	17,400	113	22.0	39,900	120	7600	128	19.1	-	-	
1952	80,500	117	18,700	122	23.2	39,300	118	8500	143	21.6	-	-	-
1953	83,600	121	19,500	127	23.3	41,000	123	9000	151	22.0	38	38	76
1954	87,000	129	20,300	132	23.3	39,900	120	8700	147	21.8	40	40	80
1955	91,200	132	21,400	140	23.5	42,600	131	9500	160	22.3	41	43	84
1956	98,100	142	23,300	152	23.7	46,900	141	10,700	183	22.8	46	47	93
1957	101,200	146	24,100	158	23.8	48,200	145	11,000	186	22.8	53	52	105

TRAFFIC VOLUME AND CAPACITY AFTER THE OPENING YEAR

The number of passengers carried on the Shinkansen rapidly increased after its opening and recently reached over 150 million a year (see Fig. 4.1). The total passengers carried since its opening in 1964 exceeded 1000 million on 25 May 1976. Since the line was extended to Hakata in March 1976, it has begun to average about 500,000 passengers a day, with the record number of 1,030,000 passengers a day on 5 May of that year. It has become the most important rail line in Japan and, although it accounts for only 5.6% route-km of the total JNR system, it carries 25% of the JNR traffic volume.

TRAIN DIAGRAMS AFTER THE OPENING

The train diagram of the Shinkansen has been rewritten 16 times to meet the traffic demand. At the same time the train diagram of the narrow-gauge lines was revised to fit the new diagrams of the Shinkansen and carry on the high-speed train service of the entire network. Consequently, in 1975 the number of scheduled trains had increased four-fold and train-km eight-fold, compared with the opening year 1964. Typical diagram revisions are as follows:

1 October 1964 (for the opening). The number of scheduled trains per day was 60 up- and down-trains operating in a 1–1 pattern, or in a pattern of one Hikari and one Kodama every hour. The traveling time between Tokyo and Shin-Osaka was held down at 4 hours by the Hikari and 5 hours by the Kodama owing to poor roadbed conditions.

1 November 1965. Progress in improving the track condition reduced the traveling time to 3 hours and 10 minutes by Hikari and 4 hours by Kodama, as originally planned. The pattern was then changed to 2–2, i.e. two Hikaris and two Kodamas every hour.

15 March 1972. With the Shinkansen extended down to Okayama from Shin-Osaka, train operations in the 4–4 pattern began. At first, through operation of the Hikari between Tokyo and Okayama was not considered feasible, and three types of operation for these trains, with variations in the number of stopping stations, was decided.

10 March 1975. On completion of the Shinkansen, a little over 1000 km between Tokyo and Hakata, the timetable of JNR, including the narrow-gauge lines, was drastically revised. A 5–5 train diagram pattern was first adopted for the Shinkansen. Four Hikaris and four Kodamas, at most, were operated to augment its transport capacity.

As a rule, through operation of the Hikaris leaving and arriving at Tokyo station for and from a station below Shin-Osaka was scheduled in a train-stopping pattern, W, A, B and H (see Fig. 4.2).

In July 1975 the diagram was rewritten again. Today nine trains are operated every hour on the Shinkansen: five Hikaris at most and four Kodamas. They are run at the rate of 275 a day, which is almost the limit of the Shinkansen capacity.

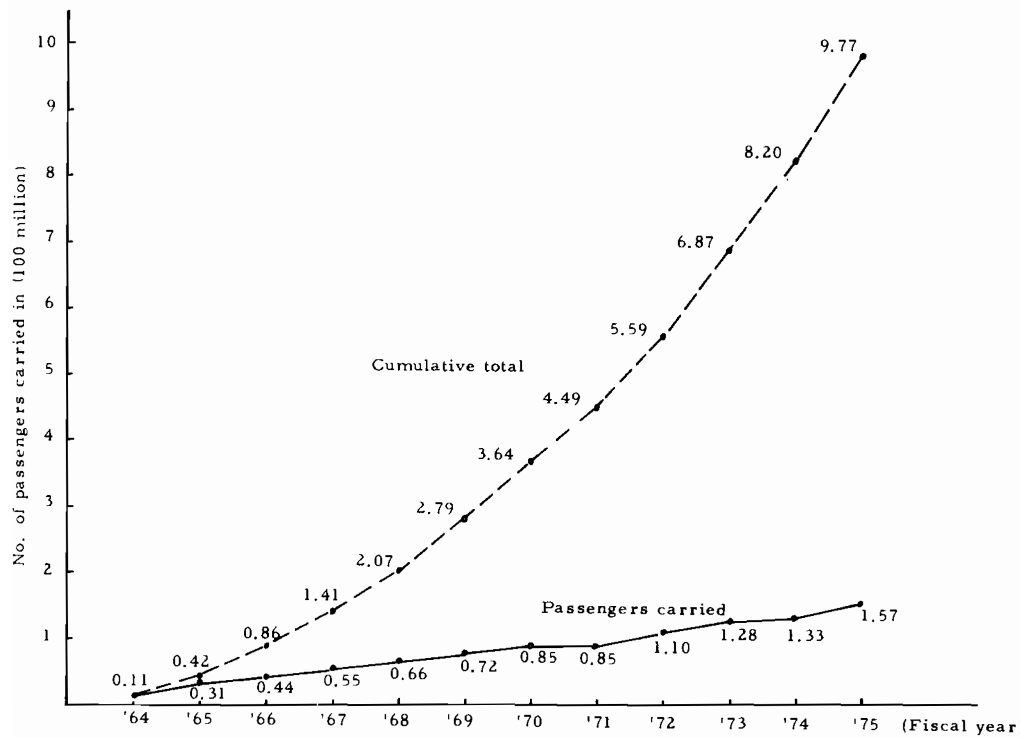


Fig. 4.1. Annual increase in number of passengers carried on the Shinkansen.

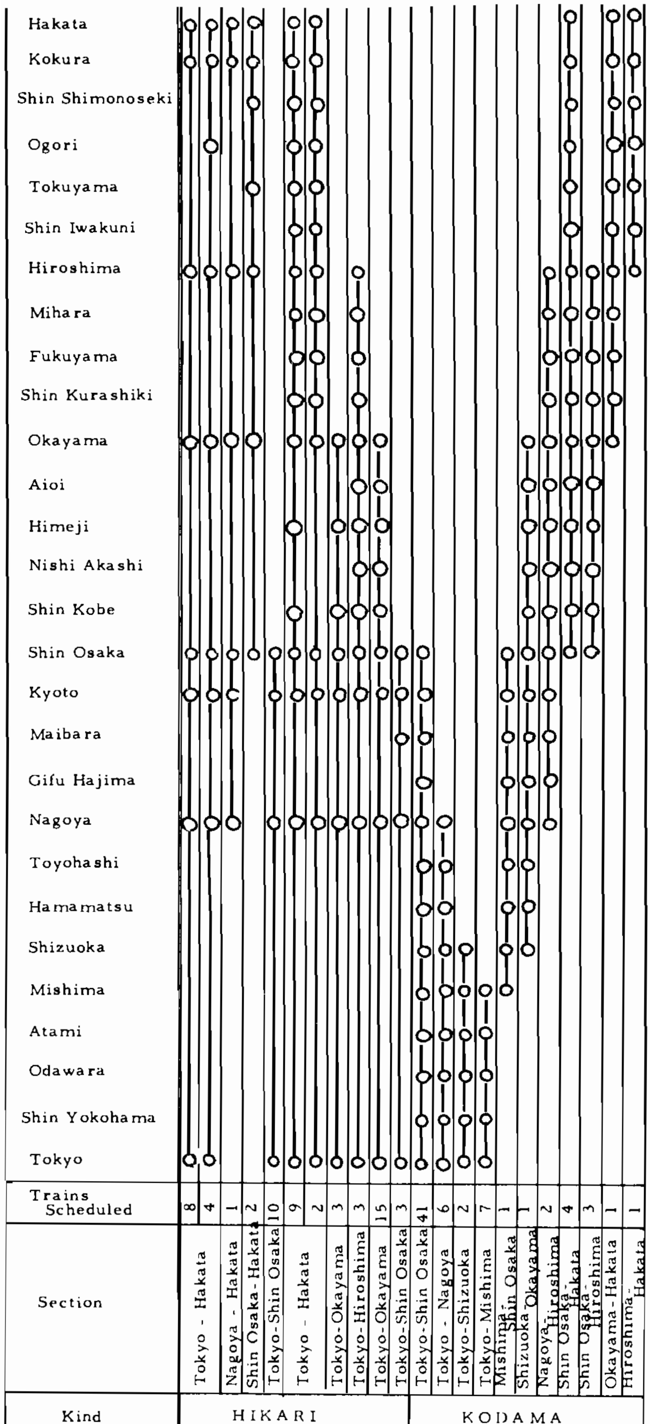


Fig. 4.2. Train stopping stations (as of March 1975).

Transportation Control

DISPATCHING SYSTEM

The outstanding features of the Shinkansen are high speed, mass transport, and high efficiency. The trains are run at the top speed of 21 km/h, with an average distance between stations of 40 km. For smooth operation, therefore, the trains must be meticulously controlled and the data needed for dispatching must be collected and transmitted promptly and accurately. A General Control Center links up all trains in operation, stations, operating depots in the field, and the Railway Operating Divisions, which collect and transmit data. The salient points of the Shinkansen dispatching system are given below.

United control of the whole line. The whole line of some 1100 km is under the united control of the General Control Center.

Overall dispatching. Passenger service dispatchers, train operating dispatchers, track and structure dispatchers and electric dispatchers are all housed under the same roof; this enables them to keep in touch at all times.

Direct dispatching. The General Control Center and the trains operating on the line are linked by train wireless. (Dispatch data are transmitted to the narrow-gauge line trains via the stations.) Thus, dispatching instructions are transmitted directly.

DISPATCHING FACILITIES

For the operation of the Shinkansen dispatching system (see Fig. 4.3 for a diagram) as described above, up-to-date technical devices and several kinds of dispatching installations have been introduced, which are described in detail in the paper by Y. Ogura, Chapter 34 of these Proceedings. Briefly, they are as follows.

Centralized Traffic Control (CTC). There are indication panels and control panels for safe and efficient operation and control of all the trains in groups.

Centralized Substation Control (CSC). This is for the operation and remote control of all unmanned substations and their sectioning posts.

Computer-Aided Traffic Control (COMTRAC). To deal with the growing number of trains, the diverse types of trains in use, and the increasing complexity of the dispatching work, computers have been introduced which control train routes automatically and adjust train operation efficiently. The new system has been in regular operation since 1975.

Train wireless. Connected directly to the General Control Center, train wireless is fully exploited in assisting the work of the dispatchers. Part of the circuit is used for the public telephones aboard the trains.

Equipment for emergency use. To protect trains in case of earthquakes and heavy rain, seismometers, rain gauges and anemometers are set up along the line to transmit data to the General Control Center, so that emergency action can be taken.

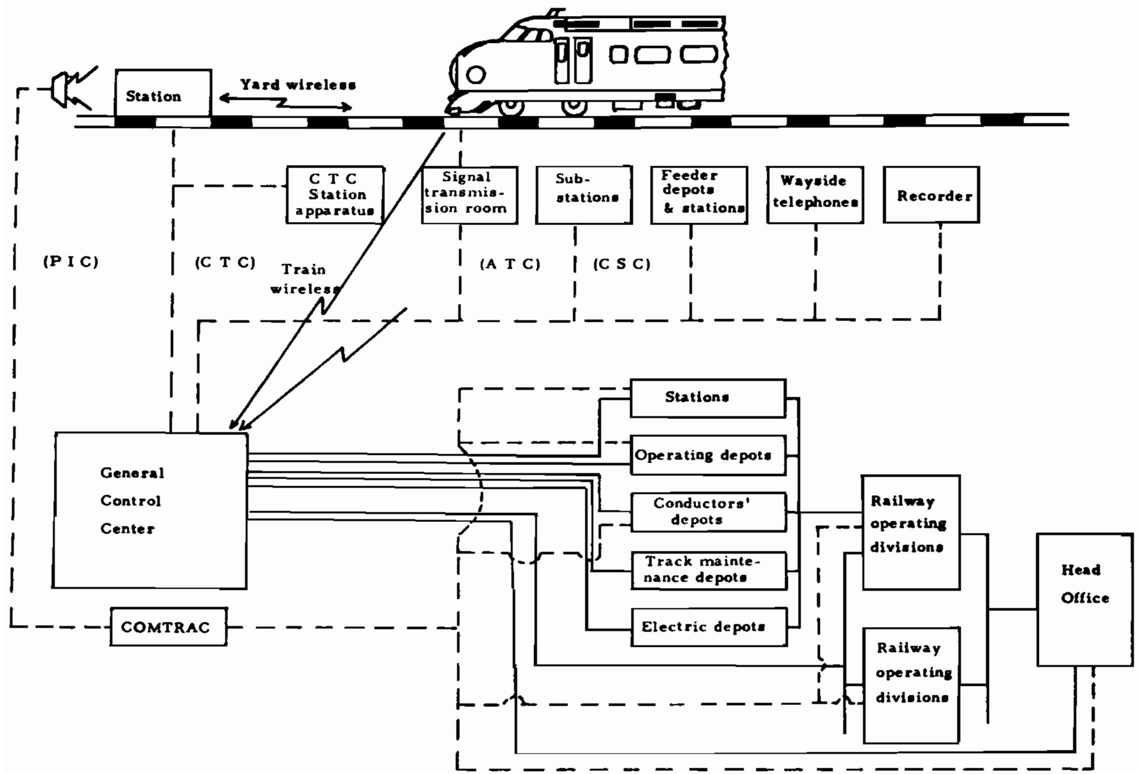


Fig. 4.3. Block diagram of Shinkansen dispatching system.

Operation Safeguards

BASIC CONCEPT OF SAFEGUARDS

A safeguards system has been adopted for the Shinkansen high-speed trains. Six basic points of the system are:

1. To design and manufacture rolling stock and facilities which will ensure safety and comfort on trains operating at a maximum speed of 210 km/h.
2. To introduce high-level technology for the safety devices so that the operators' dependence on their own attention and judgement can be mitigated by multiple automatic operational systems for vital functions, which would enhance the reliability of machinery. (That is, safety devices are made fail-safe.)
3. To repeat model testing for the safety of track and rolling stock until safe performance is confirmed.
4. To provide higher education and training for the operators and improve their qualifications for service on high-speed trains, thus adding to their integrity and judgement.
5. For protection against natural disasters, such as storms and flood, to provide adequate facilities, taking local conditions and past records into consideration.
6. For prevention of interruptions to the service due to obstacles such as automobiles and rocks lying on the track, to set up guard rails and nets and to enforce regulations against trespassing on the track.

TRAIN OPERATION SYSTEM

Spacing control of the distance between trains and control of train routes are basic safety requirements. These are enforced by the following:

Train distance spacing control. Instead of the signal system, which depends on a man's eyesight (as for the narrow-gauge lines), the Shinkansen operation has adopted the ATC system. Under this system, operations such as reducing speed from 210 km/h to 30 km/h (depending on the distance between two running trains) and bringing a train to a stop behind the preceding train are performed automatically, so that all trains running can be kept a certain distance apart, according to their speed. For further safeguarding, should ATC fail, JNR has an alternative system ready to go into action for emergency train operation.

Train route control. Train route control and collection of data on train operation are performed by CTC. In 1972 COMTRAC was introduced to set train routes automatically and increase the safety of operation.

The deceleration control of trains on the Shinkansen is almost completely automated under ATC, CTC and COMTRAC. Still to be automated are: acceleration control, adjustment of train operation time, braking for coming to a stop at a station, and operation of trains during an emergency, all of which are still performed by the motorman.

TRAIN ACCIDENTS AND INTERRUPTION OF OPERATION

Railway accidents are extremely rare on the Shinkansen, and no passengers have been killed or injured since its opening in October 1964. (As more than 1000 million passengers had been carried by May 1976, the standard of safety of the Shinkansen can be considered high.) There was, however, a high rate of operation interruptions in the initial period, though they had no very far-reaching effects. The number of interruptions rapidly decreased, and today, the cases per million train-km is only about a quarter of those on the narrow-gauge lines, which is a very satisfactory situation. However, the effect of the large number of trains on the line every day cannot be ignored, and overall improvements are now in progress, with 60-kg rails replacing the earlier ones, roadbed and ballast improved and renewed, contact wire replaced by wire of larger cross-section, etc.

Passenger Service

The Shinkansen runs through the most densely populated area in the world and its passenger revenue represents over one-third of the entire passenger revenue of JNR. Two kinds of train are operated: the Hikari and the Kodama, both of which run between Tokyo and Shin-Osaka. Between Shin-Osaka and Hakata, however, the Hikaris usually run from Tokyo for through operation. The stopping stations and the traveling hours of the Hikari and the Kodama are shown in Fig. 4.4. The traveling time of the fastest trains between Tokyo and Hakata is 6 hours, 56 minutes and the scheduled speed is 155 km/h. The number of passengers alighting and boarding are shown by station in Fig. 4.5.

ROLLING STOCK

The Hikari and the Kodama are both sixteen-car trains. The Hikari, with a seating capacity of 1342, is made up of eight ordinary cars with all reserved seats, four ordinary cars with unreserved seats, two "green" cars (with higher-grade accommodation, corresponding to previous first class), a diner, and a buffet car. The Kodama, with a seating capacity of 1483, consists of four ordinary cars with reserved seats, ten with unreserved seats, one "green" car and one buffet car. All the ordinary cars have five seats sideways with an aisle between two seats and three seats; the "green" cars have four seats sideways with an aisle between. There is a lavatory and a wash room to each unit of two cars. The Hikari cars have accommodation for the handicapped.

TRAIN SERVICES

The Shinkansen was built primarily for long-distance traveling, hence, it is not available to season-ticket holders, but only to ordinary passengers, coupon-users, group tourists and parties traveling on a reserved car basis.

A passenger pays the basic fare plus the limited express surcharge. The basic

Station (City population in thousands)	Distance	Traveling time
Hakata (1002)		
	55. 9km	31m.
Kokura (1058)		
	20. 7km	11m.
Shin Shimonoseki (267)		
	47. 9km	22m.
Ogori (17)		
	41. 1km	19m.
Tokuyama (107)		
	38. 1km	18m.
Shin Iwakuni (111)		
	44. 2km	18m.
Hiroshima (853)		
	60. 2km	26m.
Mihara (84)		
	27. 9km	13m.
Fukuyama (330)		
	31. 0km	14m.
Shin Kurashiki (393)		
	25. 8km	13m.
Okayama (513)		
	55. 0km	25m.
Aioi (42)		
	20. 0km	10m.
Himeji (433)		
	31. 1km	14m.
Nishi Akashi (235)		
	22. 2km	11m.
Shin Kobe (1325)		
	32. 6km	15m.
Shin Osaka (2717)		
	39. 1km	18m.
Kyoto (1452)		
	68. 1km	27m.
Maibara (13)		
	41. 1km	18m.
Gifu Hajima (409)		
	25. 1km	13m.
Nagoya (2073)		
	67. 8km	26m.
Toyohashi (285)		
	35. 3km	16m.
Hamamatsu (468)		
	71. 5km	27m.
Shizuoka (445)		
	56. 1km	23m.
Mishima (89)		
	15. 9km	10m.
Atami (51)		
	18. 7km	11m.
Odawara (174)		
	51. 2km	24m.
Shin Yokohama (2573)		
	25. 5km	18m.
Tokyo (8424)		

Traveling time (Hikari sections):

Hakata – Kokura	32m
Kokura – Hiroshima	1 h. 12 m.
Hiroshima – Okayama	56 m.
Okayama – Shin Osaka	58 m.
Shin Osaka – Kyoto	17m
Kyoto – Nagoya	48 m.
Nagoya – Tokyo	2 h. 01 m.

Hikari (Tokyo - Okayama)	4 h. 10 m.
Hikari (Tokyo - Hakata)	6 h. 56 m.
Kodama (Tokyo - Shin Osaka)	4 h. 14 m.
Kodama (Shin Osaka - Hakata)	4 h. 40 m.

Fig. 4.4. Distance between Tokyo and Hakata: traveling time and city population.

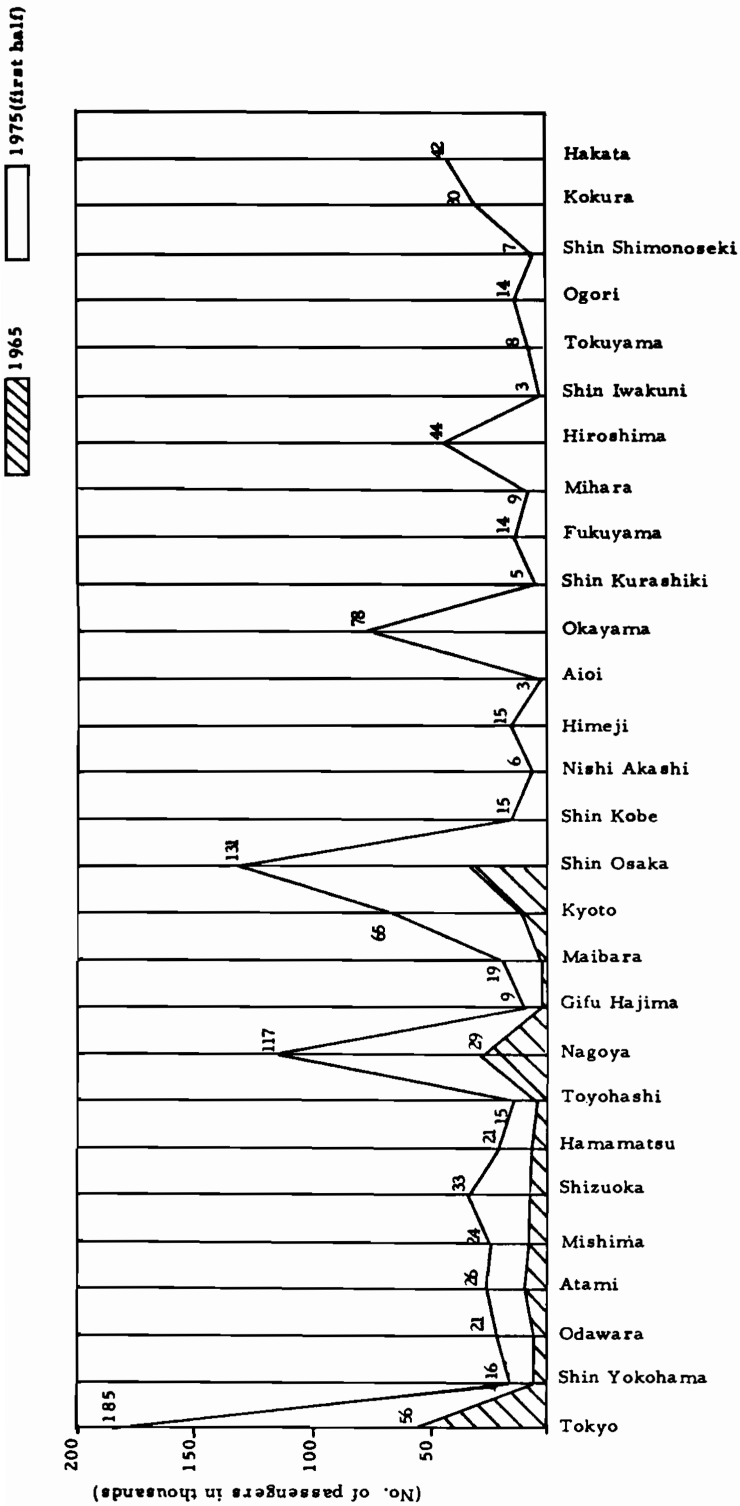


Fig. 4.5. Alighting and boarding passengers by stations (average per day).

fare and surcharge are the same for the Hikari and the Kodama, and transfer may be made from one to the other. For a seat in one of the unreserved cars, the limited express surcharge is 200 yen less than for the reserved section, and the limited express surcharge for a seat on a connecting narrow-gauge line train is 50% less. If a Shinkansen train is delayed by more than 2 hours the passengers are refunded the full amount of the limited express surcharge.

SALE OF LIMITED EXPRESS TICKETS

Limited express tickets for both the Shinkansen and the narrow-gauge line trains are sold (up to a week in advance sometimes up to three weeks) before the date of departure through the Magneto-Electronic Automatic Reservation System (MARS) at the Green Windows* in stations and at the offices of authorized travel agencies.

CATERING SERVICE

The Hikari has a diner coupled on for meals at all times. Both the Hikari and the Kodama have a buffet car for snacks. Lunch, coffee, tea, fruit juices, beer, cigarettes, etc., are also available from vendors aboard the train. Public telephones are installed aboard from which passengers can reach the principal cities along the line.

Rotation

MOTORMEN

Two motormen are assigned to each Hikari between Tokyo and Shin-Osaka. The Kodama has a motorman and an inspector for running inspection, but the motorman on the down-train is relieved at Nagoya, and the motorman on the up-train at Shizuoka. The Hikari through trains between Shin-Osaka and Hakata are manned by two motormen all the way. All other Hikaris and all the Kodamas originating from or terminating at one of the intervening stations in the Shin-Osaka–Hakata Section are manned by one motorman and one inspector, the motorman being relieved both ways at Hiroshima station.

About 1200 motormen are assigned to the Tokyo, Osaka, Hiroshima and Hakata bases. The running inspectors number approximately 300. As long-run rotation is adopted, one man's duty period averages 410 km a day.

TRAIN CREW

The standard crew for both Hikari and Kodama is four, normally consisting of one Chief Conductor, two Supervisory Conductors and one Conductor. The total number of train crew is about 1400. Their trips are so arranged that

*Ticket offices where reservations are made, so called because of their green front.

their duty period averages 7 hours a day through 4 weeks. The conductors' depots are located at Tokyo, Osaka, Hiroshima and Hakata. The W-type Hikari crew between Tokyo and Hakata is relieved at Shin-Osaka.

ROLLING STOCK

At present the Shinkansen vehicles total 2336 in 146 train sets, as shown in Fig. 4.6, a six-fold increase over the number during the initial period. Of these, about two-thirds are for the Hikaris. The vehicles are distributed among the three bases in Tokyo, Osaka and Hakata, where they are daily inspected, repaired and cleaned for use the next day.

The main details of Shinkansen electric railcar rotation are as follows:

The two kinds of trainset, Hikari and Kodama, are used as units in rotation.

The operating kilometerage of each train is very high, reaching about 1300 km per day.

By using pools under COMTRAC, a higher serviceability coefficient and greater efficiency in inspection and repair is attained.

The fluctuation of seasonal and week-end travelers and tourist parties complicates the rotation of electric railcars.

The daily inspection is performed during the non-operational night period.

When shuttling, all the trains are cleaned and serviced. This makes for faster car rotation, especially at Tokyo station.

The number of space cars for replacement of those undergoing inspection and repair is 9-12% of the total Shinkansen vehicles.

Fixed Installations and Rolling Stock

TRACK AND STRUCTURES

The Shinkansen between Tokyo and Shin-Osaka, extending 516 km, was completed in 5½ years, beginning in 1959. The construction cost 380,000 million yen. Its extension from Shin-Osaka to Hakata, 562 km, took 8 years, beginning in 1967, and cost 942,000 million yen. The construction criteria for the Tokyo–Shin-Osaka Section and for the Shin-Osaka–Hakata Section are compared in Table 4.2. The Shin-Osaka–Hakata Section was constructed with a future increase in train speed taken into consideration. As it was constructed for a planned speed of 250 km/h, it was designed with larger minimum curvature radius, a less steep maximum gradient, and larger longitudinal curvature radius and a distance between track centers than the Tokyo–Shin-Osaka Section.

The percentages of various track structures are shown in Table 4.3. The topography of the Shin-Osaka–Hakata Section called for many tunnels, accounting for as much as 50% of the whole line. Fewer embankments and more viaducts man stronger track structure. The track is designed to endure an axle load of 16 tons and, for high-speed trains, 43 sleepers per 25 meters are used. Between Tokyo and Shin-Osaka, 53-kg rails were laid, but in view of the rising costs of maintenance and since higher-speed operation was envisaged,

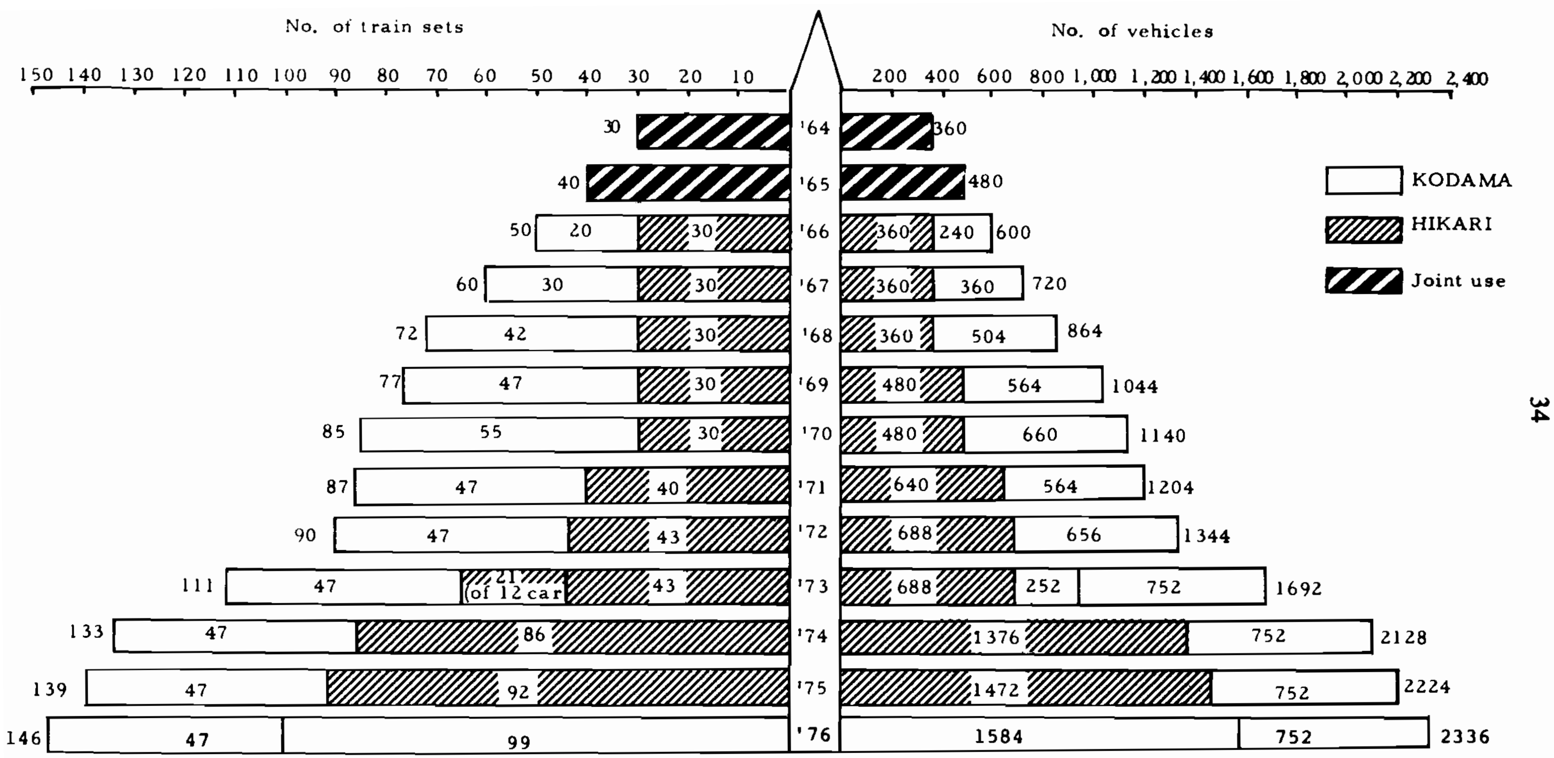


Fig. 4.6. Number of train sets and vehicles.

TABLE 4.2. *Comparison of construction criteria*

Item	Tokaido Shinkansen (Tokyo–Shin-Osaka)	Sanyo Shinkansen (Shin-Osaka–Hakata)
Planned max. speed, km/h	210	250
Gauge, mm	1435	1435
Min. curvature radius, m	2500	4000
Max. gradient, o/oo	20/1,000	15/1,000
Longitudinal curvature radius, m	10,000	15,000
Distance between track centers, mm	4200	4300
Formation level breadth, m	10.7	11.6
Rails	50T (53 kg/m)	60 kg/m

TABLE 4.3. *Use of various track structures*

Kind	Tokaido Shinkansen (Tokyo–Shin-Osaka)		Sanyo Shinkansen (Shin-Osaka–Hakata)	
	(km)	(%)	(km)	(%)
Embankment, etc.	274	53	70	12
Viaduct	116	23	164	29
Bridge	57	11	48	9
Tunnel	69	13	280	50
Total length	516	100	562	100

60-kg rails were laid between Shin-Osaka and Hakata. Those between Tokyo and Shin-Osaka are now being replaced by 60-kg rails. As rail joints promote discomfort and encourage track deterioration, long rails, about 1.5 km long, have been laid with expansion joints fitted at both ends. For the roadbed between Tokyo and Shin-Osaka, crushed stone ballast was used. However, as the track deteriorates faster than expected and as maintenance cost is high, slab track has been adopted as the standard for the Okayama–Hakata Section, with very good results. For the turnouts, the movable nose crossing is used, so that the train can run smoothly at over 200 km/h on the straight side of the turnout.

STATIONS

There are twenty-eight passenger stations and eight rolling stock bases between Tokyo and Hakata. The principal terminals, Tokyo and Shin-Osaka stations, have three platforms with five tracks and three platforms with six tracks, respectively; the other stations at which all trains stop have two island platforms with four tracks. The intermediate stations have a side platform with pass-through track, although, for topographical reasons, Atami and Shin-Kobe stations have only the main line.

The minimum curvature radius at and near some stations is smaller than that of the main line, since many obstacles occur in downtown districts. The effective length of the main line is 500 m and that of the platforms 410 m, with an allowance of 10 m given for the effective length of a train measuring 400 m.

FIXED ELECTRIC INSTALLATIONS

The Shinkansen is electrified with single-phase AC, 60 Hz, 25 kV. For the power supply to the overhead wire system, feeder substations are set up every 20 km on the Tokaido side and every 50-70 km on the Sanyo side to maintain the required voltage. Switching sections are also set up so that the trains can pass through the sections by power running. The overhead wire system between Tokyo and Shin-Osaka is of the composite compound type; for that between Shin-Osaka and Hakata, the so-called heavy compound type has been adopted.

ROLLING-STOCK BASES

These bases are set up at various places, according to the forms of transport, local conditions, rolling-stock rotation and staffing situations. They are intended to accommodate rolling stock, make up trains, undertake servicing, inspection and repair, and attend to the needs of the powered-car crews.

For maximum efficiency in reassembling cars for train makeup, shifting cars from one track to another, and all the operations that have to be performed during inspection and servicing, the tracks must be laid in the most systematic possible way, within the limitations imposed by the requirements for entry and departure tracks, inspection and servicing tracks and accommodation track.

ROLLING STOCK

All cars on the Shinkansen are motorized. A train is made up of 16 cars with a motorman's cab at both ends. Its total length is 400 m, the longest electric railcar train in the world. Electrically, two cars make a unit. The ATC apparatus is installed on the first car of the train. Table 4.4 compares the main elements of the apparatus on Shinkansen trains with those of narrow-gauge line trains.

Fixed Installations and Rolling-Stock Maintenance

FIXED INSTALLATIONS

To operate the Shinkansen safely every day, every effort is made to know the condition of each fixed installation, to introduce machine power to the greatest possible extent, and to carry out reasonable maintenance work on the line at those times of night when no trains are running. The maintenance bases are laid out at key points along the line. The conditions of the track and electric fixed installations are inspected by the general electric and track inspection cars, rail-flaw detector car, and by patrolling. Based on the data obtained, the plans for servicing the track and electric fixed installations are drawn up. Efficient maintenance work is facilitated by the use of multiple tie tampers, track liners, an overhead trolley tretching car, a maintenance car of electric facilities and other large machines.

TABLE 4.4. *Main elements of the Shinkansen railcar train compared with narrow-gauge line train*

Type	Shinkansen railcar train	Narrow-gauge train of 485 type
No. of main motors	4 × 2 cars	4 × 2 cars
Output (1 unit)	Continuous rating 185 kW × 8 = 1480 kW	Hourly rating 120 kW × 8 = 960 kW
Main motor type	MT 200 MT200A MT200B	MT54B MT54D
Max. operating speed	210 km/h	120 km/h
Gear ratio	22:63 = 1:2.17	22:77 = 1:3.50
Control system	Low-voltage tap changer type	Rheostat series parallel control, weak field, 40%
Wheel diameter	910 mm (870 mm for calculation)	860 mm (820 mm for calculation)
Brake system ATC	Electro-magnetic-controlled pneumatic brake (for all speed ranges)	
Manual handling	Electric brake (over 50 km/h) in combination with electro-magnetic-controlled pneumatic brake for all speed ranges	Electric brake (over 30 km/h) in combination with electro-magnetic-controlled pneumatic brake for all speed ranges
Train set output	6M, 1480 kW × 8^{unit} = 11,840 kW	8M4T, 960 kW × 4^{unit} = 3840 kW
Weight	970 t (16 cars with seat capacity load)	529 t (12 cars with seat capacity load)
Output per ton	12.3 kW/t	7.3 kW/t

ROLLING STOCK

The unique character of the Shinkansen required a new and unconventional approach to the inspection and repair of its rolling stock. The following principles were adopted: the most durable and reliable materials must be used and all electric apparatus must be equipped with protective devices. A special "bogie inspection" of the main motors, bogies and running gear, which are the most important components in ensuring safe operation, must be made every 300,000 km between general overhauls. These general overhauls, of other less vital components, take place every 900,000 km. Details of the inspection system are given in Table 4.5.

The main characteristics of Shinkansen rolling stock maintenance are as follows:

Maintenance of ATC pick-up apparatus

The ATC apparatus, which is of great importance in ensuring safe operation at 210 km/h, has numerous electronic parts. As these parts can be used over a long period and are not particularly subject to passive wear-out, they are not disassembled at each inspection period, although their working operation and characteristics are checked.

Maintenance of bogies and running gear

As fail-out is likely, bogies and running gear are inspected and repaired with scrupulous care under an elaborate system. For maximum use of the costly train set, the carbody is removed from its bogie and mounted on another,

TABLE 4.5. *Details of the Shinkansen inspection system*

Kind	Description	Frequency of inspection	Where inspected
Daily inspection	Inspection prior to use of the car exterior; replenish expendable items at a certain frequency; check pantographs, bogies, running gear, brake systems, electric machines, door locks and interior installations, for condition, serviceability and functioning	Designated, according to conditions	Car operating and repair depot
On-board inspection	Riding on train to inspect active conditions of acceleration, deceleration, vibration, oscillation, etc., of train in operation, the serviceability in general and the functioning of all machines and installations	Whenever deemed necessary	Car operating and repair depot
Regular inspection	Inspection at the given frequency, depending on utilization of pantographs, specially high-pressure circuits, main circuits, auxiliary circuits, control circuits, door locks, brake systems, bogie, running gear, carbody, gauges, interior installations and auxiliary installations, to check condition, serviceability and functioning, as well as insulation and resistance of electric parts	Over 30 days, or within 30,000 km	Car operating and repair depot
Bogie inspection	Inspection at the given frequency, depending on utilization, to check main motors, power-transmission apparatus, brakes, trucks, springs, by dismounting or by disassembling their main parts for close examination	Within 12 months or within 300,000 km	Car operating and repair depot
General overhaul	Overall inspection in detail at the given frequency, depending on utilization, to check the principal components of electric railcars by dismounting or disassembling	Within 30 months, or within 900,000 km	Workshop
ATC operation inspection	Prior to ATC use, inspect at the given frequency the condition and functioning of all the parts of on-board installations from the exterior	Designated, according to what the rolling stock are to be used for	Car operating and repair depot
ATC characteristics inspection	Overall inspection at the given frequency of the condition and characteristics of on-board installations of CTC, leaving the trainset as it is	Within 3 months, or within 60,000 km	Car operating and repair depot workshop
Interim inspection	Inspection when deemed necessary, e.g. when a car is out of order	When deemed necessary	Car operating and repair depot
Car axle flaw detection	Inspection with ultrasonic flaw detector to check for flaws in car axles	At daily, bogie and general overhaul inspections	May be considered part of any regular inspection
Car wheel tread grinding	Inspection to keep wheel tread and flange in normal shape, using wheel tread lathe flange grinder for trainset	70,000 km as standard, but whenever deemed necessary	May be considered part of any regular inspection

Note: The above types of inspection are conducted at the Hakata Car Maintenance Center.

which has already been serviced. In addition, active performance is checked as follows:

Bogie running control. The vibration of the bogie on the run is measured. The carbody's vibration acceleration is measured, taking a 70,000-km run as standard.

Measuring of ratio between axle load and lateral force (Q/P). Since the risk of derailment is governed by the ratio between the lateral force (Q) and the axle load (*P*), this ratio is ascertained by measuring the axle load and the lateral force throughout the whole line at the rate of once in about 2 months.

Wheel axle-flaw detection. To guard against wheel axle breakage, quality control of the material and its processing is tightened, and wheel axle inspection with an ultrasonic flaw detector is periodically conducted.

Wheel-tread grinding. Periodic correction of wheel tread and prevention of flats from skidding are undertaken by grinding or wheel lathe, which can be done with the car intact.

5. *Achievements and Future Problems of the Shinkansen*

M. KAMADA

Introduction

Tokaido was the name given in olden days to the region and to the road along the Pacific coast between Tokyo, then called Edo, the seat of the Shogunate government, and Kyoto, then capital of Japan. Thus, Tokaido, as a region and a route, assumed great importance from early days. Today, the region is highly industrialized and contains the densest population and five of the largest cities in Japan; consequently, the traffic in the region is also the heaviest in the country.

The Japanese National Railways (JNR) used the name Tokaido for two of its railway lines because they more or less followed the old route. The older, narrow-gauge line, opened in 1889, is known as the Tokaido Line, and the newer standard-gauge line, opened in 1964, is called the Tokaido Shinkansen (Shinkansen literally meaning "new trunk line") to distinguish it from the older one.

Achievements

HIGH MASS TRANSPORT PERFORMANCE

The Shinkansen has a very high capacity for mass transport, due to the high carrying capacity, high speed, and high frequency of its trains. Without this high mass transport performance of the Shinkansen, it would be difficult to achieve the huge volume of passenger flow in the Tokaido region. The growth of passenger traffic and the number of trains operated on the Tokaido Shinkansen and the Sanyo Shinkansen* is given in Fig. 5.1.

In the planning stage of the Tokaido Shinkansen, however, such high performance was not anticipated. The future traffic growth then estimated was based on the predicted growth in national income announced by the Economic Planning Agency in 1956, with adjustments for the volume to be shifted over from the Tokaido Line, the impact of the parallel expressway to

*Used in contradistinction to the parallel narrow-gauge Sanyo Line.

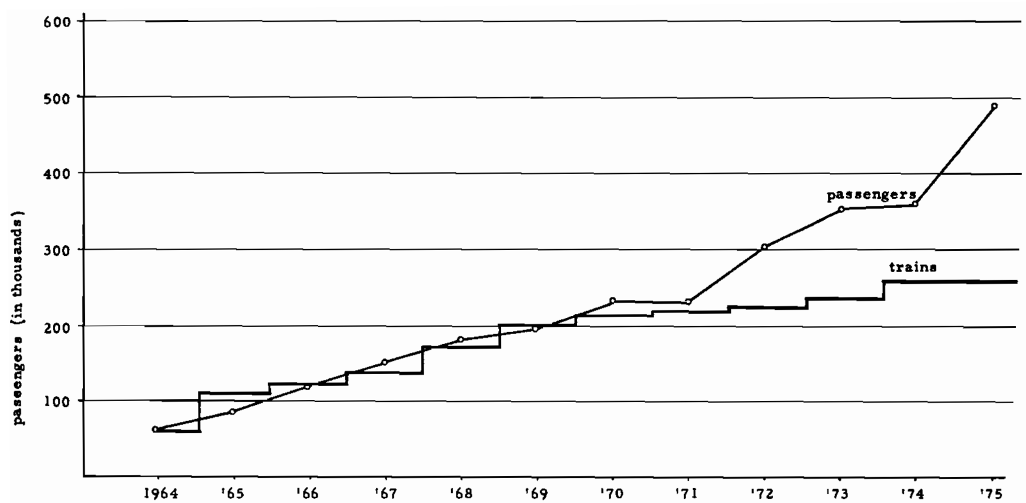


Fig. 5.1. Passengers carried and trains operated per day on the Shinkansen. Source of Data: JNR Shinkansen Administration, *Railway Statistics*, 1975.

be constructed, and the traffic to be induced by the Shinkansen. It turned out, however, that the actual growth in national income and traffic volume far surpassed what was predicted, as shown in Fig. 5.2.

HIGH-SPEED PERFORMANCE

The Shinkansen halved the duration of a railway trip. The time between Tokyo and Osaka by the Shinkansen, an express bus and an aircraft is compared in Table 5.1, and it is clear that for this distance of about 500 km there is not much to gain by flying. This is reflected in Fig. 5.3, which shows the trend of traffic between these cities by the Shinkansen and by air. For shorter distances, such as between Tokyo and Nagoya, aircraft are no match for the Shinkansen.

The greater accessibility through higher speed, together with the greater frequency and reliability of service, had the effect of inducing traffic, as shown in Fig. 5.4. It is hard to tell, however, how much of the increase was diversion from other means and how much the generation of new traffic.

Another effect of the high speed was the change it brought about in travel patterns. As shown in Figs 5.5 and 5.6, for return trips between Tokyo and Osaka, the itinerary became shorter for Shinkansen travelers, and less use was made of night trains.

HIGH-SAFETY PERFORMANCE

Initially, there was some apprehension as to the safety of the Shinkansen, a completely new system, but it has proved to be the safest way to travel. There has not been a single casualty from an accident on the Shinkansen since its inauguration over 12 years ago, in spite of the extremely heavy traffic. The number of deaths by various carriers, given in Table 5.2, shows the effectiveness of the railway, especially the Shinkansen, in reducing the social cost of accidents.

TABLE 5.1. *Travel time between Tokyo and Osaka*

Source: Japan Travel Bureau, Timetables, May 1977.

Carrier	Time	Time to, from and at airport	Total time
Shinkansen (Hikari)	3 h 10 min	-	3 h 10 min
Express bus	8h	-	8 h
Aircraft	50 min	Tokyo 60 min Osaka 25 min At airport 20 min	2 h 35 min

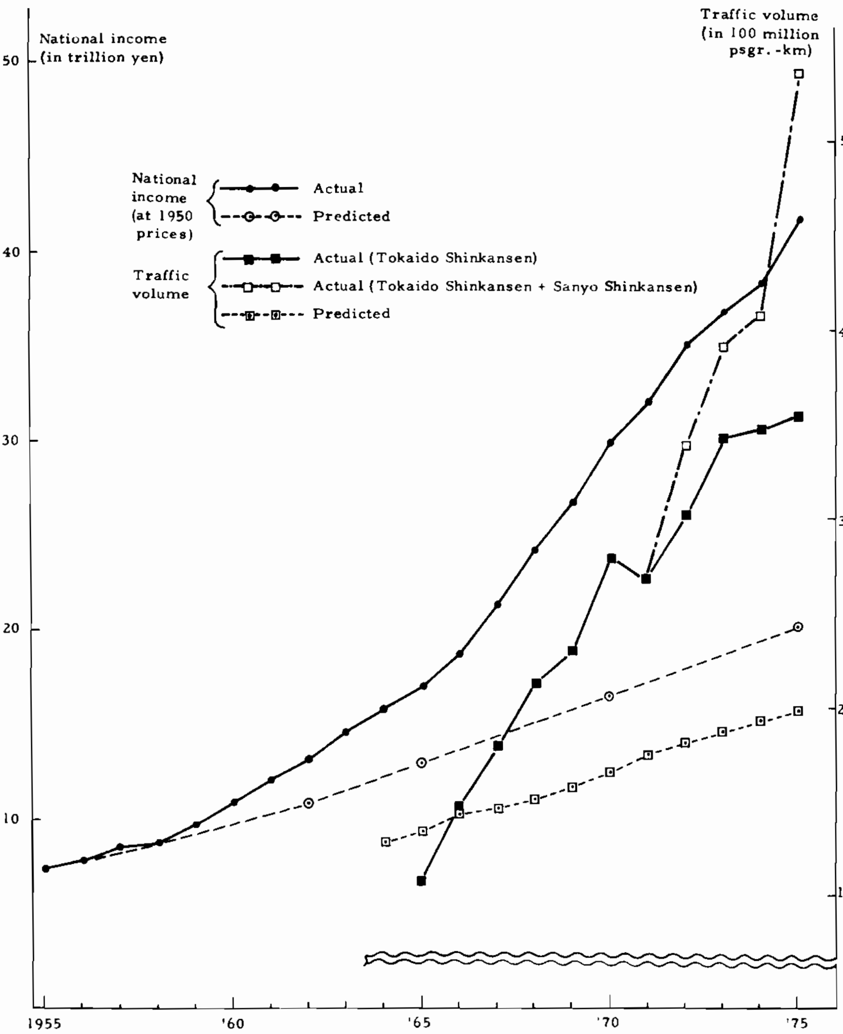


Fig. 5.2. Growth of predicted and actual traffic volume on the Shinkansen and national income. Source: JNR, Trunk Line Investigation Office, *Basic Data on Tokaido Shinkansen Project,* Jan. 1959.

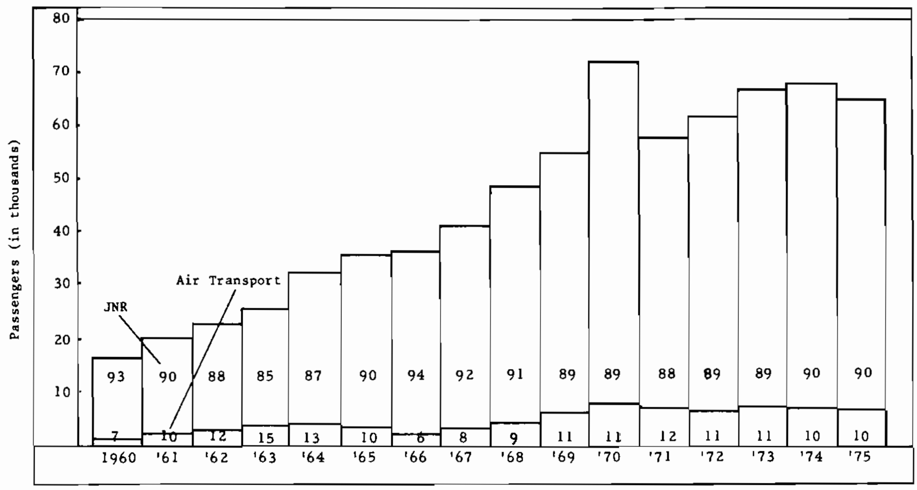


Fig. 5.3. Effect of the Tokaido Shinkansen on air transport: number of passengers per day between Tokyo and Osaka by JNR and air in percentages. (Figures in columns indicate percentages.) Sources: JNR, *Railway Statistics Yearbooks,* and Ministry of Transport, *Air Transport Statistics Yearbooks.*

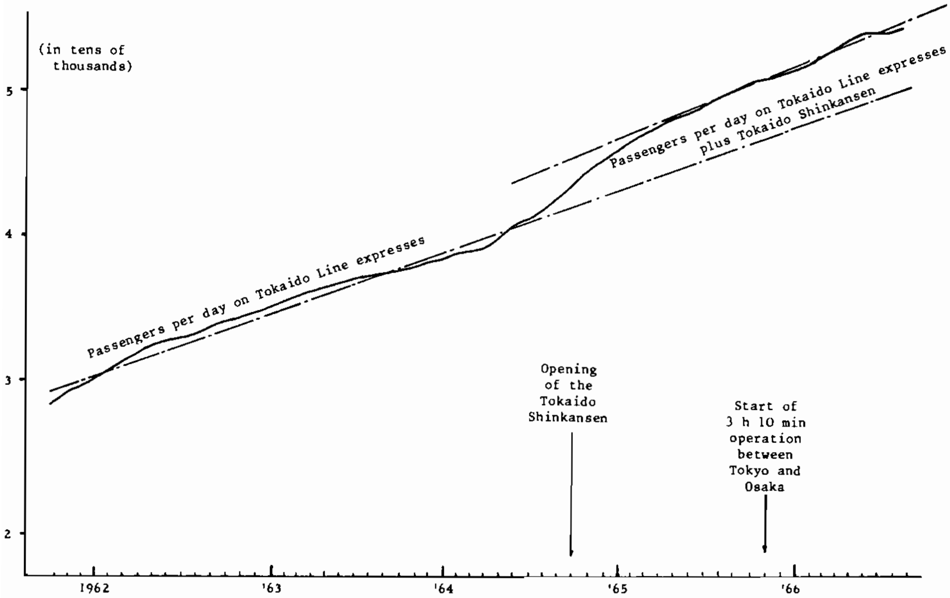


Fig. 5.4. Traffic induced by the Shinkansen. (Passengers counted only one way between Shizuoka and Hamamatsu.) Source: JNR, *Tokaido Line and Shinkansen Passenger Report,* monthly.

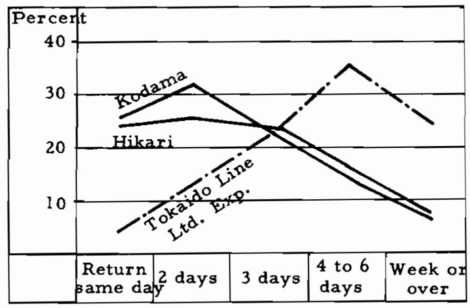


Fig. 5.5. Effect of the Shinkansen on itinerary. (For Shinkansen trains the survey was conducted in November 1964, and for the Tokaido Line Limited Express in October 1963.) Source: JNR, *Survey of Passenger Traffic Characteristics.*

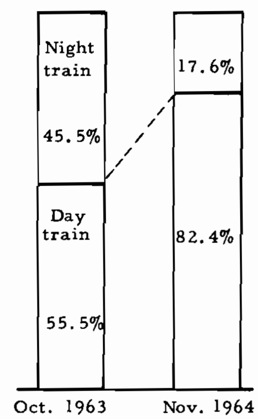


Fig. 5.6. Use of day and night trains by passengers traveling from Tokyo to Osaka. Source: JNR, *Survey of Passenger Traffic Characteristics.*

TABLE 5.2. *Safety of various means of transport (1965-1974)*
Sources: ***Rikuun Tokei Yoran*** (Land Transport Statistics Handbook); JNR ***Unten Jiko Tokei*** (Operational Accident Statistics); Private Railways ***Shitetsu Tokei Yoran*** (Private Railways Statistics Handbook); Automobile and Aircraft ***Kotsu Anzen Hakusho*** (Transport Safety White Paper).

		Traffic volume (A) (100 million passenger-km)	Deaths (B) (persons)	Incidence of deaths (B/A)	Index
Railway	JNR	19,019	54	0.003	1
	(Shinkansen)	(2551)	(0)	(0.000)	(0)
	(Other lines)	(16,468)	(54)	(0.003)	(1)
	Private railways	9748	146	0.015	5
Automobile		24,715	45,338	1.834	611
Aircraft		878	437	0.498	166

HIGH EARNING PERFORMANCE

The cost to the rail traveler consists of the basic fare according to distance, which is uniform for all JNR trains, plus a surcharge based on the speed of the train and quality of accommodation. The surcharge for the Shinkansen trains is, of course, higher than for other lines, so it earns more revenue per unit of traffic. Costs of travel by the Shinkansen, aircraft and motor vehicles are given in Table 5.3. Taking into account the additional cost of travel to and from the airport and the reliability of the services, the Shinkansen is highly competitive. The Tokaido Shinkansen produced 37% of JNR's total passenger revenue in fiscal 1975.

Efficient utilization of facilities has lowered the fixed operating costs per unit of traffic. As an example, the Tokaido Shinkansen train covers 1.7 times the distance per day of the limited express on the older Tokaido Line. Labor-saving methods and simplification of operations have reduced the ratio of personnel costs on the Shinkansen, as shown in Fig. 5.7, and have increased productivity per employee, as shown in Fig. 5.8. Energy consumption per unit of traffic is comparatively small, in spite of the high speed, as shown in Table 5.4, and this is a merit in our energy-sensitive age. The trend in the earning performance of Shinkansen is given in Fig. 5.9.

EFFECTIVE USE OF MARGIN CREATED ON THE TOKAIDO LINE

The Tokaido Line had already reached a state of saturation in 1964 when the Tokaido Shinkansen was inaugurated. By absorbing most of the daytime and nighttime ordinary expresses and all of the daytime limited expresses, the Tokaido Shinkansen created a margin in the capacity of the Tokaido Line. This was used for operating more express freight trains and long-distance sleeping-car limited expresses, which enabled JNR to meet previously unfulfilled demands. The number and kinds of trains on the Tokaido Line, before and after the inauguration of the Tokaido Shinkansen, is given in Fig. 5.10.

Impact on Regions Along the Line

REDUCTION OF TIME-DISTANCE

The reduction of time-distance by the Shinkansen widened the scope of a day's journey. Only now can a businessman leave Tokyo or Osaka by train in the morning, do business at the other end, and return the same day. Surveys show that after the opening of the Shinkansen, the number of business trips has increased while their duration has shortened. Tourism has also been affected. Tourists tend to make use of the time saved by the Shinkansen by traveling further, and this is seen in the greater number of vacationers from the Tokyo area to the Osaka area, and vice versa. However, some hotel operators, for example, have been adversely affected by the Shinkansen. They find that, while more people were visiting their localities, less of them needed to stay overnight in their hotels.

TABLE 5.3. *Cost of travel between Tokyo and Osaka by various means of transport*
Source: Japan Travel Bureau, Timetables, 1977.

	Cost (yen)		Remarks
	Oct. 1964	Apr. 1976	
Shinkansen (ordinary car)	2480	5510	
Aircraft	7000	10,400	
Express bus		4200	Cost of gasoline
Automobile (per car)		13,400	+ toll *

*Cost of gasoline based on 120 yen/liter, at 8 km/liter.

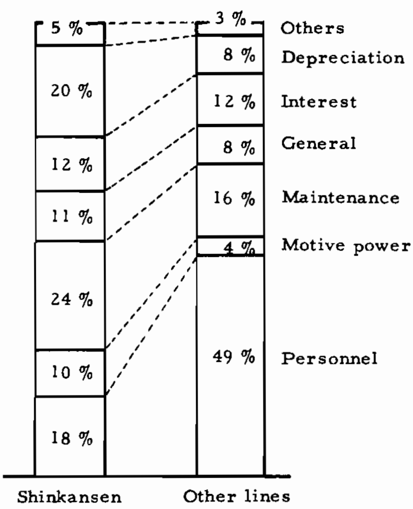


Fig. 5.7. Composition of Shinkansen and other lines (1974). Source: JNR Shinkansen Administration, *Status of Shinkansen Operation,* 1975.

Table 5.5 shows the time saved by using the Tokaido Shinkansen instead of a limited express on the parallel Tokaido Line, and gives the value of this time, computed in monetary terms.

URBANIZATION

The Tokaido Shinkansen has not only accelerated the growth of the major cities on the line, but has also speeded up the transformation of the corridor into a huge megalopolis. In addition, the ease of travel on the Shinkansen had an impact on city functions, strengthening or weakening their administrative, financial and other controlling functions. As a general trend, it may be said that in the Tokaido region the controlling influence of Tokyo and Osaka, especially that of Tokyo, is becoming stronger, while that of Nagoya, sometimes called "the middle capital", is weakening.

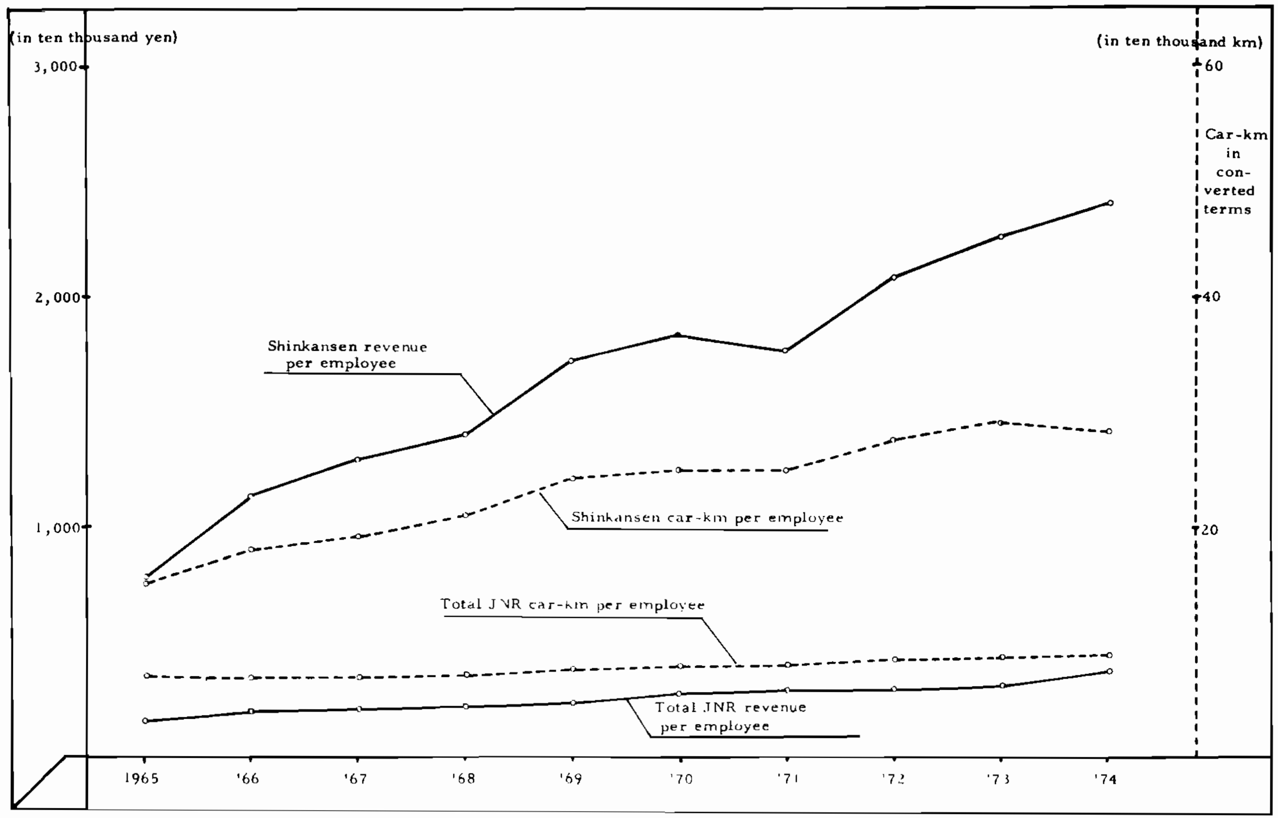


Fig. 5.8. Productivity of the Shinkansen and total JNR. Source: JNR Shinkansen Administration, *Status of Shinkansen Operation,* 1975.

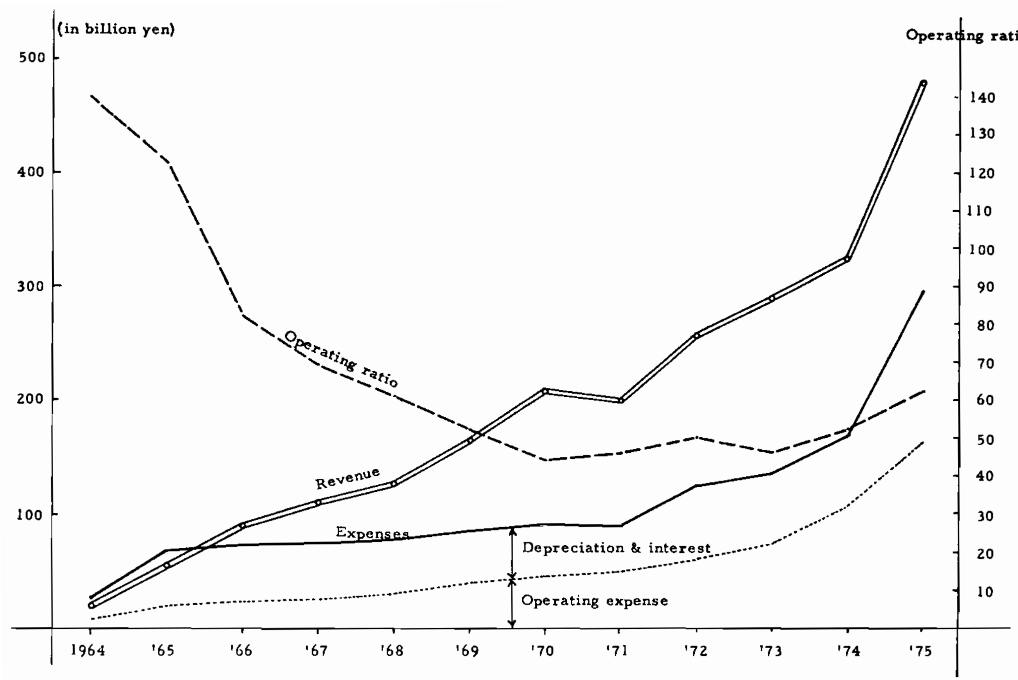


Fig. 5.9. Earning performance of the Shinkansen. Source: JNR Shinkansen Administration, *Status of Shinkansen Operation*, 1976.

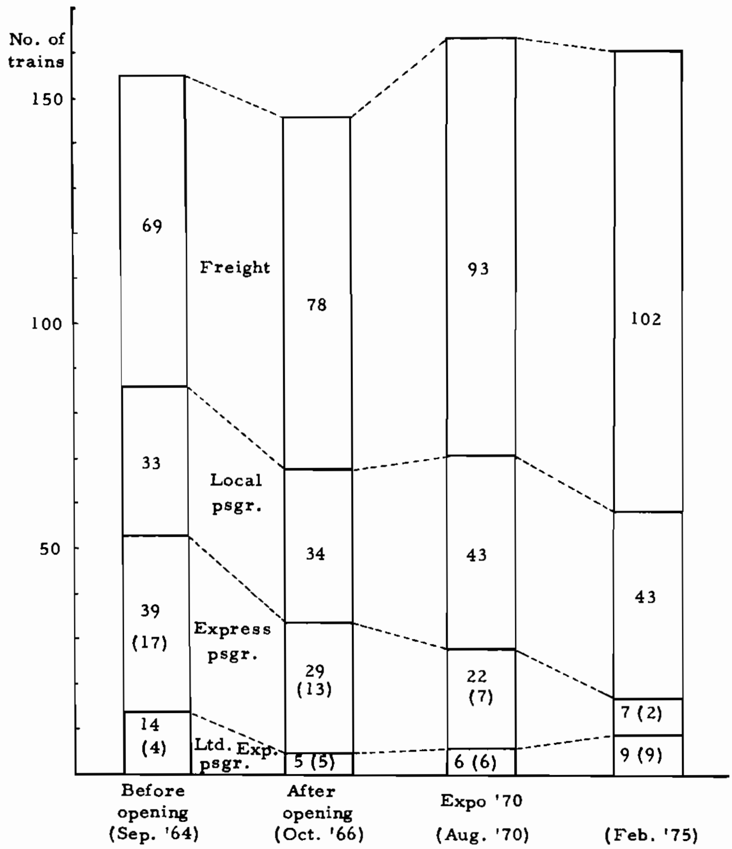


Fig. 5.10. Tokaido line trains before and after opening of the Shinkansen. Up-trains only between Shizuoka and Hamamatsu daily. (Figures in parentheses are for sleeper trains and have been included in the total.) Source: JNR, Train Operation Data.

TABLE 5.4. *Energy consumption of different carriers*

Source: Data computed by JNR from Ministry of Industry and Trade, *Energy Tokei* (Energy Statistics); Ministry of Transport, *Rikuun Tokei Yoran* (Land Transport Statistics Handbook); JNR, Information Systems Department Data.

Passenger	kcal/passenger-km	Freight	kcal/ton-km
Railway (incl. private railways)	80 (1)	Railway (incl. private railways)	190 (1)
Shinkansen	100 (1.3)	Truck	1210 (6.4)
Bus	120 (1.5)	Coastal ship	350 (1.8)
Automobile	700 (8.8)		
Aircraft	780 (9.8)		

Note: Figures in parentheses are indices with railway as 1.

TABLE 5.5 *Value of time saved by the Shinkansen*
Source: JNR, *Impact of the Tokaido and Sanyo Shinkansen,* 1976

Year	No. of passengers (thousands)	Average ride per passenger (km)	Scheduled speed of Shinkansen* (km/h)	Time saved (million hours)	Value of 1 hr† (yen at 1975 prices)	Value of time saved (in 100 million yen)
1964	11,018	355	112.5	11	542	60
1965	30,967	343.9	144.4	50	567	284
1966	43,784	330.9	144.4	68	629	428
1967	55,250	324.2	144.6	84	708	595
1968	65,903	319.1	143.5	98	800	784
1969	71,574	318.1	137.1	99	888	879
1970	84,628	329.6	136.5	120	988	1186
1971	84,509	314.0	134.8	112	1075	1204
1972	97,551	304.0	134.9	125	1192	1490
1973	113,080	299.3	136.4	146	1192	1740

*Scheduled speed on non-Shinkansen lines = 86 km/h.
† Value of 1 hour = GNP/(Working population × 300 days × 8h/day).

Expansion of the Shinkansen

EXTENSION TO OKAYAMA AND HAKATA*

The coastal area from Osaka to Fukuoka, consisting of six prefectures, accounts for 20% of Japan's population and 33% of her industrial output. The density of traffic in the area has therefore always been very high, approaching that of the Tokaido region, and it was feared that the railway line here would reach saturation point over the entire route by 1973 or 1974. JNR therefore decided to build the Sanyo Shinkansen as a major project of its Third Long-Range Seven-Year Plan (1965-1971). After obtaining the Transport Minister's approval, construction was started in 1968 on the first half from Shin-Osaka† to Okayama and, 2 years later, on the second half from Okayama to Hakata. Details of the Sanyo Shinkansen are as follows:

Section	Length (km)	Station	Construction cost (billion yen)	Date of opening
Shin-Osaka–Okayama	160.9	5	224	15 March 1972
Okayama–Hakata	392.7	10	718	10 March 1975

Sufficient data are not yet available for the Okayama–Hakata section, but, on the Shin-Osaka–Okayama section, traffic has grown as shown in Table 5.6.

LEGISLATION FOR CONSTRUCTION OF NATIONWIDE SHINKANSEN NETWORK

The rapid economic growth from the latter half of the 1950s was accompanied by excessive concentration of population and industries in the major cities, and sparsity of population and decreasing economic activity in

*Hakata is the name of the station in Fukuoka City.
† Shin-Osaka is the name of the Shinkansen station in Osaka City.

TABLE 5.6. *Traffic volume on the Sanyo Shinkansen (Passengers carried in millions; figures in parentheses indicate passenger-km in 100 millions)*
Source: JNR Shinkansen Administration, *Railway Statistics,* 1975.

Year	Between Shin-Osaka and Okayama	Between Okayama and Hakata	Between Shin-Osaka and Hakata
1972	27 (42)	-	-
1973	32 (49)	-	-
1974	35 (53)	-	-
1975	49 (79)	44 (102)	77 (181)
Total	143 (223)	44 (102)	77 (181)

rural and outlying areas. On the assumption that a Shinkansen network was essential to correct this social strain and regional imbalance, the Diet initiated legislation to this end, which took the form of the Law for Construction of a Nationwide Shinkansen Network, enacted in May 1970.

Under this law, the Minister of Transport determines the basic plan of the lines to be constructed, after consulting the Railway Construction Council which is an advisory to the Minister. This council is composed of Diet members, vice-ministers of the ministries concerned, experts, the President of JNR and the President of the Japan Railway Construction Public Corporation. The basic plan for a 7000-km network, as shown in Fig. 5.11, was thus conceived. Construction priorities are determined for the routes making up the network, and construction is then carried out either by JNR or the Japan Railway Construction Public Corporation. JNR is obligated to operate all the lines thus built.

LINES UNDER CONSTRUCTION

The first lines designated to be built under the law were: the first stage of the Tohoku Shinkansen (Tokyo–Morioka, approx. 500 km), the Joetsu Shinkansen (Tokyo–Niigata, approx. 300 km) and the Narita Shinkansen (Tokyo–Narita, approx. 65 km). The Tohoku Shinkansen will become a part of the vital artery along the length of Japan, from Hokkaido to Kyushu. A section of this line is to be completed early as a test track for further development of safety measures, environmental preservation measures, and new technology for the future Shinkansen. The Joetsu Shinkansen will become the first to cut across the main island from the Pacific to the Japan Sea side. The Narita Shinkansen will become a high-speed link between the Tokyo city center and the new international airport to open soon. The construction tempo of these lines has slowed down in the last few years owing to the Government's policy of cutting down public spending.

LINES TO BE CONSTRUCTED

It was subsequently decided to construct the following lines, which are being investigated and surveyed for the preparation of detailed construction plans:

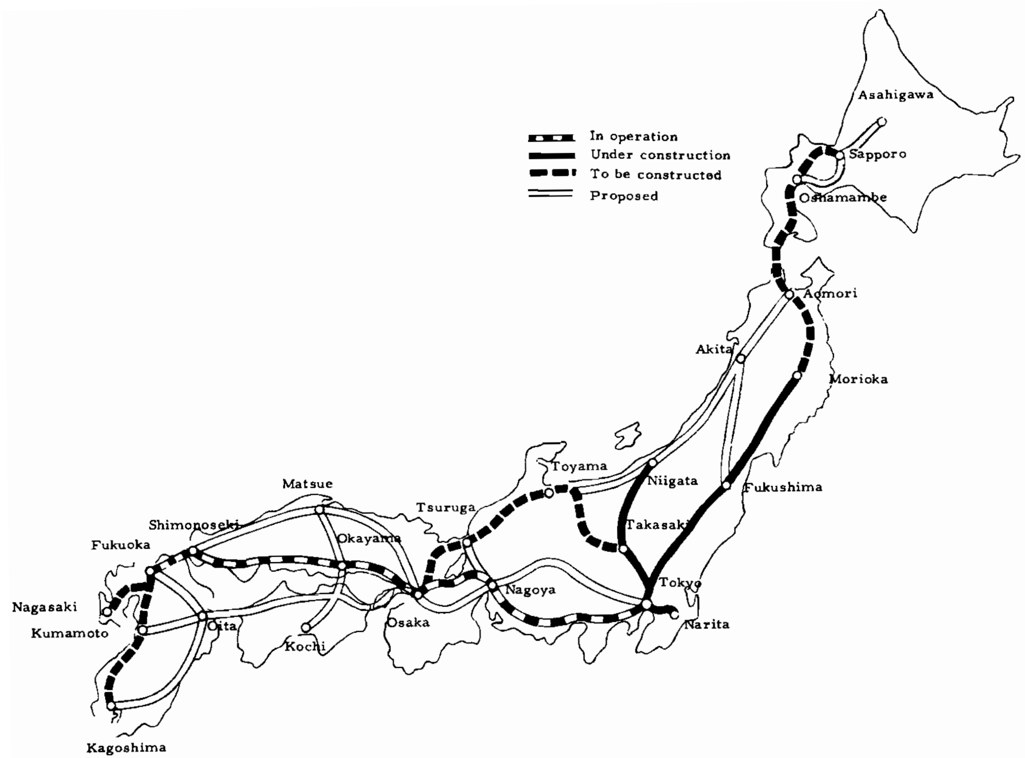


Fig. 5.11. Nationwide Shinkansen network (basic plan approx. 7000 km).

		km (approx.)
Second stage of Tohoku Shinkansen	Morioka–Aomori	170
Hokkaido Shinkansen	Aomori–Sapporo	370
Hokuriku Shinkansen	Tokyo–Osaka (via Toyama)	590
Kyushu Shinkansen	Fukuoka–Kagoshima	270
	Fukuoka–Nagasaki	120

The Hokkaido and the Tohoku Shinkansen will be connected by the Seikan Undersea Tunnel at present under construction. Linking the main island of Honshu and Hokkaido, it will be approximately 54 km long, and on completion will be the longest tunnel in the world.

OTHER LINES PROPOSED IN THE BASIC PLAN

Twelve more lines, totaling 3500 km, are proposed in the basic plan, two of which are to link Honshu and Shikoku islands via a series of double-decked railway–highway bridges. Of these bridges, the Akashi Kaikyo Bridge, with a center span of 1780 meters, will be the world's longest suspension bridge.

Future Problems

ENVIRONMENTAL

It was rapid economic growth that gave rise to the urgent need for the Shinkansen and brought about its great success. This economic growth and the resulting affluence, however, has changed people's attitudes and values. In the early years of the Shinkansen, when the people concentrated more on making a living, it was the high speed and convenience of the Shinkansen that caught their attention. With the rise in living standards, their aspirations turned not only to homes of their own, but homes in a good environment. Thus, the problems of noise and vibration of the Shinkansen came to the fore, as was the case with motor vehicles and aircraft. This problem now carries so much weight that difficulties are being met in constructing new lines in built-up areas and city peripheries. In 1975 the Environment Agency issued a notification setting the noise limit at 70 dB (A) and 75 dB (A). While JNR has made some progress in reducing noise as a result of research and development work in the field, it is still technically difficult to meet the limitations in an economic way.

FINANCIAL

The success of the Tokaido Shinkansen brought new hope and confidence to railroading, and, as expected, the Sanyo Shinkansen is also achieving good results. This is why the Tohoku Shinkansen and the Joetsu Shinkansen are looked forward to with the same expectations, and why a nationwide Shinkansen network has been planned.

Internally, however, this has brought about another problem, a financial one. Difficulties are being met in the procurement of construction funds. In addition, the lines to be constructed in the latter stage will not be so remunerative as the earlier ones; some would possibly operate at a deficit, since they will be routed through lighter traffic areas. The lines constructed so far have been demand-following, but if, from social policy, demand-leading lines, which are not always profitable, are to be built, there would have to be some form of external subsidy. In this connection, it should be noted that JNR as a whole has been showing a deficit since 1964, not because of the Shinkansen, which has had very favorable financial results, but because of the local lines operating in very light traffic areas, which cannot be closed. The Government has started to give financial aid for this situation.

The Government is at present re-examining the Shinkansen network project in the light of these conditions, and will announce its stand in the Third Comprehensive National Development Plan, to be made public in the near future.

ULTRA-HIGH-SPEED RAILWAY

The demand for high-speed transport is rising, and there has been a great increase in the use of aircraft for long-distance travel. The disadvantage of aircraft, however, lies in its small potential for mass transport. Existing airports will need to be expanded or new ones built, but this will be extremely difficult from the viewpoint of land procurement and environmental preservation.

Research and development work is in progress in JNR for a non-conventional railway system aiming at speeds up to 500 km/h. This is the superconducting magnet-levitated, linear-motor propelled vehicle. In 1972 a quarter-scale model was successfully tested, and a 7-km experimental guideway is now being built to test a half-scale model. It is hoped that this will also solve the noise problem.

When the Tokaido Shinkansen was built, it was called the "Dream Superexpress". The day of the "New Dream Superexpress" may be coming.

Socio-Economic Impact: Models and Applications

6. *Determination of Socio-Economic Impact: Problems for Consideration*

M. ALBEGOV

The object of this section is to discuss the socio-economic impacts of the Shinkansen; to this end four groups of problems that are important for IIASA and for its international activities should be emphasized.

The first type of problem area deals with the impacts of large programs on the economic and social life of a country. An approach to resolution of these impacts is treated in the paper by S. Okabe where he examines the feasibility of the growth of two regions in Japan after the completion of a Shinkansen trunk line. The paper points out the influence of the Shinkansen on the growth of tourism, and the effect this growth has on the size of hotels, restaurants, and construction which in turn leads to increased demand for construction products such as cement. Another approach which could also give similar results would be to utilize calculations based on input–output balances. This would, however, require a good knowledge of all types of impacts and integrated input–output models corresponding to the task under investigation. If one can estimate the impacts of large projects on a national economy on a qualitative basis, the problem of measuring social impacts still remains. One way to resolve this difficulty may be to formulate a scenario of regional development and to compare the value of objective functions. The problem is treated in the discussion part of this section.

The second area of concern to IIASA is the methodological problem of estimating the economic effects of large programs. The first question in this category is how to delineate the task under consideration from the viewpoint of the national economy. How can we find boundaries of the problem in which expansion does not influence the results of the analysis? How can approach variants be compared in order to obtain the value of economic effectiveness? K. Amano deals with these topics in his paper by comparing two variants with Shinkansen and without Shinkansen. In his example the variants are different, not only from the viewpoint of final results, but also from that of required capital investment and other important data. It is not clear, though, what kind of technical improvement might be included in the ordinary railway variant. It may be that there exists an intermediate variant which is more effective than the first two. The comparison of variants in order to obtain results concerning the economic effectiveness of large programs is a very important matter.

The third area of concern deals with the mathematical modeling of large economic programs. This problem is treated in the paper by N. Sakashita, and brings out some important characteristics. It is well known that many types of models exist that deal with regional, industrial, transportation and other large systems. These models are usually quite complicated and require significant efforts in their application. Additional effort would be required on the part of model-builders in general to pool knowledge on model building, incorporate common characteristics of successful models, and apply the results in other models designed to solve related but different problems. As an international institute, IIASA is interested in spreading such knowledge and experience.

An additional problem is that most authors of models emphasize the strengths of their models and avoid the weaknesses. This, of course, applies to me and I think also to the majority of model-builders. It is indeed important to stress the positive features of a model, but it is also important to point out those aspects of a model which need improvement. It is well known that there are many approaches and techniques which could be used to analyze large-scale programs; it would appear beneficial to combine different approaches and techniques in concrete situations in order to achieve a better understanding of the problem.

The nature of this conference on the Shinkansen is basically retrospective, but, as shown in the presentations in this section, IIASA and the international community can use retrospective experience to improve future planning processes: to determine what is useful for prospective planning, to determine marginal time horizons, and to determine how far a model may be extended into the future before validity is questioned.

The papers presented in this section, and the discussion which follows, should help to clarify much of the current effort in Japan and other countries to determine the socio-economic effects of large-scale planning programs.

7. *Regional Economic Impact of the Shinkansen*

K. AMANO

Introduction

We proposed, in 1970, a model to estimate the long-term global economic effects of transportation facility projects [1]. We also described the results obtained from applying the model to a comparison of the economic effects of hypothetical plans for alternative bridge construction between the Japanese mainland and the Shikoku island. This model has already been applied for estimating the regional economic effects of various large-scale projects for transport facilities in Japan [2].

In this paper, the basic structure of the model is described and the economic effects estimated by the model of the Tokaido Shinkansen are given as an example.

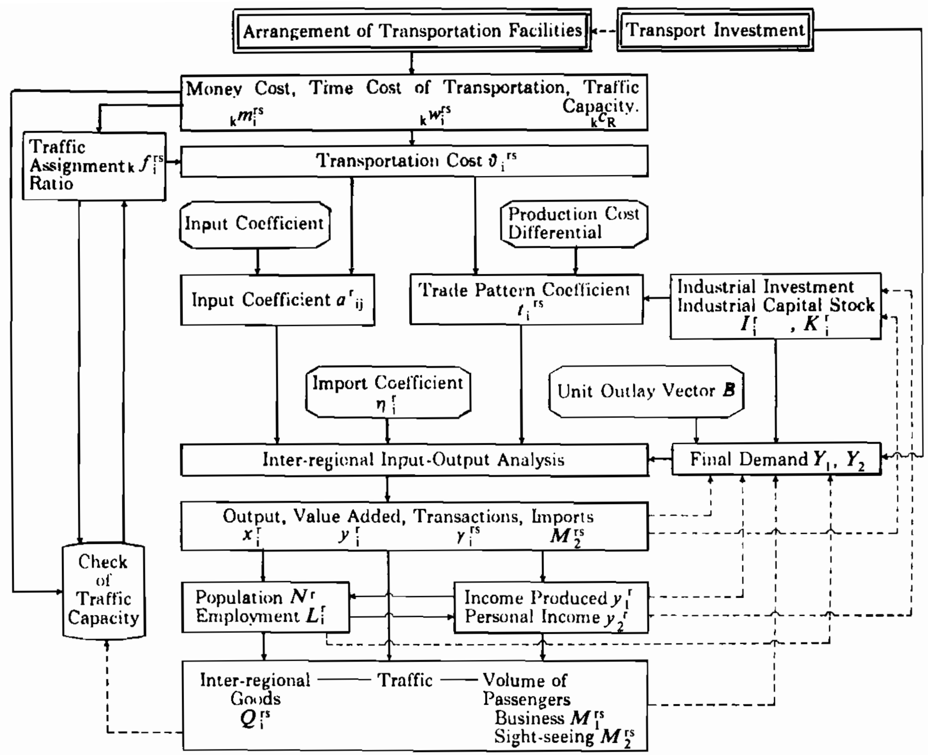
Model of the Economic Effect of Improving Transportation Facilities

We proposed an econometric model to analyze the long-term total economic effect and regional economic effect of improving transportation facilities. The interregional I–O analysis has been expanded dynamically through this research, modeling the variations in trade pattern coefficient and input coefficient caused by improvement of transportation facilities. Thus the I–O analysis has been rid of its weakest point, which is formed by cross-sectional data, and has been developed to become suitable for long-term estimation of transportation facilities improvement.

A system chart of this model is shown in Fig. 7.1, and the main points are as follows. The savings on interregional transportation costs by improving transportation facilities changes the trade pattern coefficient and input coefficient. First, this process was analyzed and clarified in a proposed mathematical model. Then, using the econometric model, it was shown that variation in these structural coefficients changes the present economic indices as well as the future final demand and interregional trade pattern coefficient, and that improvement of transportation facilities changes the regional economic structure cumulatively year by year.

This econometric model has the following five features.

An econometric model for estimating the trade pattern coefficient, which determines the trade pattern endogenously, was developed. In this model three economic indices are used as variables: capital stock, interregional transport cost, and other local conditions by region and industry.



Notes:
Subscripts i and j indicate industrial sectors or kinds of commodities.
Superscripts r and s indicate regions.
Subscript k indicates a particular traffic route.
Dashed lines denote a time lag of one year.

Fig. 7.1. System chart of the proposed model.

The variation of the input coefficient from the transport sector and the additional value in each region and industry affected by the savings in transport costs is given endogenously by a theoretical equation. Thus, by this model we have solved the problem of the inelasticity of the input coefficient and the trade pattern coefficient, which is usually considered the weakest point in I–O analysis, and we utilized these two coefficients as policy variables for including the saving in transport costs in the econometric model.

The model is constituted so that the vector of the regional final demands is determined endogenously by the economic indices of the previous year. Thus a time series continuity can be given to the model.

We could increase the precision of this model, using the interregional transaction sum calculated by interregional I–O analysis, to estimate the interregional traffic volume and the population migration. This can be considered one of the great advantages of our model, which includes the interregional I–O analysis.

Traffic capacity is checked endogenously, and it is ascertained that the estimated interregional traffic volume is not a latent demand but a real solution, and that transport costs between regions will be changed mechanically as a result of a check on traffic capacity.

For example, three partial models in the econometric global model are given below.

MODEL FOR INTERREGIONAL TRAFFIC ASSIGNMENT RATIOS BY COMMODITY

The first problem is to estimate how each user responds to changes in money costs and time costs.

Each user will select the most desirable transportation route. Consequently, the interregional traffic assignment ratio of each facility will be changed. This change is estimated by the following equation:

$$ {}_kf_i^{rs} = \frac{1}{n} + b_i \left(\frac{\sum_{k=1}^{n} {}_kw_i^{rs}}{n} - {}_kw_i^{rs} \right) + c_i \left(\frac{\sum_{k=1}^{n} {}_km_i^{rs}}{n} - {}_km_i^{rs} \right) \qquad (1) $$

$ {}_kf_i^{rs} $ = traffic assignment ratio of commodity i by transportation facility k between regions r and s ;

n = number of transport routes existing between r and s ;

b_i, c_i = positive constants for each commodity ;

$ {}_kw_i^{rs} $ = time cost by transport route k ;

$ {}_km_i^{rs} $ = money cost by transport route k.

This suggests that if some traffic routes exist between two regions, the traffic assignment ratio of each route will be determined as a function of the cost differentials in terms of time and money.

TRANSPORT COST BETWEEN REGIONS

As a result of the variation in the traffic assignment ratio, the interregional transport cost estimated by the next equation will be changed. This cost, v_i^{rs}, which represents the total cost or loss of transporting one unit of commodity i from region r to region s, is shown by

$$v_i^{rs} = m_i^{rs} + \lambda_i w_i^{rs}$$

$$m_i^{rs} = \sum_{k=1}^{n} {}_k f_i^{rs} \, {}_k m_i^{rs} \, , \quad w_i^{rs} = \sum_{k=1}^{n} {}_k f_i^{rs} \, {}_k w_i^{rs} \, . \tag{2}$$

In this equation, λ_i is the transformation ratio of time cost to money cost. Using b_i and c_i of equ. (1), the value of λ_i in equ. (2) is estimated by:

$$\lambda_i = \frac{b_i}{c_i} \, . \tag{3}$$

The reasoning is as follows. Each passenger or cargo owner selects the route which minimizes the total transport cost after comparing the money cost and time cost for each transport route. Assuming that this result is expressed in the present traffic share, the ratio of the partial derivatives of the assignment ratio with respect to time cost and money cost is

$$\frac{\partial_k f_i^{rs} \big/ \partial_k w_i^{rs}}{\partial_k f_i^{rs} \big/ \partial_k m_i^{rs}} = \frac{b_i}{c_i} \, .$$

This can be regarded as the value ratio of time cost to money cost for cargo owners or carriers.

MODEL FOR THE TRADE-PATTERN COEFFICIENT

In the perfect market a buyer will select freely from the same commodities which many suppliers offer at their prices, and commodities of the same quality will remain at the same price.

For each business enterprise, the profit motive is a dominant factor to the supplier, and therefore, whether or not a supplier offers his goods on the market seems to depend on the difference

$$P_i^s - C_i^{rs}$$

where $$C_i^{rs} = P_{oi}^r + V_i^{rs}$$

P_{oi}^r : production cost of commodity i in region r ;

V_i^{rs} : transportation cost of the commodity i to region s ;

P_i^s : the price of the commodity i in market s .

Since the price P_i^s appears to be determined subsequently by the equilibrium of demand and supply, the dimensions of C_i^{rs} can be said to control the relative merits or competitive potential of each supply region r to the demand region s.

Proceeds of sales for each supplier within a definite period of time will not be estimated until the end of the period. A supplier for a demand region is usually not single but multiple, since suppliers compete with one another, and in that case, the larger the total cost C_i^{rs} the weaker the relative competitive potential to region s. So the supply share from region r in the whole demand in region s will decrease. We shall assume accordingly that

$$t_i^{rs} \propto e^{-b_i C_i^{rs}}. \tag{4}$$

That is to say, if all indices except the total cost C_i^{rs} are equal in each region r, the supplying share will decrease through an exponential function according to C_i^{rs} We assume the exponential function because it is convenient for the calculation.

On the other hand, when the competitive potential of each supply region r to demand region s is the same, i.e. that C_i^{rs} are equal, the sales share forms a supply region to the total demand from the demand region, which seems to be in proportion to the productive capacity S_{oi}^r in the region. So we assume that

$$t_i^{rs} \propto S_{oi}^r \quad . \tag{5}$$

This can also be explained by the domain problem as follows. Assume that a domain r which has productive capacity S_{oi}^r is divided into two domains S_{oi}^{r1}

and S^{r2}_{oi}. If these two domains have the same conditions except for productive capacity, the trade pattern coefficients to a demand region s can be said to be as follows.

$$t_i^{r_1 s} : t_i^{r_2 s} = S^{r1}_{oi} : S^{r2}_{oi}$$

provided that $$t_i^{r_1 s} + t_i^{r_2 s} = t_i^{rs} .$$

We prefer the sum of capital stock of the industry at the beginning of the period as an index of the productive capacity in the region r, S^r_{oi} in equ. (5). Then, using equs. (4) and (5), we have

$$t_i^{rs} = k_i^s \, K^r_{F_i} \times e^{b_i C_i^{rs}} .$$

Substituting $$\sum_{r=1}^{m} t_i^{rs} = 1 ,$$

$$k_i^s = \frac{1}{\sum_{r=1}^{m} K^r_{F_i} \times e^{b_i C_i^{rs}}} \tag{6}$$

Thus the model for the trade pattern coefficient is written as:

$$t_i^{rs} = \frac{K^r_{F_i} \times e^{b_i C_i^{rs}}}{\sum_{r=1}^{m} K^r_{F_i} \times e^{b_i C_i^{rs}}} \tag{7}$$

OTHER PARTIAL MODELS

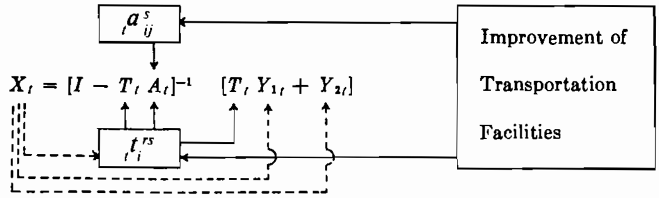
Full details of the following partial models can be found in [1, pp. 300-306]. Space does not permit a description here.

Variation of input coefficient from the transport sector and variation of value-added coefficient.

Output by region and industry.

Value-added, income-produced, and personal income.

Model for regional population.



where

$X = [X^r_i]$ = output vector;
I = unit matrix;
$T = [t_i^{rs}]$ = trade pattern coefficient matrix;
$A = [a^s_{ij}]$ = input coefficient matrix;
$Y_1 = [Y^r_{1i}]$, $Y_2 = [Y^r_{2i}]$ = final demand vectors
---→ = represents time lags.

Fig. 7.2. Summary of the model.

Employment by region and industry.
Freight flows between regions.
Capital stock by region and industry.
Final demand vector.
Balance between transport demand and transport capacity.

A summary of the entire model is shown in Fig. 7.2.

Application of the Proposed Model to the Tokaido Shinkansen

The proposed model for the traffic investment effect is on the expanded interregional I–O analysis. In applying the model, we can therefore estimate the economic effect of improving transportation facilities for all economic indices by region and industry. All the economic indices are closely combined, as shown in Fig. 7.1, and they are kept in a balanced condition in every cross-sectional term.

In 1970 we estimated the regional economic effects of various large-scale projects for transport facilities in Japan, applying this model. Output data on these assumptions are shown in Table 7.1.

Case 1: Various transportation facilities, including the Tokaido Shinkansen, are actually improved.
Case 2: Supposed condition that the Tokaido Shinkansen is not constructed.

The differences in regional economic indices (Case 1)–(Case 2) are considered to be the influence which the Tokaido Shinkansen has produced exclusively.

Japan was divided into nine regions, as shown in Fig. 7.3. All coefficients and necessary data for this model, the outline of which was explained in previous sections, were obtained for these nine regions. The estimate extended from 1960 to 1970 in each case. The exogenous changes in interregional transport money cost, time cost and capacity were given for 1961, 1965 and 1968. The estimated results for each case and the differences between cases

TABLE 7.1. *Output data*

		Region		Industry
1.	Capital stock by region and industry	9	×	10
2.	Final demand by region and sector	9	×	8 (demand sector)
3.	Industrial capital investment by region and industry	9	×	10
4.	Sum of export by region and industry	9	×	10
5.	Interregional traffic assignment ratio by industry	9×9	×	7
6.	Change of transport cost between regions by goods	9×9	×	7
7.	Interregional trade pattern coefficient by goods	9×9	×	7
8.	Increment of trade pattern coefficient by goods from 1960s	9×9	×	7
9.	Input coefficient and additional value rate from transport sector	9	×	10
10.	Production sum by region and industry	9	×	10
11.	Primary, secondary, tertiary production sum by region	9	×	3
12.	Annual increasing rate of production sum by region and industry	9	×	10
13.	Additional value by region and industry	9	×	10
14.	Primary, secondary and tertiary additional value by region	9	×	3
15.	Interregional transaction sum by goods	9×9	×	10
16.	Interregional migrating population	9×9		
17.	Production and individual income by region	9	×	2 (income)
18.	Primary, secondary and tertiary industry-occupied population by region	9	×	3
19.	Interregional freight traffic volume by transport facilities and goods	9×9	×	3×7
20.	Interregional traffic volume of passengers by object	9×9 (section)	×	2 (by object)
21.	Traffic volume of passing freight by section and traffic route	14	×	3
22.	Traffic volume of departure and arrival by region and transport facilities	9	×	3

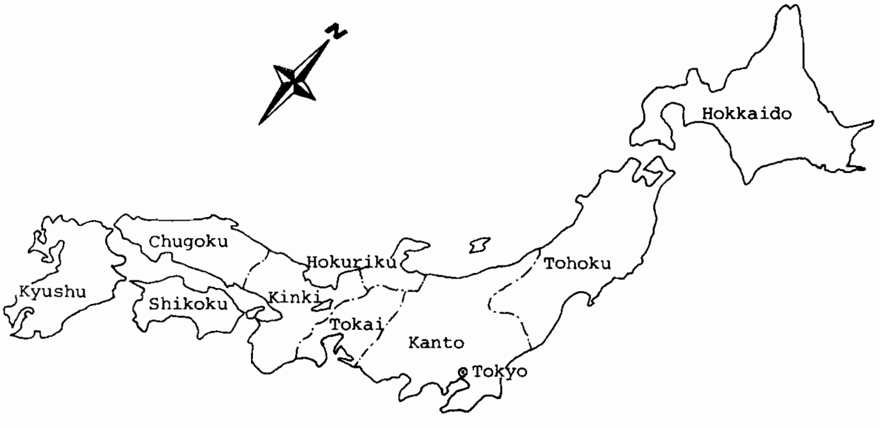


Fig. 7.3. Regional divisions.

were obtained for each year. Figures 7.7 - 7.8 show an example of the difference in effects between Case 1 and Case 2.

The trade-pattern coefficient showed what percentage of the total demand for a particular commodity in a region was supplied from each region. For example, the rate of self-supply of chemical goods in Tohoku, as shown in Fig. 7.4 (a), was forecast as 37.9% in 1970, and the remaining 62.1% was supplied from the other eight regions. But in Case 2 the rate of self-supply of Tohoku would be decreased by 0.8% and dependence on Kanto and Kinki would be increased by 0.1% and 0.3%, respectively, in Case 2.

In Fig. 7.5 (a), the industrial output of the machinery industry for each region is shown in Case 1 for 1960, 1966, and 1970, respectively. The difference between Cases 1 and 2 is shown in this figure. For example, the Tokai region had a larger output as a result of the construction of the Tokaido Shinkansen, but the Tohoku, Shikoku, and Chugoku regions would experience decreased industrial output. Similarly Fig. 7.5 (b) shows the effects on total output. It is seen from the figure that the Tokaido Shinkansen is advantageous to the total national output and, in particular, was to bring the Tokai and Kinki regions an increase in output of 432 and 243 billion yen, respectively, in 1970.

Figure 7.6 shows the effect of the Tokaido Shinkansen on the value added for each region in 1970. In this figure we can see the great economic effect of the Tokaido Shinkansen on the national total (except for agriculture and mining). Two regions along the railway line receive particularly large positive impacts.

The number of workers by region and industry is shown in Fig. 7.7. The national total number of workers was to be increased by 57,000 in 1970 due to the construction of the Tokaido Shinkansen. But the converse is shown in some regions. Figure 7.8 shows the number of travelers for business and pleasure between Kanto and the other eight regions and between Kinki and the other eight regions. The differences between Cases 1 and 2 are also shown. For example, the business travelers from Kinki to Kanto number about 36.2 million persons in Case 1 for 1970. The Tokaido Shinkansen increases this number by 9.9 million.

Similar data were obtained for other items: for example, total income produced, individual income, population, and freight flow in each year and region. The economic effects of the Tokaido Shinkansen can be judged from these data.

Conclusions

The conclusions drawn from our assumptions on the regional economic effects of the Tokaido Shinkansen are:

(a) The effect of the Tokaido Shinkansen on the national total in 1970 would increase by the industrial output by 220 billion yen ($730 million) and increase production income by 62 billion yen ($207 million). Thus the Tokaido Shinkansen will continue to make a great contribution to the economic activity of Japan.

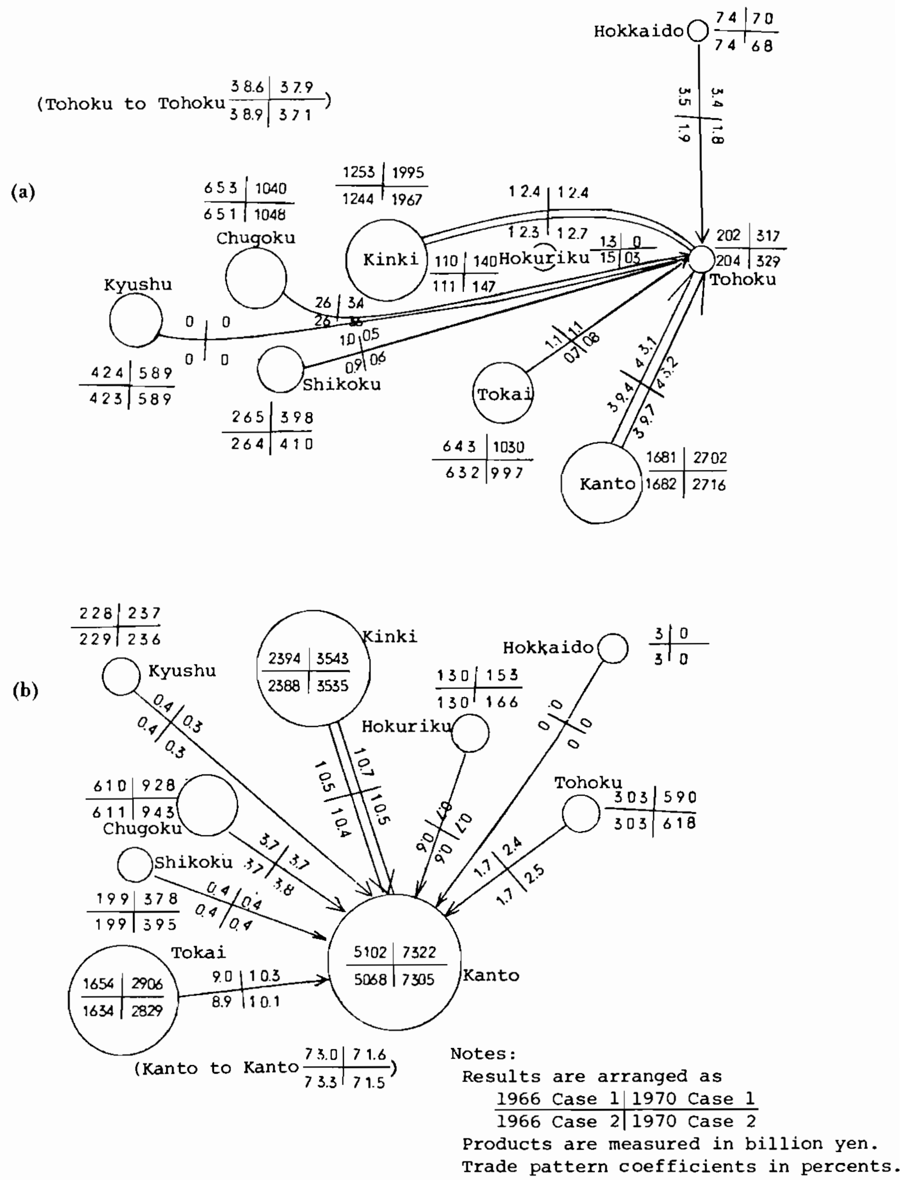


Fig. 7.4. (a) Tohoku trade pattern coefficients — chemicals. (b) Kanto trade pattern coefficients — machinery.

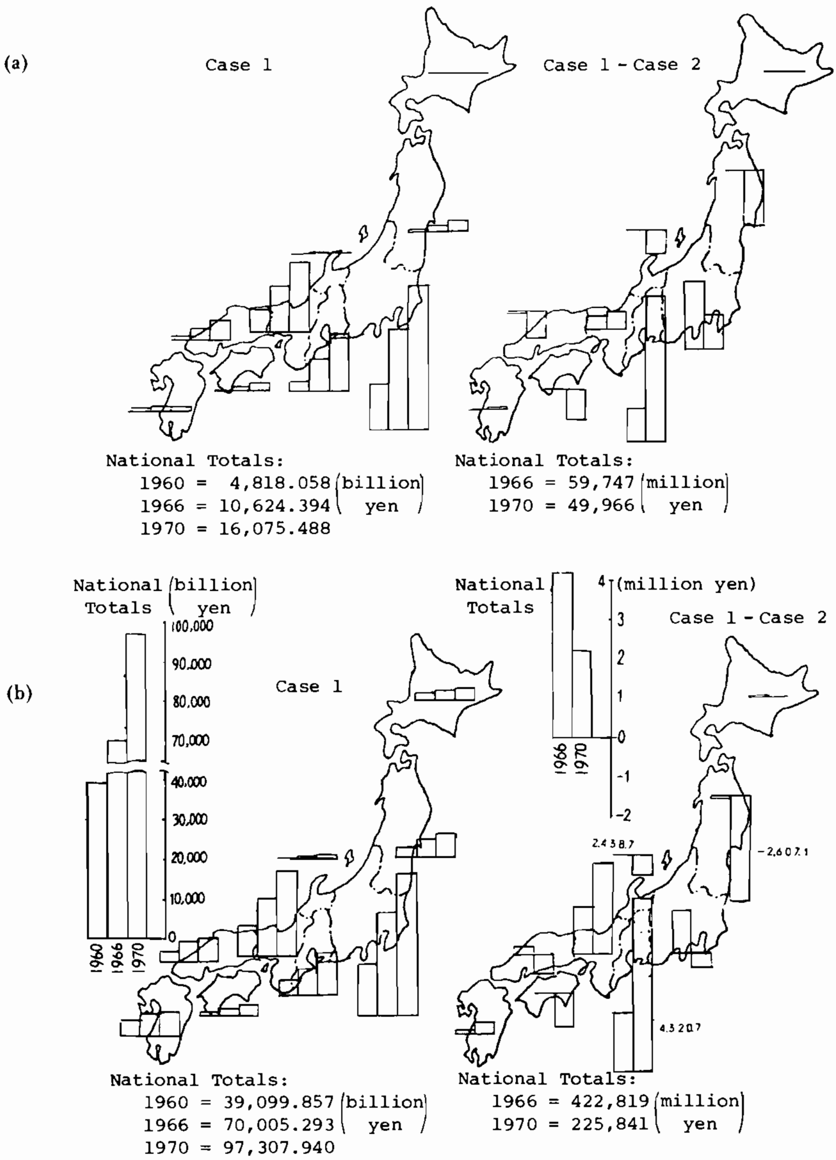


Fig. 7.5. (a) Output of machinery by region. (b) Total output by region.

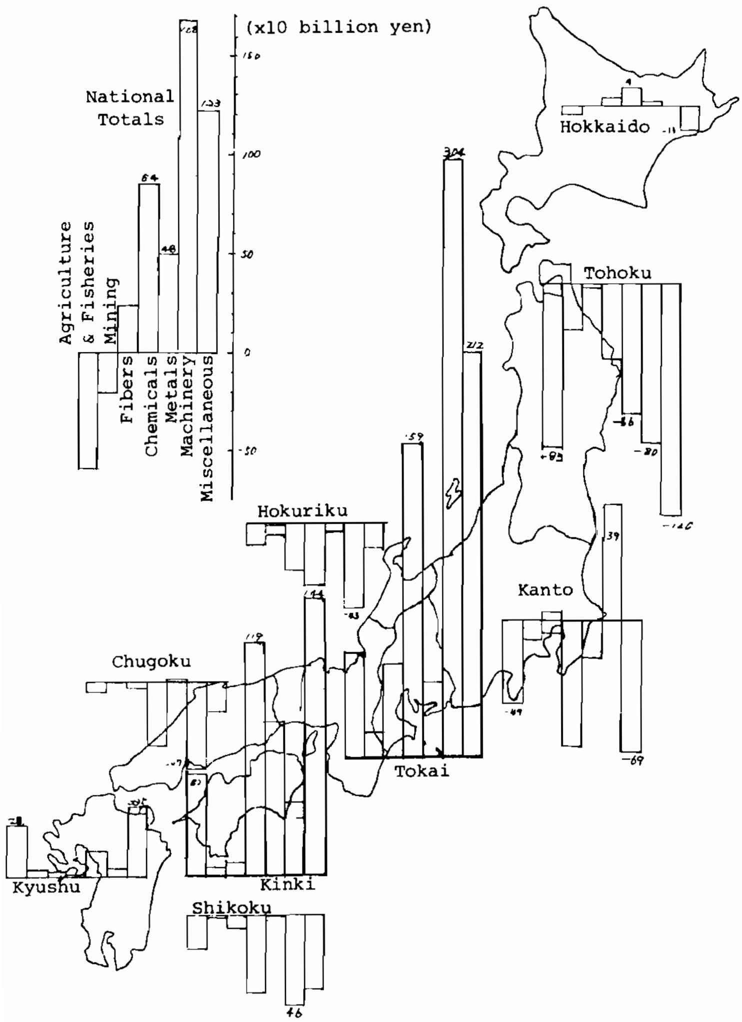


Fig. 7.6. Value added by region and industries, 1970 (Case 1 — Case 2).

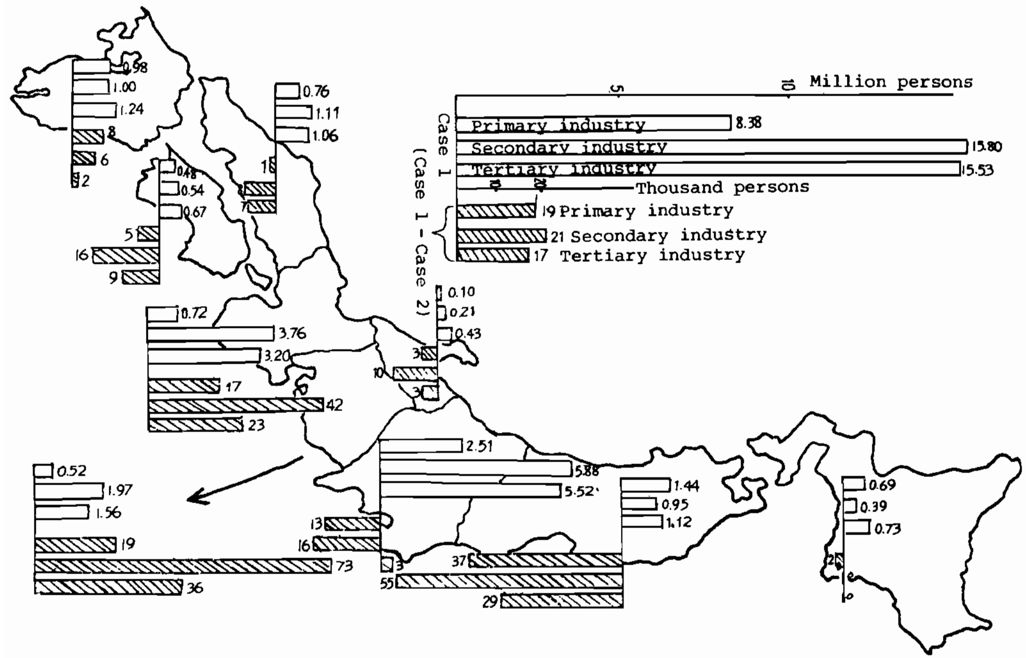


Fig. 7.7. Number of workers by region and industry, 1970.

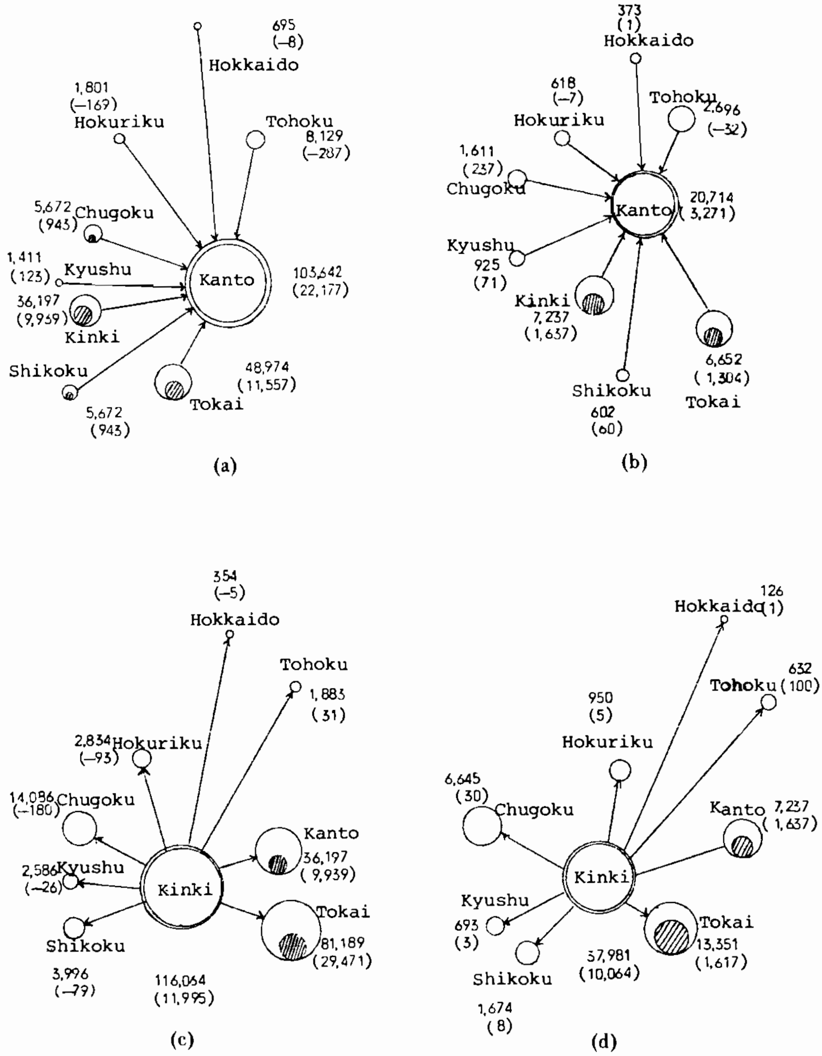


Fig. 7.8. (a) Business travelers, Kanto, 1970, for Case 1 and Case 2. (b) Tourists, Kanto, 1970, for Case 1 and Case 2. (c) Business travelers, Kinki, 1970, for Case 1 and Case 2. (d) Tourists, Kinki, 1970, for Case 1 and Case 2. *Note:* Case 2 is indicated in parentheses and by shaded areas. All figures in units of 1000 persons.

(b) The Tokaido Shinkansen will accelerate the concentration of population and industries on the central Pacific coast, for example in the Tokai, Kinki, and Kanto regions.

The model seems to be capable of comparing the effects of improving various transportation facilities if it is applied to various traffic projects in Japan. We can therefore expect effective information when choosing an optimum future transportation system in the context of regional planning.

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2. Amano, K. and M. Fujita, *A Study on the Regional Economic Efficiency of Improving Transportation Facilities,* privately printed in the Department of Transportation Engineering, Kyoto University, Japan, 1968.

Appendix

A study was carried out under the direction of K. Amano for the Ministry of Transportation and JNR on the future options for transportation system development in Japan. In this study the trade pattern coefficient model was used. Some characteristics of the study are given in this Appendix.

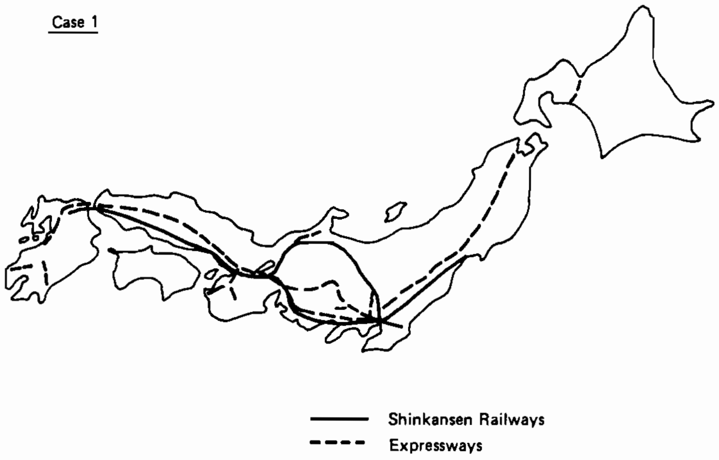
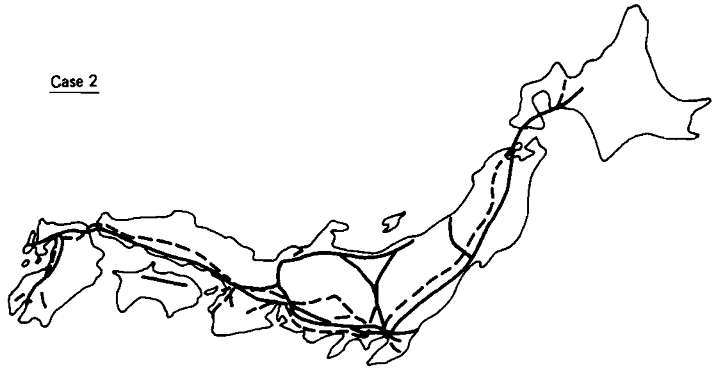
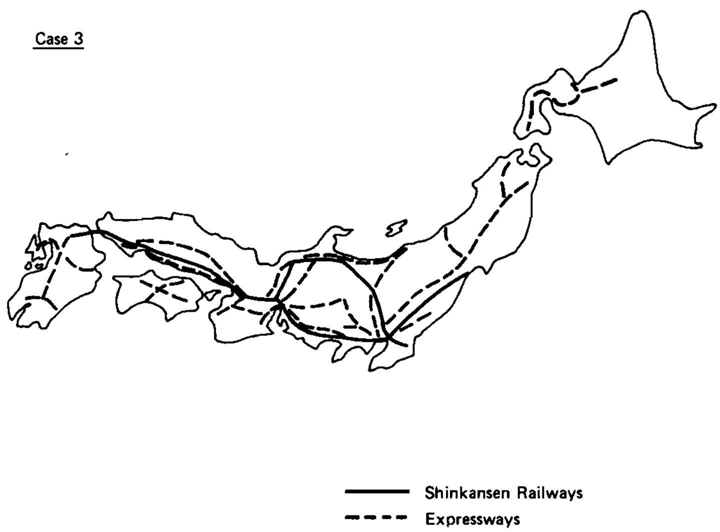


Fig. 7A.1. Proposed layouts of transportation facilities.

Case 2



Case 3



Case 4

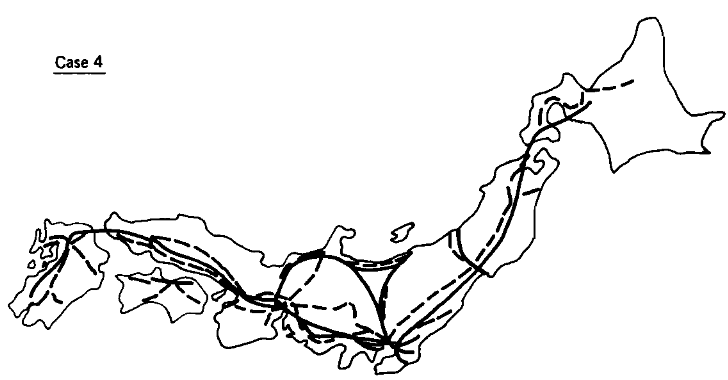


Fig. 7A.1. (contd)

TABLE 7A.1. *Characteristics of cases — cumulative length and construction costs*

		Shinkansen railways		Expressways		Total
		Total length (km)	Const. cost (billion $)	Total length (km)	Const. cost (billion $)	construction cost
Existing in 1971		160	600	731	1700	2300
Proposed for 1985	Case 1	1540	5667	2509	5867	11,533
	Case 2	3800	13,933	2509	5867	19,800
	Case 3	1540	5667	5974	13,933	19,600
	Case 4	3800	13,933	5974	13,933	27,867

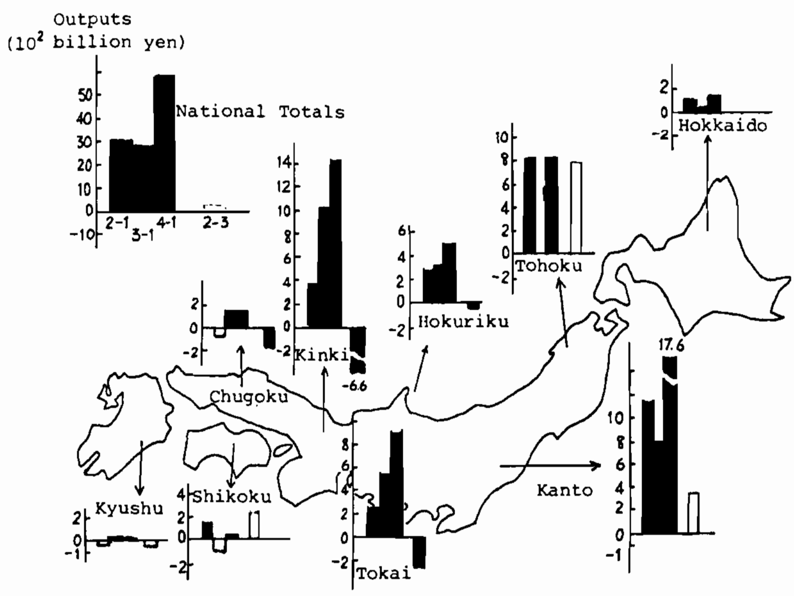


Fig. 7A.2. Case deviations of outputs by region, 1987.

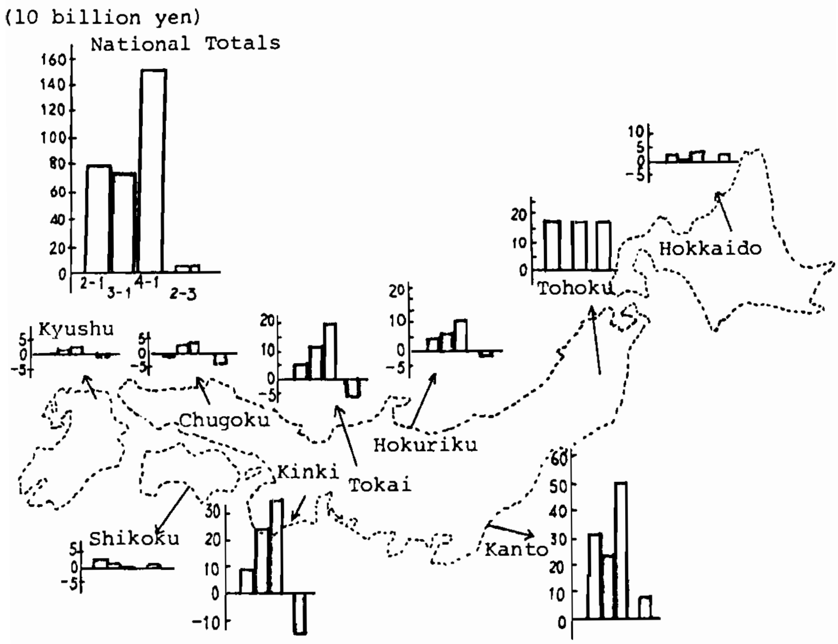


Fig. 7A.3. Case deviations of personal income by region, 1987.

8. *Application of the Spatial Econometric Model (SPAMETRI) to the Evaluation of the Economic Effects of the Shinkansen* *

N. SAKASHITA

1. Introduction

A number ofeconometric models have been developed in Japan which trace the interregional structure of post-war economic growth and forecast the impact of given regional allocations of public investment; see, for example, Economic Planning Agency of Japan (1968), Amano and Fujita (1970), and Fukuchi (1972). However, there exists in these models a certain imbalance between the treatment of the demand side and the supply side, and this may affect the accuracy of the long-range forecasting ability of the models. For example, the model used by the Economic Planning Agency tended to emphasize the supply side, even though use was made of somewhat problematical income determination functions. By contrast, the Amano–Fujita model was more or less biased toward the demand side, although this approach was based on the input–output analysis.

Outside Japan a comprehensive forecasting model has been developed by Meyer and others to evaluate the total effect of transport investment in a particular area of a country; see Meyer (1971). This model made extensive use of national and regional input–output techniques and of the concept of regional productive capacities, thus permitting important spatial dimensions to be included in the Macroeconomic Transport Simulation (METS) model. Even this model, however, is not completely free from the aforementioned problem of imbalance. In particular, changes in the spatial structure of a national economy as a result of transport investment are not fully treated, and this could be a fatal weakness in interregional simulation models of this kind. Attention might also be drawn to the following less serious defects of the model: the lack of interdependence between the quantity supplied and the quantity demanded in each region which must be at least partially interconnected through regional intermediate demand; the failure to

*A substantial part of this paper is a partial reproduction of a previous paper by the author, Sakashita (1974).

Additional computation for the Shinkansen Study was performed in cooperation with the Institute of Behavioral Science in Tokyo. Special credit should be given to Mr. Kunihisa and Mr. Oka of the Institute for their kind help to the author.

differentiate between regional income produced and regional disposable income which ignores the question of interregional income flows (an important factor for policy intervention); the oversimplified lag structure, etc.

In the study reported here an attempt has been made to overcome these difficulties in the original METS model by making several major modifications to the system, with particular emphasis on the role of distance variables in the formation of regional productive capacities. At the same time we have tried to utilize fully the available economic theories of intermodal transport choice among competitive facilities. In estimating the large number of parameters involved, the calibration method in the original METS model was not adopted. Instead, a conventional econometric estimation technique was employed. Overall application of the usual simultaneous estimation method was out of the question in view of the tremendous size of the model, relative to the availability of time-series data. In order to avoid this problem, it was necessary to build a recursive structure into the model except in the expenditure functions submodel. The model to be discussed here is referred to as the Spatial Econometric Model for Japan (SPAMETRI). In the next section, an outline of the model is provided by means of a flow chart, and all symbols are defined in Section 3. The complete framework of our simulation model is presented in Sections 4 through 11.

2. Analytical Purpose and its Outline of the Model

As indicated above, the analytical purpose of the model is to evaluate the interregional effect of a nation-wide transport investment project. A project of this dimension would undoubtedly change the spatial structure of the national economy drastically, so that traditional techniques of cost–benefit analysis which hinge upon *ceteris paribus* assumptions are hardly applicable to the evaluation of the total impact of the project. The only available analytical technique to deal with situations of this kind appears to be systems analysis, and it was for this reason that the SPAMETRI was developed. This model deals with the spatial and intertemporal allocation of transport investment, as well as all other public investments. Social capital is divided into three parts: Social Capital A, relating to transportation facilities; Social Capital B, relating to industrial production; and Social Capital C (the remainder), relating mainly to social welfare facilities.

The whole structure of SPAMETRI is divided into two major parts: Production–Expenditure Model and Traffic–Transport Model. Outlines of these two parts are presented as flow charts in Figs. 8.1(a), (b), (c), and Figs. 8.2(a),(b). In addition, a more understandable summary chart is given in Fig.8.3. As can been seen from Fig. 8.3 particularly, the structure of SPAMETRI is relatively simple and ordinary, except for a unique concept of "time distance" or "accessibility of the region" variables which will be explained in Section 4. Nevertheless, because of the multidimensional character of the model resulting from its interregional setting, the number of equations becomes extremely large.

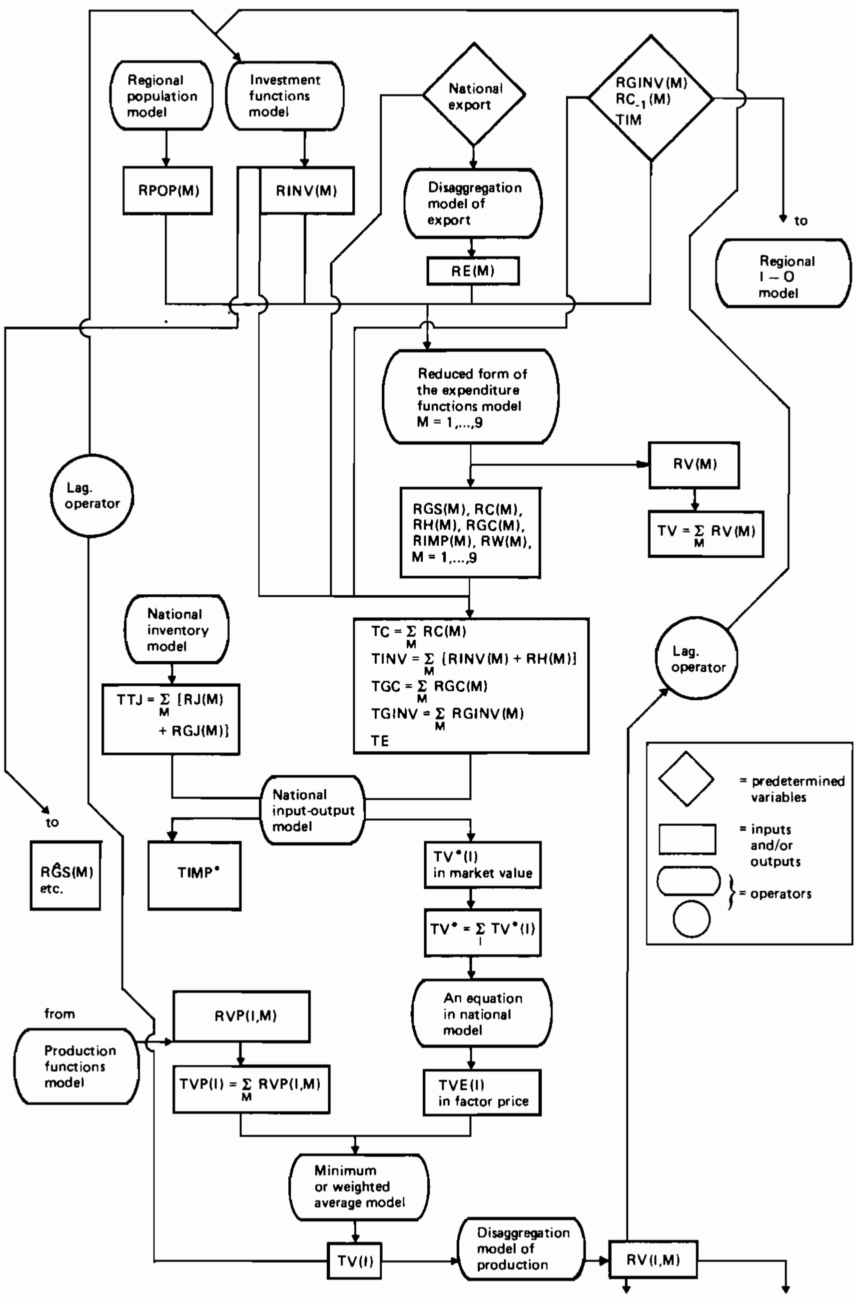


Fig. 8.1. Flow chart of the production–expenditure model. (a)

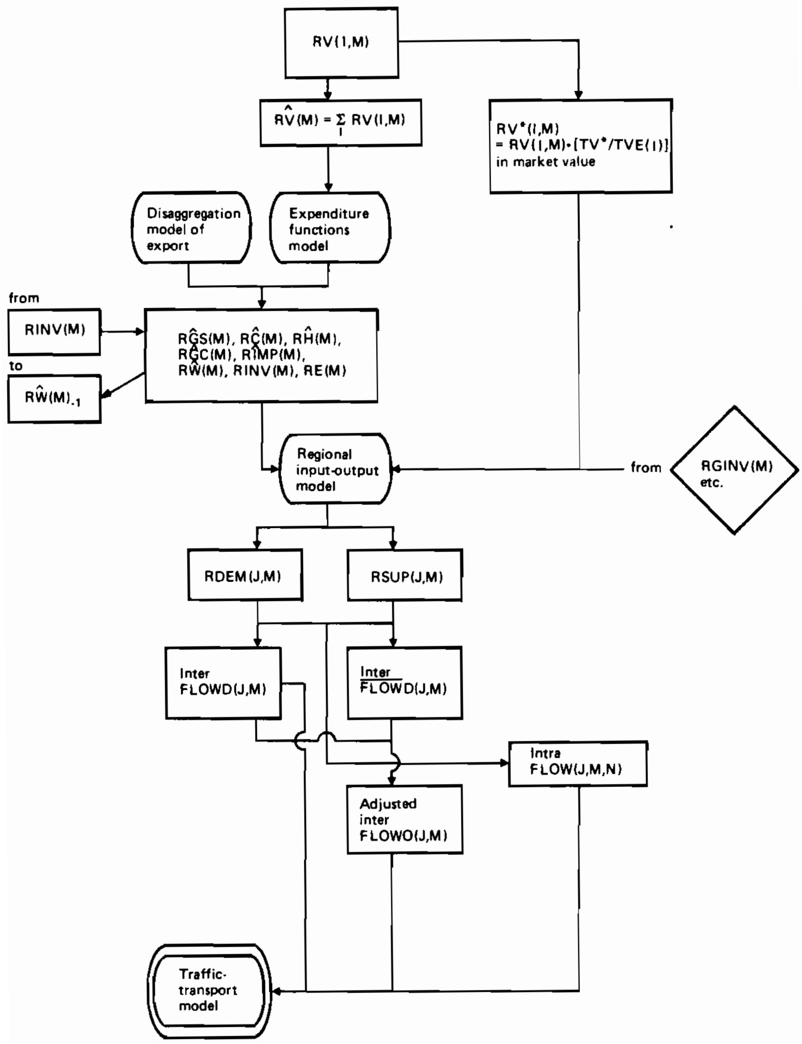
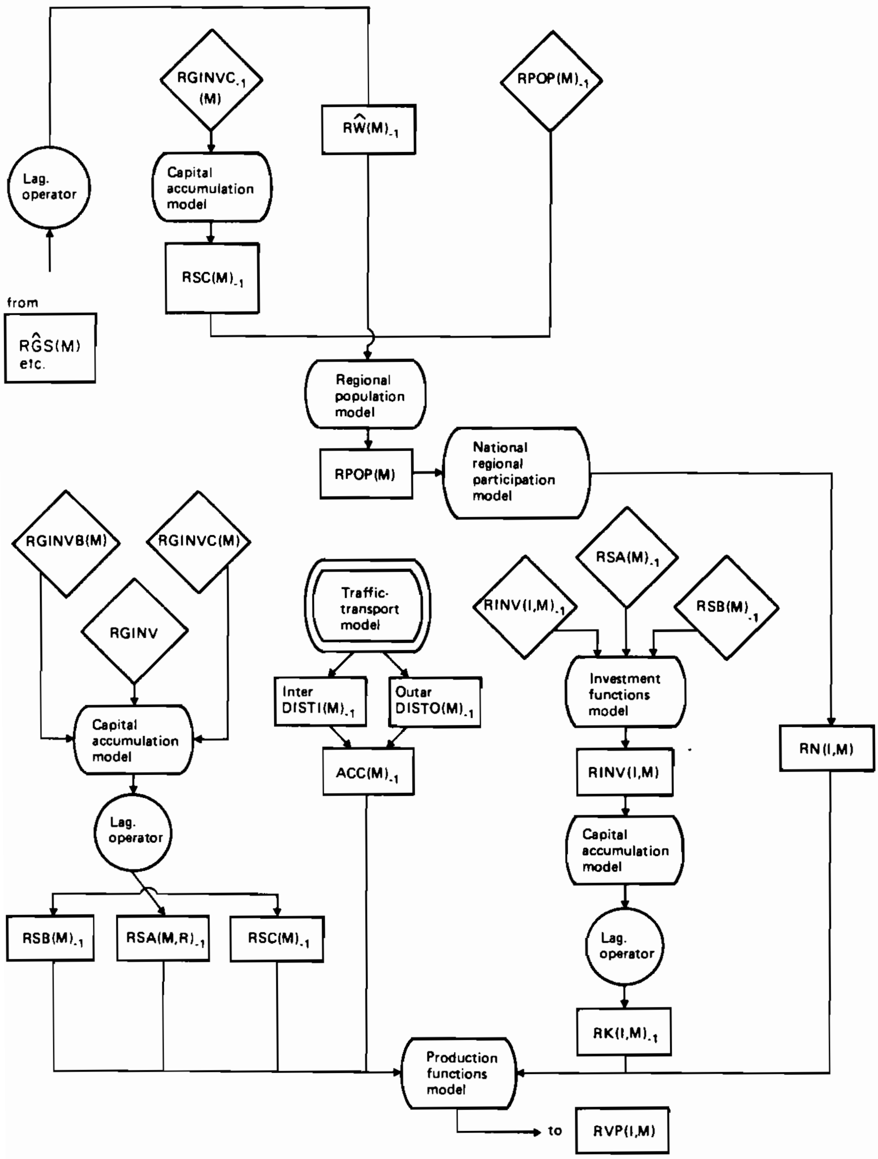

RV(I,M)
R̂V(M) = Σ_I RV(I,M)
RV*(I,M)
= RV(I,M)·[TV*/TVE(I)]
in market value
Disaggregation model of export
Expenditure functions model
from
RINV(M)
to
RŴ(M)-1
RĜS(M), RĈ(M), RĤ(M),
RĜC(M), RÎMP(M),
RŴ(M), RINV(M), RE(M)
Regional input-output model
from
RGINV(M) etc.
RDEM(J,M)
RSUP(J,M)
Inter FLOWD(J,M)
Inter FLOWD(J,M)
Intra FLOW(J,M,N)
Adjusted inter FLOWO(J,M)
Traffic-transport model

Fig. 8.1. (b)



RGINVC$_{-1}$ (M)
$R\hat{W}(M)_{-1}$
RPOP(M)$_{-1}$
Lag. operator
Capital accumulation model
RSC(M)$_{-1}$
from
$R\hat{G}S(M)$ etc.
Regional population model
RPOP(M)
National regional participation model
RGINVB(M)
RGINVC(M)
RGINV
Capital accumulation model
Lag. operator
RSB(M)$_{-1}$
RSA(M,R)$_{-1}$
RSC(M)$_{-1}$
Traffic-transport model
Inter DISTI(M)$_{-1}$
Outer DISTO(M)$_{-1}$
ACC(M)$_{-1}$
RSA(M)$_{-1}$
RINV(I,M)$_{-1}$
RSB(M)$_{-1}$
Investment functions model
RINV(I,M)
Capital accumulation model
Lag. operator
RK(I,M)$_{-1}$
RN(I,M)
Production functions model
to
RVP(I,M)

Fig. 8.1. (c)

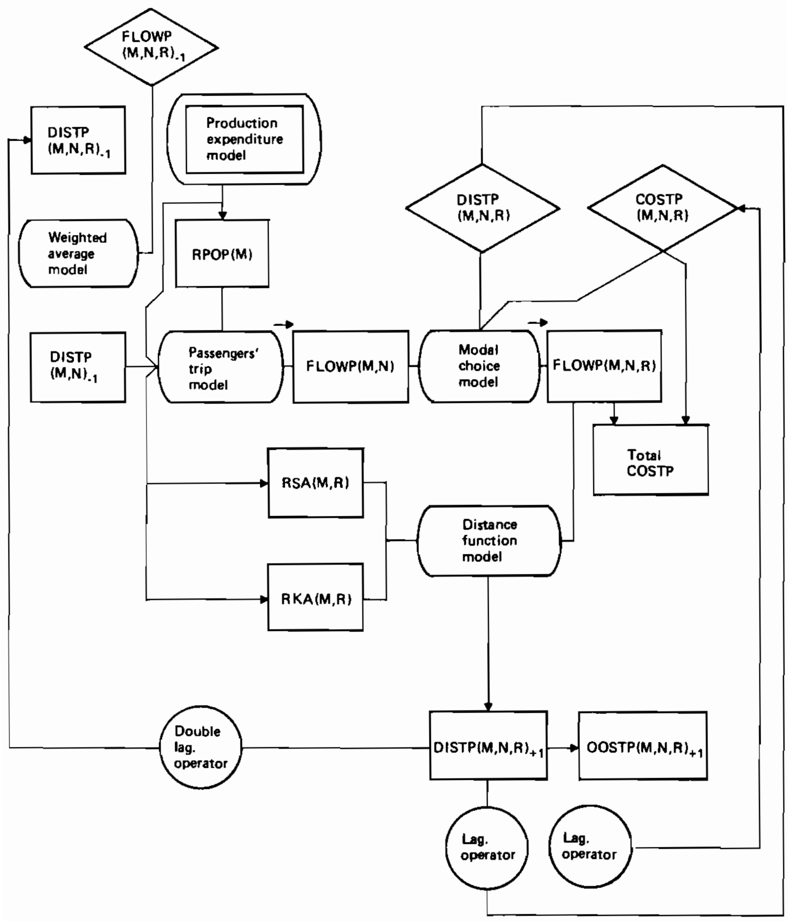


Fig. 8.2. Flow chart of the traffic–transport model. (a)

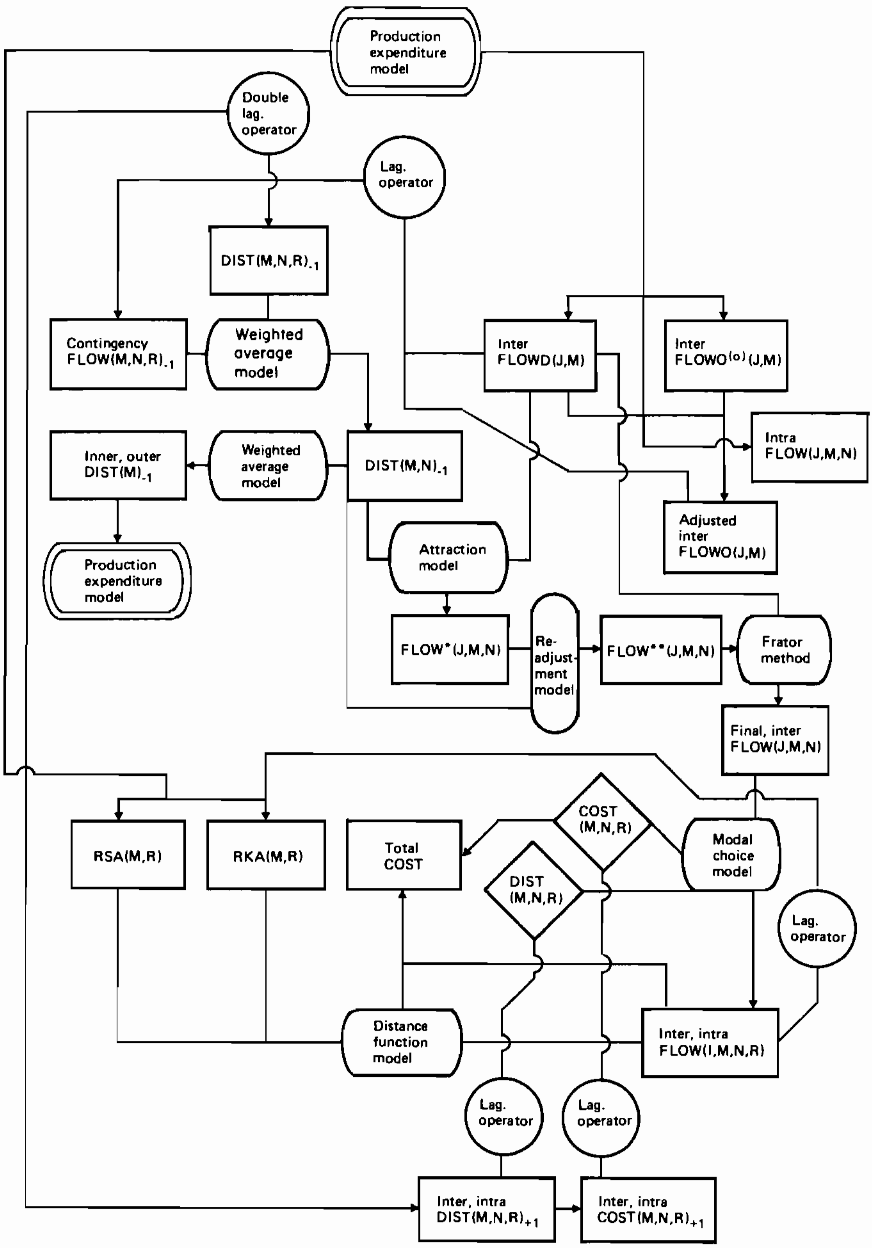

Production expenditure model
Double lag. operator
Lag. operator
DIST(M,N,R)$_{-1}$
Contingency FLOW(M,N,R)$_{-1}$
Weighted average model
Inter FLOWD(J,M)
Inter FLOWO$^{(o)}$(J,M)
Intra FLOW(J,M,N)
Inner, outer DIST(M)$_{-1}$
Weighted average model
DIST(M,N)$_{-1}$
Adjusted inter FLOWO(J,M)
Attraction model
Production expenditure model
FLOW*(J,M,N)
Re-adjust-ment model
FLOW**(J,M,N)
Frator method
Final, inter FLOW(J,M,N)
COST (M,N,R)
RSA(M,R)
RKA(M,R)
Total COST
DIST (M,N,R)
Modal choice model
Lag. operator
Distance function model
Inter, intra FLOW(I,M,N,R)
Lag. operator
Lag. operator
Inter, intra DIST(M,N,R)$_{+1}$
Inter, intra COST(M,N,R)$_{+1}$

Fig. 8.2. (b)

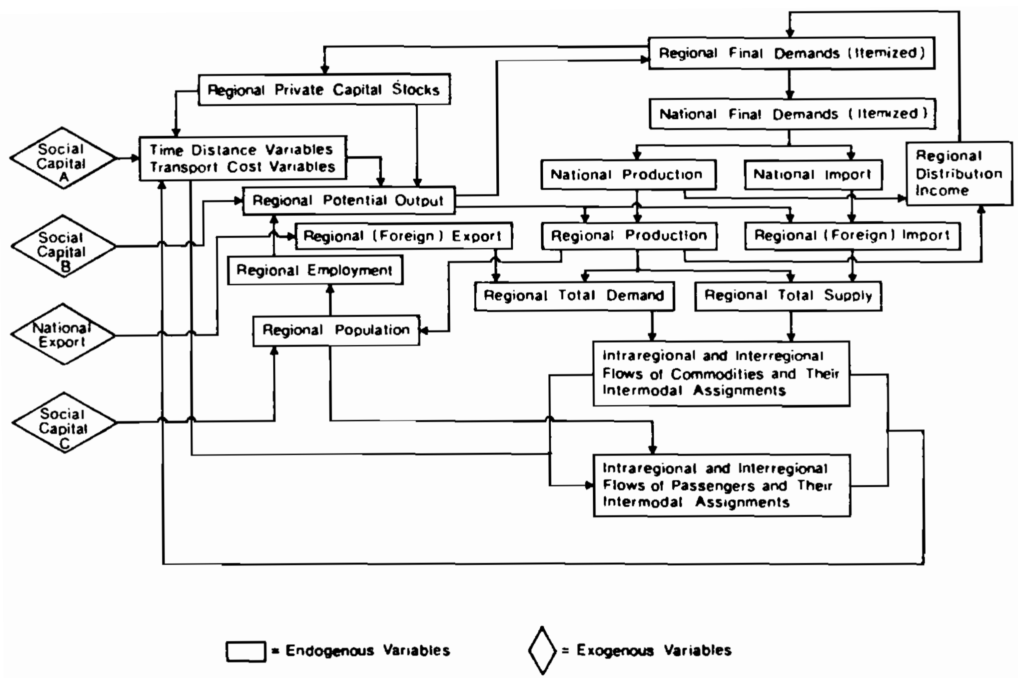


Fig. 8.3. Summary flow chart of SPAMETRI.

3. Notation

VARIABLES

FLOW (X,Y,R)	=	total commodity flow from location X to location Y by transportation mode R;
FLOWP (X,Y,R)	=	passenger flow from location X to location Y by transportation mode R;
DIST (X,Y,R)	=	time-distance for commodities from location X to location Y by transportation mode R;
DISTP (X,Y,R)	=	time-distance for passengers from location X to location Y by transportation mode R;
COST (X,Y,R)	=	transport cost for commodities from location X to location Y by transportation mode R;
COSTP (X,Y,R)	=	transport cost for passengers from location X to location Y by transportation mode R;
TVP (I)	=	national potential output of industry I;
TK (I)	=	national capital stock of industry I;
TN (I)	=	national employment of industry I;
TSB	=	national social capital stock of category B;
TVP	=	national potential output;
RVP (I,M)	=	potential output of industry I in region M;
RK (I,M)	=	capital stock of industry in region M;
RN (I,M)	=	employment of industry I in region M;
RSB(M)	=	social capital stock of category B in region M;
RVP (M)	=	potential output in region M;
RW (M)	=	personal income in region M;
RV (I,M)	=	realized income produced by industry I in region M;
TIM	=	year by Showa calendar (1975 = S50);
RC (M)	=	private consumption expenditure in region M;
RH (M)	=	private housing investment in region M;
RPOP (M)	=	population of region M;
RINV (I,M)	=	private fixed investment of industry I in region M;
RJ (M)	=	private inventory investment in region M;
RGC (M)	=	government current expenditure in region M;
RGJ (M)	=	government inventory investment in region M;
RGINV (M)	=	government fixed investment in region M;
TC	=	national private consumption expenditure;
TINV	=	national private fixed investment;
TJ	=	national private inventory investment;
TGC	=	national government current expenditure;
TGINV	=	national government fixed investment;
TV (I)	=	national realized income produced by industry I;
TE	=	national exports;
TIMP	=	national imports;
RIMP (M)	=	foreign imports into region M;
RE (M)	=	foreign exports from region M;

RDEM (J,M) = total demand for commodity J in region M;
RSUP (J,M) = total supply of commodity J in region M;
FLOW (J,M,N) = flow of commodity J from region M to region N;
FLOW (J,M,N,R) = flow of commodity J from region M to region N by transportation mode R;
RATIO (J,M,N,R) = FLOW (J,M,N,R)/FLOW (J,M,N) = assignment ratio of transportation for commodity J;
FLOWP (M,N) = flow of passengers from region M to region N;
FLOWP (M,N,R) = flow of passengers from region M to region N by transportation mode R;
RATIOP (M,N,R) = FLOWP (M,N,R)/FLOW (M,N) = assignment ratio of transportation for passengers;
RKA (M,R) = private capital stock of transportation facilities of mode R in region M;
RINVA (M,R) = private fixed investment of transportation facilities of mode R in region M;
RSZ (M) = social capital stock of category Z in region M; Z = A(R),B,C;
GROWTH (X) = growth rate of variable X;
RN (M) = total employment in region M;
ACC (M) = accessibility of region M;
ACCP (M) = passenger accessibility of region M;
DISTO (M) = outer time-distance of region M;
DISTI (M) = inner time-distance of region M;
FLOWD (J,M) = arrived flow of commodity J in region M;
FLOWO (J,M) = generated flow of commodity J in region M.

PARAMETERS

A1( ), B1 ( ), ..., B2( ), ... = constant coefficients of equations;
VA(I,M) = coefficient of value added of industry I in region M.

DIMENSIONS

I,J = 1,2,3 = industries or commodities (primary, secondary, tertiary);
M,N = 1,...,9 = regions of Japan (1 = Hokkaido, 2 = Tohoku, 3 = Kanto, 4 = Tokai, 5 = Hokuriku, 6 = Kinki, 7 = Chugoku, 8 = Shikoku, 9 = Kyushu);*
R = 1,2,3,4 = modes of transportation (railway, automobile, shipping, aviation).

OBSERVATION PERIODS OF VARIABLES

1955 1970 for economic and demographic variables;
1961 1970 for transport variables.

*In this classification, Hokkaido contains one prefecture, there are seven in Tohoku, nine in Kanto, four in Tokai, three in Hokuriku, six in Kinki, five in Chugoku, four in Shikoku, and seven in Kyushu, which make forty-six prefectures in Japan, excluding Okinawa.

4. Hierarchical Definitions of the Time–Distance Variable

It is impossible to explain all the details of SPAMETRI in this short article. We therefore concentrate on some key components of the model. Let us start from the definition of the time-distance variables.

The time–distance variables play an important role as an argument of each relevant production function. A concrete account of this will be given later.

BASIC DATA

DIST (MP,NQ,R) = time-distance (for commodities) from a central location in prefecture P in region M to a central location in prefecture Q in region M by transportation mode R ($M \overline{\neq} N$; $P \neq Q$).

INSIDE DISTANCE OF PREFECTURES

$$\text{DIST (MP,MP,R)} = \frac{1}{\text{NUM (MPN)}} \sum_{\text{MPN}} \frac{1}{4} \text{DIST (MP,MPN,R)}$$

= time-distance within prefecture P in region M by transportation mode R;

MPN = neighboring prefecture to MP;

NUM (MPN) = number of MPNs.

The constant ¼ is derived from a theoretical assumption that the level of economic activity at the point having a distance r from the center of the prefecture is expressed by $f(r) = a\text{-}br$.

DISTANCE WITHIN AND BETWEEN REGIONS BY MODE

$$\text{DIST (M,M,R)} = \frac{\sum_{\text{MP}} \sum_{\text{NQ}} \text{FLOW* (MP,MQ,R) DIST (MP,MQ,R)}}{\sum_{\text{MP}} \sum_{\text{MQ}} \text{FLOW* (MP,MQ,R)}}$$

= time-distance within region M by transportation mode R ($P \overline{\neq} Q$).

$$\text{DIST (M,N,R)} = \frac{\sum_{\text{MP}} \sum_{\text{NQ}} \text{FLOW* (MP,NQ,R) DIST (MP,NQ,R)}}{\sum_{\text{MP}} \sum_{\text{NQ}} \text{FLOW* (MP,NQ,R)}}$$

= distance from region M to region N by transportation mode R ($M \neq N$).

Note the asymmetry: DIST (M,N,R) ≠ DIST (N,M,R).

DISTANCE WITHIN AND BETWEEN REGIONS

$$\text{DIST (M,N)} = \frac{\sum_{R} \text{FLOW* (M,N,R) DIST (M,N,R)}}{\sum_{R} \text{FLOW* (M,N,R)}}$$

= average time distance from region M to region N (M $\overset{=}{\neq}$ N).

Note the asymmetry: DIST (M,N) $\neq$ DIST (N,M) when M $\neq$ N.

DISTANCE OF REGIONS AND NATION

$$\text{DISTO (M)} = \frac{\sum_{N} \text{FLOW* (M,N) DIST (M,N)} + \sum_{N} \text{FLOW* (N,M) DIST (N,M)}}{\sum_{N} \text{FLOW* (M,N)} + \text{FLOW* (N,M)}} \quad (M \neq N)$$

$$\text{DISTI (M)} = \text{DIST (M,M)}$$

$$\text{DIST} = \frac{\sum_{M}\sum_{N} \text{FLOW* (M,N) DIST (M,N)}}{\sum_{M}\sum_{N} \text{FLOW* (M,N)}} \quad (M \overset{=}{\neq} N)$$

ACCESSIBILITY OF REGIONS

$$\text{ACC (M)} = \frac{1}{1 + \text{DISTO (M)} + \text{DISTI (M)}}$$

In the above formulation, FLOW* implies that these terms are not actual flow quantities (i.e. FLOW) but smoothed values of the latter. If we express the element of the origin and destination table concerning FLOW by x_{ij}, its row sum by $x_{i.}$, and its column sum by $x_{.j}$, the smoothed values are calculated by the following formula:

$$x^{*}_{ij} = \frac{x_{i.}\ x_{.j}}{x_{..}}$$

where

$$x_{..} = \sum_{i} x_{i.} = \sum_{j} x_{.j} \quad .$$

TABLE 8.1. *DIST for 1963-1968 (hr)*

1963	30.92
1964	29.21
1965	29.58
1966	28.61
1967	27.56
1968	26.04

The first reason for this smoothing is that the individual elements of our origin and destination data showed quite irregular fluctuations (especially compared to their marginal sums), so that they could not be used as appropriate weighting factors. A second and more important reason is that these time-distance variables are assumed to represent potential accessibility indices of the regions and not their actual weighted averages. For this purpose the above formulation is felt to be more suitable. Some of the findings relating to intertemporal changes in the distances of regions are shown in Table 8.1.

For the passengers' trip, the variables of DISTIP and DISTOP are treated similarly. In the case of DISTOP, however, {FLOWP* (MP, NQ, R) + FLOWP* (NQ, MP, R)} are used as weights in order to eliminate the asymmetry regarding origin and destination so that DISTOP (M,N,R) = DISTOP (N,M,R), etc.

The variables ACCP (M) derived from DISTOP (M) and DISTIP (M) play an important role in the Shinkansen Study because they reflect the impact of Shinkansen construction most directly.

5. Expenditure Functions Model

In this submodel, such real-term endogenous variables as RV, RW, RC, RH, RGC, and RIMP are explained by a set of six linear expenditure equations and one identity for each region. Using the data of 1955-1970, the parameters of the structural equations are estimated by the two-stage least-squares method applied to each region one by one. In this estimation, the national income produced, TV, is treated as if it is a predetermined variable. For that purpose, a nation-wide expenditure model is estimated by the 2SLS method, and the time series of $\widetilde{TV}$ calculated from the final test of estimated national model is used for the regional estimation of expenditure functions model.

Sixty-three (= 7 × 9) equations of the expenditure functions model with one definitional relation of

$$TV = \sum_{M} RV(M)$$

are treated simultaneously in the *ex post facto* simulation (final test) of this model. If the result of this simulation is contrasted with that of the similar simulation performed with the national expenditure functions model, we observe very small "disaggregation" biases ranging from -3.2% to 1.2%. This consequence implies strong homogeneity among different regions in Japan with regard to the expenditure behavior.

Needless to say, the model in this section is a typical Keynesian model of effective demand.

6. Investment Functions Model and Capital Accumulation

For the secondary and tertiary industries, national investment functions of the following form are estimated by the 1955-1970 data:

$$\mathrm{TINV}(\mathrm{I}) = \alpha(\mathrm{I}) + \beta(\mathrm{I})\{\mathrm{TV}(\mathrm{I}) - \mathrm{TVP}(\mathrm{I})_{-1}\} + \gamma(\mathrm{I})\,\mathrm{TINV}(\mathrm{I})_{-1}, \qquad \mathrm{I} = 2,3.$$

Then TINV (I)'s are disaggregated into RINV (I,M) by the following formula:

$$\frac{\mathrm{RINV}(\mathrm{I,M})}{\mathrm{TINV}(\mathrm{I})} = \alpha(\mathrm{I,M}) + \beta(\mathrm{I})\frac{\{\mathrm{RSA}(\mathrm{M}) + \mathrm{RSB}(\mathrm{M})\}_{-1}}{\sum_{\mathrm{N}}\{\mathrm{RSA}(\mathrm{N}) + \mathrm{RSB}(\mathrm{N})\}_{-1}} + \gamma(\mathrm{I})\frac{\mathrm{RINV}(\mathrm{I,M})_{-1}}{\sum_{\mathrm{N}}\mathrm{RINV}(\mathrm{I,N})_{-1}}$$

$$\sum_{\mathrm{M}}\alpha(\mathrm{I,M}) + \beta(\mathrm{I}) + \gamma(\mathrm{I}) \equiv 1, \qquad \mathrm{I} = 2,3.$$

For the primary industry, the following investment functions are estimated separately for all regions:

$$\mathrm{RINV}(1,\mathrm{M}) = \alpha(1,\mathrm{M}) + \beta(1,\mathrm{M})\{\mathrm{RV}(1,\mathrm{M})_{-1} - \mathrm{RVP}(1,\mathrm{M})_{-1}\} + \gamma(1,\mathrm{M})\,\mathrm{RINV}(1,\mathrm{M})_{-1}.$$

Capital accumulations are depicted by the following equations for both the private capital stock and the social capital stock:

$$(\text{capital stock}) = \alpha\,(\text{capital stock})_{-1} + (\text{investment}).$$

7. Production Functions Model

The production functions with the variable elasticity of substitution are estimated for three industries in all regions. Their general form is:

$$RV = \exp\left\{a_0 + a_1\ ACC_{-1}\right\} \cdot \left\{u\ (RK_{-1})\right\}^{a_2 + a_4 \log \frac{RSZ}{RK_{-1}}} \times (RN)^{a_3 + a_5 \log \frac{RSZ}{RN}}$$

in which u is the degree of utilization of the capital stock. The values of u are estimated by the actual time series of output–capital ratio for each industry. To obtain the potential production functions in which RV is replaced by RVP, u is set to be unity.

As RSZ variables, RSB is used for the primary and secondary industries, and RSB or RSC is used for the tertiary industry. In addition, the ACC variable is replaced by the ACCP variable in the tertiary industry in order to clarify the role of Shinkansen construction.

8. National and Regional Input–Output Models

NATIONAL SUMMATION OF FINAL DEMAND

$$TC = \sum_{M} RC(M).$$

$$TINV = \sum_{M}\left\{\sum_{I} RINV(I,M) + RH(M)\right\}.$$

$$TJ = \sum_{M}\left\{RJ(M) + RGJ(M)\right\}.$$

$$TGC = \sum_{M} RGC(M).$$

$$TGINV = \sum_{M} RGINV(M).$$

NATIONAL INCOME PRODUCED

The expressions TC,...,TGINV which are calculated above represent scalar variables. Therefore, some type of commodity allocation vector is required in order to obtain the vector-value of total output. Assuming only one final demand scalar F, this relation can be shown as

$$\begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} + \tilde{M} \begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} = A \begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} + \begin{bmatrix} f_1^0 \\ \cdot \\ \cdot \\ \cdot \\ f_n^0 \end{bmatrix} \quad F$$

in which $\tilde{M}$ is a diagonal matrix of input–output ratios. The value-added vector can be calculated as follows:

$$\begin{bmatrix} v_1 \\ \cdot \\ \cdot \\ \cdot \\ v_n \end{bmatrix} = \tilde{V} \begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} = \tilde{V}\,[I - A + \tilde{M}]^{-1} \begin{bmatrix} f_1^0 \\ \cdot \\ \cdot \\ \cdot \\ f_n \end{bmatrix} F = \begin{bmatrix} a_1 \\ \cdot \\ \cdot \\ \cdot \\ a_n \end{bmatrix} \quad F$$

where $\tilde{V}$ is a diagonal matrix of value-added coefficients. With regard to imports, we have

$$m = 1'\tilde{M} \begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix} = 1'\tilde{M}\,[I - A + \tilde{M}]^{-1} \begin{bmatrix} f_1^0 \\ \cdot \\ \cdot \\ \cdot \\ f_n^0 \end{bmatrix} F = bF$$

where $1'$ is an addition vector of $(1,\ldots,1)$.

Finally, we have the following expression for the demand side of income produced in each industry:

$$\begin{aligned} TV\,(I)^d \;=\; & A\,(I,C,T)\;TC + A\,(I,INV,T)\;TINV \\ & + A\,(I,J,T)\;TJ + A\,(I,GC,T)\;TGC \\ & + A\,(I,GINV,T)\;TGINV + A\,(I,E,T)\;TE. \end{aligned}$$

The superscript d indicates that the expression represents quantities on the demand side. The coefficients A( ) and B( ) correspond to a_j and b in the previous equations. However, these are assumed to change through time, T. Furthermore, these coefficients are subject to the following constraint:

$$\sum_{I} A\,(I,Z,T) + B\,(Z,T) \equiv 1$$

for all T,Z = C, and INV,J,GC,GINV,E.

The realized value of TV(I) can be regarded as a weighted average of $TV(I)^d$ and the corresponding potential output TVP(I). It is very difficult, however, to determine the precise values of the weights and for this reason a simpler formulation was employed:

$$TV(I) = \text{Min}\ [TV(I)^d, TVP(I)],$$

in which

$$TVP(I) = \sum_M RVP(I,M)$$

in order to obtain the realized value of TV(I). In the case of imports it was simply assumed that

$$TIMP = TIMP^d.$$

In the forecasting procedure the pattern of change of A( ) and B( ) will be projected by some variant of the RAS method.*

REGIONAL DISAGGREGATION OF PRODUCED INCOME AND EXPORTS

$$RV(I,M) = TV(I) \left[A10(I,T) \frac{RV(I,M)_{-1}}{\sum_M RV(I,M)_{-1}} + B10(I,T) \frac{RVP(I,M)_{-1}}{\sum_M RVP(I,M)_{-1}} \right]$$

$$RE(M) = TE \left[A12(T) \frac{RE(M)_{-1}}{\sum_M RE(M)_{-1}} + B12(T) \frac{\sum_I RVP(I,M)_{-1}}{\sum_M \sum_I RVP(I,M)_{-1}} \right]$$

For consistency, it is necessary that

$$Ai[(I),T] + Bi[(I),T] \equiv 1 \quad (i = 10,11,12)$$

in this formulation of regional disaggregation.

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*The method is called "Modified RAS Method of Sakashita".

TOTAL REGIONAL DEMAND AND TOTAL REGIONAL SUPPLY

By the use of regional input–output analysis, the total regional demand and the total regional supply of commodities, i.e. RDEM(J,M) and RSUP(J,M), are derived from RV(I,M), RC(M), RINV(I,M), RH(M), RGC(M), RGINV(M), RE(M), and from RV(J,M), RIMPT(M), RJ(M) where J = 1,2. The equations are as follows:

$$\begin{aligned} \mathrm{RDEM}(J,M) &= \sum_I \sum_I C(J,I,M,T) \frac{\mathrm{RV}(I,M)}{\mathrm{VA}(I,M,T)} + D(J,M,T)\,\mathrm{RC}(M) \\ &+ E(J,M,T)\left\{\sum_I \mathrm{RINV}(I,M) + \mathrm{RH}(M)\right\} \\ &+ F(J,M,T)\,\mathrm{RGC}(M) + G(J,M,T)\,\mathrm{RGINV}(M) \\ &+ H(J,M,T)\,\mathrm{RE}(M) \end{aligned}$$

$$\mathrm{RSUP}(J,M) = \frac{\mathrm{RV}(J,M)}{\mathrm{VA}(J,M)} + I(J,M,T)\,\mathrm{RIMPT}(M) - J(J,M,T)\,\mathrm{RJ}(M).$$

The first items on the right-hand side of the first equation represent intermediate demands for commodities. The term VA(I,M,T) is a value-added coefficient and the C( ) terms are the usual input coefficients, both of which are changeable over time.

9. Intraregional and Interregional Commodity and Passenger Flows

A rather complicated technique is used to derive the intraregional and interregional commodity flows from RSUP(J,M) and RDEM(J,M) variables. The basic idea is a mixture of the attraction model in the form of

$$\begin{aligned} \mathrm{FLOW}(J,M,N) = \mathrm{RDEM}(J,N)\Bigg\{ & A13(J,M,N) \\ & + B13(J,N)\left[\frac{\mathrm{RSUP}(J,M)}{[\mathrm{DIST}(M,N)_{-1}]^{C13}} \sum_Q \frac{\mathrm{RSUP}(J,Q)}{[\mathrm{DIST}(Q,N)_{-1}]^{C13}}\right]\Bigg\} \end{aligned}$$

$$(J = 1, 2, M \gtreqless N)$$

in general and the so-called Frator method.

On the other hand, intraregional and interregional passenger flows are estimated by a rather simple gravity model:

$$\text{FLOWP (M,N)} + \text{FLOWP (N,M)} = \frac{1}{[\text{DISTP (M,N)}_{-1}]^{A14}} [\text{B14 (M,N)}\{\text{RPOP (M) RPOP (N)}\} + \text{C14 (M,N)}\{\text{RV (M)}_{-1}\ \text{RV (N)}_{-1}\}] \quad (\text{M} \neq \text{N}).$$

Then the commodity and passenger flows are disaggregated into those flows on different transport modes by the respective modal choice models. The basic idea of the latter is as follows:

$$\text{RATIO (J,M,N,R)} = F^{\text{JMNR}} \left\{ \frac{\text{DIST (M,N,R)}}{\overline{\text{DIST}}\ \text{(M,N)}}, \frac{\text{COST (M,N,R)}}{\overline{\text{COST}}\ \text{(M,N)}} \right\}$$

$$\text{FLOW (J,M,N,R)} = \text{RATIO (J,M,N,R) FLOW (J,M,N)}$$

$\overline{\text{DIST}}$ (M,N), $\overline{\text{COST}}$ (M,N) = a simple average over R.

$$\text{RATIOP (M,N,R)} = G^{\text{MNR}} \left\{ \frac{\text{DISTP (M,N,R)}}{\overline{\text{DISTP}}\ \text{(M,N)}}, \frac{\text{COSTP (M,N,R)}}{\overline{\text{COSTP}}\ \text{(M,N)}} \right\}$$

$$\{\text{FLOWP (M,N,R)} + \text{FLOWP (N,M,R)}\} = \text{RATIOP (M,N,R)}\{\text{FLOWP (M,N)} + \text{FLOWP (N,M)}\}.$$

In determining the actual functional forms of F^{JMNR} and G^{MNR}, such theoretical models as those developed by Sakashita (1965), Quandt and Baumol (1966), and Sasaki (1974) were considered. Finally, the following form was adopted as a practical solution:

$$v_i = a_i + b\left(\frac{c_i - \bar{c}}{\bar{c}}\right) + d\left(\frac{t_i - \bar{t}}{\bar{t}}\right)$$

where v_i is the assignment ratio to mode of transportation i, c_i and t_i are unit transport cost and transport time by the same mode, and $\bar{c}$ and $\bar{t}$ are simple means of c_i and t_i over $i = 1,..,k$. For the consistency of $\Sigma i v_i \equiv 1$, it is necessary that $\Sigma i a_i = 1$. The following statistical model emerges:

$$\begin{array}{l} v_1 = a_1 Q_1 + \ldots + a_{k-1} Q_{k-1} + b\left(\frac{c_1 - \bar{c}}{\bar{c}}\right) + d\left(\frac{t_1 - \bar{t}}{\bar{t}}\right) \\ \vdots \qquad\qquad \vdots \qquad\qquad\qquad \vdots \end{array}$$

$$v_{k-1} = a_1 Q_1 + \ldots + a_{k-1} Q_{k-1} + b\left(\frac{c_{k-1} - \bar{c}}{\bar{c}}\right) + d\left(\frac{t_{k-1} - \bar{t}}{\bar{t}}\right)$$

$$v_{k-1} = -a_1 Q_1 - a_2 Q_2 - \ldots - a_{k-1} Q_{k-1} + b\left(\frac{c_k - \bar{c}}{\bar{c}}\right) + d\left(\frac{t_k - \bar{t}}{\bar{t}}\right)$$

where $\{Q_i\}$ is a set of dummy variables which assume the following values:

$$Q_i = \begin{cases} 1 \text{ for equation } i \ (i = 1,2,\ldots,k-1); \\ -1 \text{ for equation } k; \\ 0 \text{ for other equations.} \end{cases}$$

10. Distance Functions Model

The time – distance variables DIST(M,N) between regions M and N(M $\neq$ N) are explained by the congestion variables. A typical form of these equations is:

$$\mathrm{DIST\,(M,N,R)} = \alpha_0\,\mathrm{(M,N,R)} + \alpha_1\,\mathrm{(M,N,R)} \sum_{X \in [M,N]} \left[\frac{\sum_J \{\mathrm{FLOWO\,(J,X,R)} + \mathrm{FLOWD\,(J,X,R)}\}}{\mathrm{RSA\,(X,R)} + \mathrm{RKA\,(X,R)}}\right]^{\alpha_2} .$$

In this equation, (M,N) means the set of regions whose transport facilities are related to the traffic from region M to region N.

Actually a different and a little more complicated form is considered for the distance functions in order to obtain more satisfactory fitting of estimation. Similar functions are designed for DISTP(M,N,R) variables.

COST(M,N,R) and COSTP(M,N,R) variables are derived from the time distance variables by the following formula in general:

$$\Delta\,\mathrm{COST\,(M,N,R)} = \mathrm{A21\,(M,N,R)}\ \Delta\,\mathrm{DIST\,(M,N,R)} + \mathrm{B21\,(M,N,R)\ TIM}$$

$$\Delta\,\mathrm{COSTP\,(M,N,R)} = \mathrm{A22\,(M,N,R)}\ \Delta\,\mathrm{DISTP\,(M,N,R)} + \mathrm{B22\,(M,N,R)\ TIM}.$$

In the above formulation, we need the specification of the factors which explain the time behavior of RKA(M,R). We specify it as:

$$RINVA(M,R) = A17(M,R)\ \Delta FLOW(M,R)_{-1} + B17(M,R)\ \Delta FLOWP(M,R)_{-1} + C17(M,R)\ TIM$$

in which

$$FLOW(M,R) = \sum_{N} FLOW(M,N,R) + \sum_{N} FLOW(N,M,R)$$

$$FLOWP(M,R) = \sum_{N} FLOWP(M,N,R) + \sum_{N} FLOWP(N,M,R)$$

$$RKA(M,R) = A16(M,R)\ RKA(M,R)_{-1} + RINVA(M,R)\ .$$

11. Regional Population Growth and Employment

The basic idea in this model section is given by the following set of equations:

$$\begin{aligned} GROWTH[RPOP(M)] = {} & 0(M) \\ & + A23(M)\left\{GROWTH[RV(M)]_{-1} - GROWTH[TV(M)_{-1}\right\} \\ & + B23(M)\ \Delta\left\{DISTP - DISTP(M)\right\}_{-1} \\ & + C23(M)\left\{GROWTH[RSC(M)]_{-1} - GROWTH[TSC]_{-1}\right\} \end{aligned}$$

$$RN(M) = \left\{A24(M) + B24(M)\ TIM\right\} RPOP(M)$$

$$RN(I,M) = \left\{A25(I,M) + B25(I,M)\ TIM\right\} RN(M)$$

where $\Sigma_I A25(I,M) \equiv 1$ and $\Sigma_I B25(I,M) \equiv 0$. Here GROWTH(X) refers to the annual growth rate of variable X.

Again the actual estimation deviates from the above general formulation and some exogenous information is utilized to forecast the future movement of the population and employment variables.

12. Ex Post Facto Simulations and Application of the Model to the Shinkansen Study

As stated in Section 3, 1955-1970 time series data are available for the economic and demographic variables, but only 1961-1970 data are available for the transport variables. Therefore, the equations which contain some transport variables have to be estimated by the data for shorter periods.

Because of this limitation, together with other technical difficulties, the *joint ex post facto* simulation (final test) with the production-expenditure model (PEM) *and* the traffic-transport model (TTM) is possible only for 1963-1968. However, a single *ex post facto* simulation with PEM can be performed with exogenous supply of DISTIP(M) and DISTOP(M) variables extrapolated backward by the available data. This single simulation with PEM was carried out for the years 1956-1963 which cover the major construction periods of Shinkansen.*

In order to evaluate the economic effects of Shinkansen construction, we performed simulations of three types in which one is *actual* and two are *hypothetical,* so to speak.

The first simulation is a so-called final test in which we use actual time series of the exogenous variables, particularly RGINVA(1,M), government fixed investment in the railway that includes the construction investment of Shinkansen especially for M = 3,4, and 6. We call this simulation Shinkansen Simulation (S-SIM).

The second simulation is a hypothetical one in which the same time series of the exogenous variables are used but the endogenous DISTIP(M), DISTOP(M), and ACCP(M) variables are replaced by exogenously given less efficient values for 1965-1968. This change means that we are assuming non-existence of Shinkansen for the same period in spite of the unchanged investment series for the National Railway (JNR) in the preceding years. In other words, we are assuming that the same amounts of railway investment were put into other directions than Shinkansen. The hypothetical values of DISTIP(M), etc., are given by the comparison of the performance of the ordinary railway with that of Shinkansen. This is called Non-Shinkansen Simulation (NS-SIM).

Finally, the third simulation is the most hypothetical one. RGINVA(1,M) for M = 3,4, and 6 in 1959-1965 are reduced to make allowance for the *non-existence* of Shinkansen construction investment or equivalent investment in the ordinary railway. DISTIP(M), DISTOP(M), and ACCP(M) variables for 1965-1968 become even less efficient because of the reduction of RGINVA(1,M) in the preceding years. We call this simulation Reference Simulation (R-SIM).

Because of aforementioned separation between joint and single simulations, we have the classification of simulations shown in Table 8.2.†

S-SIM 1 and NS-SIM 1 produce the same results because of the same time behavior of exogenous variables. In R-SIM1 and R-SIM 2, ACC(M) and ACCP(M) are conveniently endogenized by their relations to RSA(M) and {ΣRSM(N)}.

The *relative* benefit–cost analyses are performed at the time point of 1965 by comparing the difference of benefits between S-SIM and R-SIM with that of

*The construction investment for the Shinkansen was implemented from 1959 to 1965. The cost of construction in nominal terms is given in Table 8.3.

†For the overlapping period of 1963, the results of the Joint Simulation are adopted. Furthermore, the results for 1956-1962 are also adjusted in connection with the comparison between 1963 results of the Single Simulation and those of the Joint Simulation.

TABLE 8.2. *Classification of simulations*

	1956-1963 (Single)	1963-1968 (Joint)
Shinkansen simulation	S-SIM 1	S-SIM 2
Non-Shinkansen simulation	NS-SIM 1	NS-SIM 2
Reference simulation	R-SIM 1	R-SIM 2

TABLE 8.3. *Cost of construction*

	Shinkansen construction cost	Total construction investment of JNR	(A)/(B) (%)
1959	21(8)	1076	2
1960	103(31)	1164	9
1961	524(233)	2071	25
1962	1027(202)	2518	41
1963	1448(98)	2914	49
1964	657(15)	2593	25
1965	32(3)	3312	1
Total	3812(590)	15,648	24

Notes: Unit: 100 million yen. Land purchase costs are included in the figures and are shown in parentheses.

benefits between NS-SIM and R-SIM. The present value of benefits in each case is calculated by the following formula with some suitable benefit variable(s) X.

$$B = \sum_{t=-6}^{3} \frac{X(1965+t)}{(1+r)^t} \qquad r\text{ : discounting factor}$$

Naturally, X can be the national income produced, and {B(S-SIM)-B(R-SIM)} and {B(NS-SIM)-B(R-SIM)} should be contrasted with the present value of costs in the form:

$$C = \sum_{t=-6}^{3} \frac{Y(1965+t)}{(1+r)^t}$$

in which Ys are differences between {RGINVA(1,M)} for S-SIM (or NS-SIM) and that for R-SIM.

At the same time, the regional concentration pattern of population, income produced and so on are compared among different simulations by the technique of Hoover index.

TABLE 8.4. *Summary of Shinkansen simulation (10^6 yen at 1970 fixed price)*

Year	(0) Actual time series of {ΣRV(M)}	(1) RGINVA (1S,M) for M = 3,4,6[a]	(2) S-SIM {ΣRV(M)}	(3) NS-SIM {ΣRV(M)}	(4) R-SIM {ΣRV(M)}	(5) (2)-(4)	(6) (3)-(4)	(7) Inverse of discounting factor	(8) Error analysis (0)-(4)
1959	13,803,750	4874	13,873,260	13,873,260	13,867,783	5477	5477	1.500730	−64,033
1960	15,586,640	25,990	15,422,997	15,422,997	15,410,152	12,845	12,845	1.402552	176,488
1961	17,541,470	60,426	17,274,385	17,274,385	17,118,621	155,764	155,764	1.310796	422,843
1962	19,200,180	116,328	19,245,136	19,245,136	19,099,457	145,679	145,679	1.225043	100,723
1963	21,407,330	133,288	21,699,825	21,699,825	21,564,764	135,061	135,061	1.144900	−157,434
1964	23,354,380	75,682	22,001,067	22,001,067	21,874,040	127,027	127,027	1.070000	1,480,340
1965	24,728,547	3649	25,066,816	25,066,816	24,968,923	97,893	97,893	1.000000	240,376
1966	27,570,834	0	30,579,355	30,442,634	30,311,980	267,375	130,654	0.934579	2,741,146
1967	33,973,103	0	33,550,072	33,306,274	33,162,923	387,149	143,351	0.873439	810,180
1968	38,775,226	0	37,204,649	37,073,333	36,932,068	272,581	141,265	0.816298	1,843,158

Notes: (a) Investment in Shinkansen construction adjusted for SPAMETRI figures. (b) Base shares = inhabitable land areas.

13. Numerical Results and Conclusion

Numerical results of the above simulations and benefit–cost analyses are given in Table 8.4. Some interesting conclusions regarding the economic effects of Shinkansen construction are derived from these results.

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9. *Impact of the Sanyo Shinkansen on Local Communities*

S. OKABE

Introduction

Improved means of transport shortens economic distances by reducing the cost and time of transport and induces greater potential for intensive use of land by promoting industrial development and urbanization.

As a means of transport unlike any other the Shinkansen has its own peculiar influence over the region through which it runs.

First, the Shinkansen is a new high-speed transport system. As such, it reduces the time-distance between regions and cities, and contributes to the enhancement of their cultural and economic interchanges.

Second, the Shinkansen is a long- and medium-distance means of passenger transport only: it does not undertake freight service. This means that its impact on the places it goes to is different from that of railway lines and highways that carry both passengers and freight. In creating the right conditions for plant location, for instance, opening a conventional railway or expressway can be a direct inducement, but this does not apply to the Shinkansen since it does not carry freight. What the Shinkansen can do is encourage the interregional flow of people and speed up the transmission of information, and this in turn brings about social changes in the local communities. The Shinkansen has brought about a number of changes in the local communities. The number of travelers on the line has increased; it encourages the flow of passengers between places which had been isolated; it changes passenger transport routes to the hinterland and affects the passenger traffic volume of competing carriers. The impact of such a change in the passenger flow spreads to the environs and the hinterland of the cities at which Shinkansen trains stop. For instance, the increase in the influx of tourists increases the need for a new tourist route to link the train-stopping city and its hinterland and to enlarge existing tourist facilities or establish new ones.

Third, the Shinkansen has established its stations at 30- to 40-km intervals, usually in cities. This means that city functions might eventually be reorganized and redistributed between the "train-stopping cities" and the "non-stopping" cities. The reduction of time-distance by the Shinkansen leads to greater social and economic interchange between the local train-stopping cities and the major central cities, and enables the local cities to undertake more of their own city functions. On the other hand, part of a local city's extensive commercial functions is likely to be taken over by the central cities.

This will eventually lead either to the concentration or to the dispersion or shifting of city functions, with some cities prospering and others declining. At any rate, the Shinkansen triggers changes in the regional setup, which was previously based on slower transport (mainly the non-Shinkansen railway lines). These changes take place, for instance, in the distribution of the extensive city functions, intercity relationships, and in the connection between a city and its hinterland.

It is in this context that the actual impact of the Sanyo Shinkansen* upon local communities is discussed in this paper. The Sanyo Shinkansen, however, has been in operation for only a few years. Hence, only the earliest perceptible trend in changes in transport service, the impacts therefrom and the measures taken by local communities to cope with the changes can be given.

The Localities Concerned

The Sanyo Shinkansen line extends from Osaka to Hakata. It also has connections with other lines and with bus and ferry routes, so its influence is far-reaching. The characteristics of the localities along the line and the hinterland areas will be briefly described.

The region has been well developed since olden days and has become a traffic artery linking Kyushu, Osaka and regions further east. Cities, prefectures and regions mentioned in this paper are listed in Table 9.1. The localities along the Sanyo Shinkansen are highly urbanized and enjoy great economic activity, particularly in the concentration of manufacturing plants, ranking next to the region along the Tokaido Shinkansen. The region contains few cities with a population higher than 500,000. The largest are Kobe with a population of 1,300,000, Okayama with 500,000, Hiroshima with 800,000, Kita-Kyushu with 1,000,000, and Fukuoka with 950,000. There are a large number of small or medium-sized cities with a population of under 200,000, but many of them have very considerable industrial activity.

Thus, the localities along the Sanyo Shinkansen have all the features of advanced areas, while the surrounding prefectures are less developed, relatively low in population, and poor in industrial activity. The income per capita here is far below the national level, as shown in Table 9.2. The impact of the Sanyo Shinkansen on these surrounding prefectures is, therefore, of interest.

Impact on Passenger Transport

REDUCTION OF TRAVELING TIME

The maximum speed of 200 km/h on the Shinkansen (average 161 km/h by Hikari) corresponds to almost twice that of other lines, where the top speed is

*The name of Sanyo Shinkansen is not officially used. For convenience, however, the section between Tokyo and Shin-Osaka is called the Tokaido Shinkansen and that between Shin-Osaka and Hakata the Sanyo Shinkansen.

TABLE 9.1. *Cities, regions, and area divisions in West Japan*

	Regions		Prefecture	Principal cities
Nishi Nippon (West Japan)	Kinki		Osaka	Osaka*
			Hyogo	Kobe*, Himeji*
	Chugoku	Sanyo	Okayama	Okayama*, Kurashiki*
			Hiroshima	Fukuyama*, Onomichi, Mihara*, Hiroshima*
			Yamaguchi	Iwakuni*, Tokuyama*, Ogori*, Yamaguchi, Hagi, Shimonoseki*
		Sanin	Tottori	Tottori, Yonago
			Shimane	Matsue, Hamada, Tsuwano
	Kyushu	Kita Kyushu	Fukuoka	Kita Kyushu*, Fukuoka*
			Saga	Saga, Karatsu
			Nagasaki	Nagasaki, Sasebo
		Naka Kyushu	Oita	Oita, Beppu
			Kumamoto	Kumamoto
		Minami Kyushu	Miyazaki	Miyazaki
			Kagoshima	Kagoshima
			Okinawa	Naha
	Shikoku		Tokushima	Tokushima
			Kagawa	Takamatsu
			Ehime	Matsuyama, Imabari
			Kochi	Kochi

Notes: (1) *indicates cities at which Sanyo Shinkansen trains stop. (2) Cities east of Osaka are not included.

100 km/h and the average 86 km/h. The first effect is thus the reduction of time-distance between regions and cities.

It formerly took 11 hours and 50 minutes to travel by train between Tokyo and Hakata. The Shinkansen reduced this to 6 hours and 56 minutes. Between Tokyo and Hiroshima the time has been cut from 7 hours and 40 minutes to 5 hours and 10 minutes and between Osaka and Hakata from 8 hours and 30 minutes to 4 hours and 40 minutes, as shown in Table 9.3.

The time-distance reduction has affected not only the cities along the line but also those in the hinterland. This is largely attributable to the reinforcement and improvement in the service of the connecting narrow-gauge lines effected before and after the opening of the Shinkansen. When the

TABLE 9.2. *General features of the prefectures along the Sanyo Shinkansen*

Source: Regional Economic Statistics, Tokyo Keizai Shimpo, 1976.

	Total area (km^2)		Inhabitable area (km^2)		Population (in 1000)		Industrial output (in billion yen)		Per capita national income (in 1000 yen)	
National total	372,312	100.0	117,050	100.0	110,949	100.0	127,575	100.0	935	100.0
(Along Sanyo Shinkansen)										
Prefecture										
Hyogo	8350	2.2	2520	2.2	4914	4.4	7675	6.0	925	98.9
Okayama	7077	1.9	2117	1.8	1830	1.7	3256	2.6	896	95.8
Hiroshima	8447	2.8	2117	1.8	2630	2.4	4006	3.1	981	104.9
Yamaguchi	6034	1.6	1644	1.4	1547	1.4	2540	2.0	846	90.5
Fukuoka	4922	1.3	2642	2.3	4228	3.8	3504	2.7	908	97.1
Total	34,830	9.4	11,040	9.4	15,149	13.6	20,981	16.4	—	—
(Hinterland)										
Tottori	3491	0.9	910	0.8	587	0.5	347	0.3	727	77.8
Shimane	6625	1.8	1334	1.1	775	0.7	357	0.3	676	72.3
Kagawa	1870	0.5	960	0.8	961	0.9	1077	0.8	835	89.3
Ehime	5657	1.5	1315	1.1	1479	1.3	1632	1.3	789	84.4
Saga	2410	0.7	1330	1.1	850	0.8	476	0.4	702	75.1
Nagasaki	4096	1.1	1676	1.4	1589	1.4	714	0.6	689	73.7
Kumamoto	7383	2.0	2743	2.3	1717	1.6	612	0.5	631	67.5
Oita	6324	1.7	1774	1.5	1196	1.1	971	0.8	695	74.3
Miyazaki	7734	2.1	1864	1.6	1089	1.0	458	0.4	654	70.0
Kagoshima	9144	2.5	3342	2.9	1741	1.6	534	0.4	586	62.7
Total	54,734	14.7	17,248	14.7	11,984	10.8	7178	5.6		

Note: Area as of 1970, population as of 1975, industrial output as of 1974 and income per capita as of 1973.

TABLE 9.3. *Traveling time from Tokyo and Osaka before and after the Sanyo Shinkansen opening*

Source: JNR data.

	Departure station							
	Tokyo				Shin-Osaka			
Arrival station	Before opening (a)	After opening to Okayama	After opening to Hakata (b)	(a)–(b)	Before opening (a)	After opening to Okayama	After opening to Hakata (b)	(a)–(b)
Okayama	5:30	4:10	4:10	1:20	2:10	1:00	1:00	1:10
Hiroshima	7:40	6:30	5:10	2:30	4:20	3:20	2:00	2:20
Hakata	11:50	10:20	7:00	4:50	8:30	7:10	3:50	4:40
Matsue	8:50	7:40	7:40	1:10	5:30	4:20	4:20	1:10
Takamatsu	7:20	6:00	6:00	1:20	4:00	2:50	2:50	1:10
Matsuyama	10:30	9:00	*7:30	3:00	7:10	5:50	*4:20	2:50
Kumamoto	14:00	12:20	9:00	5:00	10:30	9:10	5:50	4:40
Nagasaki	14:50	13:10	9:40	5:10	11:20	9:50	6:30	4:50

*Via the Mihara Shinkansen station.

Shinkansen was opened down to Okayama in 1972, hovercraft were introduced for the Uno–Takamatsu Ferry Route to reduce the traveling time by 37 minutes to 23 minutes, and additional express trains were put into service from Takamatsu Station. For connection with the Sanin region, the track capacity of the Hakubi Line (between Okayama and Yonago) was raised and additional express trains put into service. When the extension down to Hakata was completed, the number of buses operating between Hiroshima and Hamada to connect with the Shinkansen was increased, and high-speed ferry boats from Mihara to Shikoku Island were introduced. Additional express trains were put into service from Mihara Station to the Sanin region.

This augmentation of the main connection lines, together with the opening of the Shinkansen, has done much to reduce the traveling time-distance to and from the hinterland. From Kyoto to Yonago, for instance, the shortest route used to be the Sanin Line, taking 5 hours and 20 minutes. Now that the Shinkansen is open, this is reduced to about 4 hours by the Hakubi Line, changing at Okayama. To reach Western Shikoku (to Matsuyama City and others) from Osaka, it used to take 7 hours and 10 minutes by the shortest route, but this is now cut to 4 hours and 20 minutes via Mihara, using the high-speed ferry.

Naturally, this reduction in time-distance increases what can be done in a day. Assuming the longest time-distance for the sphere of activity coverable in a day to be 4 hours one way, all the localities along the Sanyo Shinkansen, including Osaka and Fukuoka, lie within the sphere. A round trip between Okayama and Tokyo, Matsue and Osaka, or Matsuyama and Osaka also is possible within the same day, though there will be little time to spare.

This expansion of a day's activity not only encourages the flow of passengers but also changes the weight of interregional passenger traffic. JNR has investigated the changes brought about by the Shinkansen opening in the travel of city dwellers in the regions west of Osaka [1]. According to this investigation, the percentage of those traveling to the Osaka and Kobe district rose from 10% before the opening to 17% afterwards in the North Kyushu region, from 16% to 24% in the Yamaguchi and Hiroshima region, from 4% to 28% in the Sanin region, and from 19% to 26% in the Shikoku region. Travel originating in the Sanin region to the Yamaguchi and Hiroshima region rose from 13% to 19%, that originating in the Okayama district and terminating in the Sanin region from 1% to 10%. Thus, the changes that have taken place in the travel destinations after the opening of the Shinkansen clearly reflect the merits and greater convenience of the time-distance reduction. These tendencies can be interpreted as a sign of the changes that will take place in the established interrelationship between regions and cities.

INCREASE OF TRAFFIC AND CHANGES IN TRANSPORT ROUTES

The Shinkansen, with its high speed, comfort, and safety, was expected to be well patronized from the start. JNR has estimated the traffic volume before the opening of the Shinkansen down to Hakata, taking into account the natural increase of traffic, the inducement it would offer to users, the possible diversion of rail travelers to the expressway and from other competitive means of transport to the railway, and the distribution of rail travelers between the Shinkansen and the narrow-gauge lines.

According to JNR's study [1], the number of passengers using express trains between Okayama and Hakata in 1975, the first year of opening, would increase as much as 40% over 1971. The traffic by section (one-way daily average) would reach 55,000 passengers between Shin-Osaka and Shin-Kobe, this being the greatest number, and the number would grow smaller toward Kyushu, falling to 28,000 between Shin-Shimonoseki and Kokura, as shown in Fig. 9.1. These estimates are compared with the actual number of passengers carried after the Shinkansen was opened, as shown in Fig. 9.2. As shown in these figures, the actual traffic by section is above the estimate. The total number of passengers carried between Shin-Osaka and Hakata increased by about 20% over the same period the year before.

The diversion and inducement of users after the Shinkansen opened down to Hakata, as shown in Fig. 9.3, are 55% from the narrow-gauge lines, 30% from other modes of transport, the inducement accounting for 6%. The cause of the remaining 9% increase is unknown. Of the diversion from other modes of transport, the largest is 23% from airlines. The Sanyo Shinkansen certainly had a good start.

IMPACT ON OTHER COMPETITIVE MODES OF TRANSPORT: AIRLINE ROUTES

The greatest impact of the Shinkansen has been on the airlines. Table 9.4 and Fig. 9.4, showing the air traffic between cities along the Shinkansen before and after its opening down to Hakata, disclose that the intercity air passenger

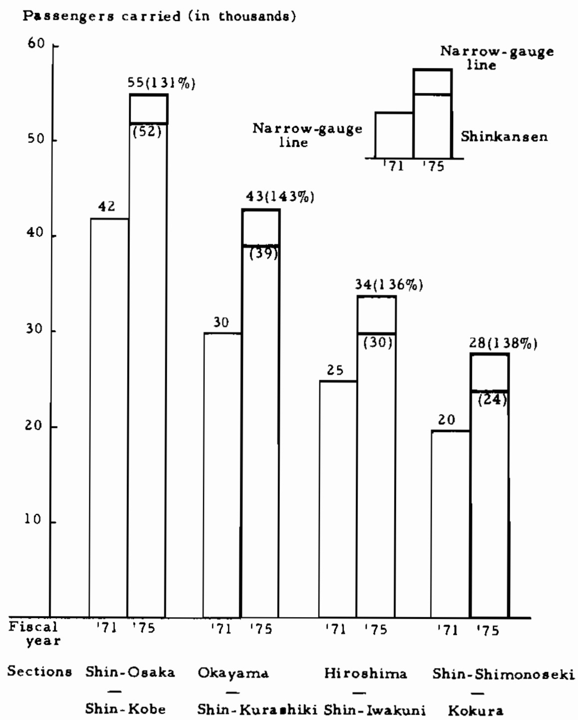

Fig. 9.1. Number of passengers using narrow-gauge railways and the Shinkansen.

traffic on the main air routes all registered a decline, although to varying degrees. The most adverse effect was on the Hiroshima–Fukuoka and Osaka–Hiroshima routes, and air service on these two routes were closed soon after the opening of the Shinkansen down to Hakata. The next most adversely affected were the Osaka–Ube and Osaka–Kita–Kyushu air routes. As of January–March 1976, the passenger traffic here was still on the decline. The number of air passengers on the Tokyo–Ube, Tokyo–Hiroshima, Nagoya–Fukuoka, and Osaka–Fukuoka routes remained constant. The Tokyo-Fukuoka route declined for a year after the Shinkansen opening down to Hakata, but is now slowly picking up.

It is not easy to determine how permanent the impact of the Shinkansen will be on the competitive modes of transport, for public interest in the initial novelty of the line must be taken into account. Nevertheless, the prospects are dim for airlines on short-distance flights along the Shinkansen route.

Comparison of the fare and traveling time by rail and airline after the Shinkansen was opened is given in Table 9.5 and reveals the following:

1. The rail fare for a distance over 1000 km is about 30% lower than the air fare, but the traveling time puts the railway at a disadvantage compared with the flight time, including access. When the railway traveling time is one and

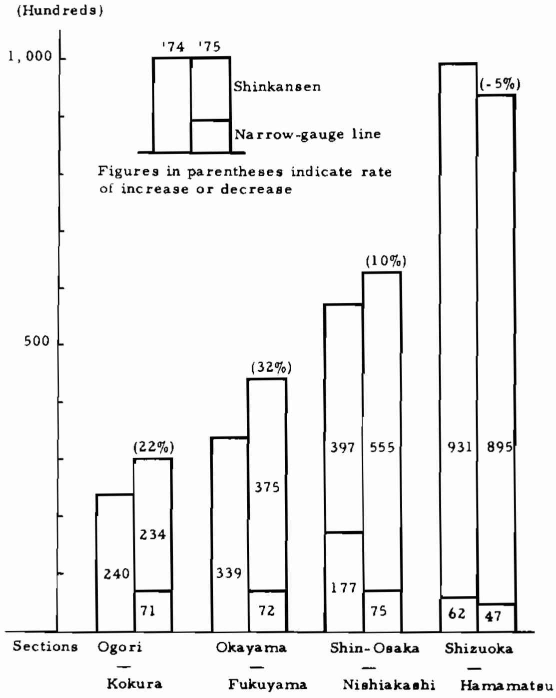

Fig. 9.2. Number of passengers carried after the Shinkansen was opened.

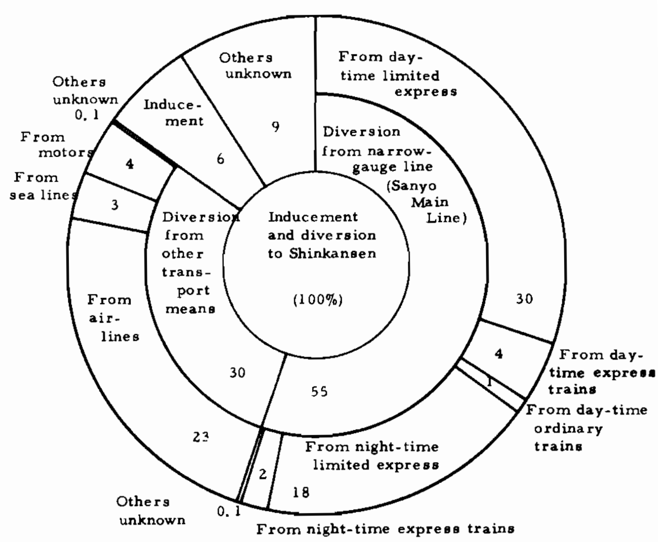

Fig. 9.3. Use of the Shinkansen after it was opened to Hakata.

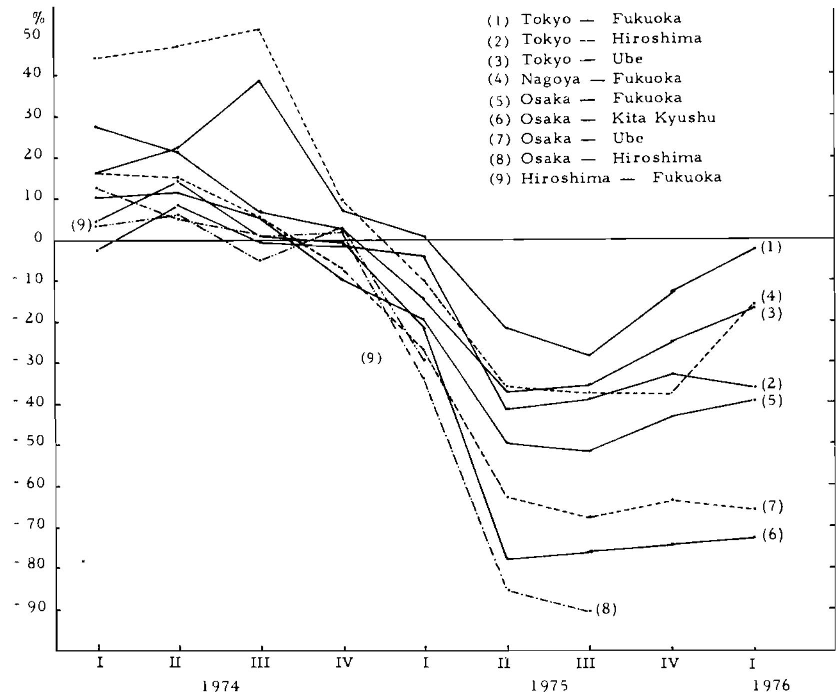

Fig. 9.4. Data of increase or decrease of airline passenger traffic against preceding year.

one-half or more times the flight time, including access, the decline in air passenger traffic might be only temporary or almost nil.

2. Between cities 700 km or less apart by rail, the train's advantage in fare over the airline diminishes, but so does the airline's advantage in traveling time. When the rail distance is less than 500 km, the traveling time by Shinkansen is less than by air, including access time. Hence, the decline of airline traffic between such cities becomes conspicuously large.

3. On routes where passengers must transfer from the Shinkansen to a narrow-gauge line for nearby and hinterland cities, this advantage weakens, and for routes to Shikoku, which involve transfer to ferryboats, the airplane has an advantage over the train.

It seems, then, that the only airline route along the Shinkansen that is capable of recovering the traffic lost to the new rail line in a short time is the Tokyo–Fukuoka route. For the other routes along the line, it seems that the airlines will require a long time to recover their lost traffic. It may be that the loss of air passengers to the cities beyond Fukuoka in Kyushu is only a temporary phenomenon, as airplanes have an advantage over trains here in traveling time.

TABLE 9.4. *Passenger traffic on competitive airlines*

Source: *Koku Yuso Tokei Nempo* (Air Transport Statistic Yearbook) compiled under the supervision of the Ministry of Transport.

(Unit: persons)

		Tokyo - Fukuoka	Tokyo - Ube	Tokyo - Hiroshima	Nagoya - Fukuoka	Osaka - Fukuoka	Osaka- Kita Kyushu	Osaka - Ube	Osaka - Hiroshima	Hiroshima - Fukuoka
1974	Jan.-Mar.	459,514	12,701	54,361	68,359	448,073	60,873	23,805	73,431	18,285
		(3.3)	(-6.4)	(-10.6)	(7.4)	(2.3)	(-6.3)	(-7.8)	(3.6)	(1.7)
	Apr.-June	483,549	13,816	60,488	70,591	445,339	65,033	25,339	70,902	17,379
		(5.2)	(8.8)	(11.3)	(3.3)	(-0.6)	(6.8)	(6.4)	(-3.4)	(-4.9)
	July-Sept.	585,531	15,271	63,720	81,577	455,745	68,273	28,067	71,401	18,198
		(21.1)	(10.5)	(5.3)	(15.6)	(2.3)	(5.0)	(10.7)	(0.7)	(4.7)
	Oct.-Dec.	470,357	13,938	59,753	69,793	395,410	64,269	24,225	72,184	18,505
		(-19.7)	(-8.7)	(-6.2)	(-14.4)	(-13.2)	(-5.9)	(-3.7)	(1.1)	(1.7)
1975	Jan.-Mar.	462,399	10,869	52,151	61,370	360,916	47,731	17,430	49,188	12,201
		(-1.7)	(-22.0)	(-12.7)	(-12.1)	(-8.7)	(-25.7)	(-28.0)	(-31.9)	(-34.1)
	Apr.-June	377,910	8,710	35,417	45,043	224,070	14,400	9,426	10,121	–
		(-18.3)	(-19.9)	(-32.1)	(-26.6)	(-37.9)	(-69.8)	(-45.9)	(-79.4)	
	July-Sept.	426,967	9,813	38,804	50,739	221,080	16,351	9,081	6,662	–
		(13.0)	(12.6)	(9.6)	(-12.7)	(-1.3)	(13.6)	(-3.7)	(34.2)	
	Oct.-Dec.	409,040	10,436	39,842	43,529	224,319	16,475	8.806	–	–
		(-4.2)	(6.4)	(2.7)	(-14.2)	(1.5)	(0.8)	(-3.0)		
1976	Jan.-Mar.	449,040	9,041	38,456	51,471	219,374	13,001	5,966	–	–
		(9.8)	(-13.4)	(-3.5)	(18.3)	(-2.2)	(-21.1)	(-32.2)		
Total for 1974		1,998,951	55,726	238,322	290,320	1,744,567	268,448	101,436	287,918	72,367
		(18.3)	(13.3)	(0.7)	(36.3)	(4.0)	(7.7)	(6.9)	(5.2)	(3.1)
Total for 1975		1,676,316	39,828	166,214	200,681	1,030,385	94,957	44,743	65,971	12,201
		(-16.1)	(-28.5)	(-30.3)	(-30.9)	(-40.9)	(-64.6)	(-55.9)	(-77.1)	(-83.1)

Note: The figures in parentheses indicate percentage of increase or decrease compared with previous year.

TABLE 9.5. *Comparison of operation of the Shinkansen and airlines*

Section	Operating distance (km) (a)	Fare (yen)	Operating time (min)	Traveling time includ-ing access time (min) (b)	Operating distance (km)	Fare includ-ing Green Car charge (yen) (c)	Traveling time (hrs)	Traveling time (mins) (d)	Difference between fares (yen) (a)-(c)	Time difference (d/b)	Increase or decrease of air passengers '75/'74(%)
(Cities along the line)											
Tokyo-Fukuoka	1006	19,500	90	240	1117	12,710	6.56	416	6790	1.733	−16.1
Tokyo-Ube	901	17,100	170	320	1053	12,010	6.30	390	5090	1.219	−28.5
Tokyo-Hiroshima	835	15,800	150	300	895	10,910	5.08	308	4890	1.027	−30.3
Nagoya-Fukuoka	661	12,400	75	275	811	10,710	4.53	293	1690	1.066	−30.9
Osaka-Fukuoka	520	9700	55	205	621	8610	3.44	224	1090	1.093	−40.9
Osaka-Kita Kyushu	463	8400	90	240	556	7020	3.10	190	1380	1.292	−64.6
Osaka-Ube	419	8300	80	230	497	6300	3.30	210	2000	0.913	−55.9
Osaka-Hiroshima	320	7700	65	215	343	4890	1.56	116	2810	0.540	−77.1
Hiroshima-Fukuoka	300	5800	60	180	282	4280	1.46	106	1520	0.589	−83.1
(Cities in Kyushu beyond Fukuoka)											
Tokyo-Nagasaki	1125	21,900	105	315	1331	14,310	10.22	622	7590	1.975	102.6
Tokyo-Kagoshima	1043	22,100	105	285	1491	15,510	12.15	735	6590	2.578	2.5
Tokyo-Kumamoto	993	20,200	95	275	1295	14,360	8.53	533	5840	1.938	5.8
Tokyo-Oita	913	18,400	100	310	1242	14,260	8.39	519	4140	1.674	−1.4
Nagoya-Kumamoto	668	14,200	65	275	929	12,360	6.50	410	1840	1.491	−19.5
Osaka-Nagasaki	600	12,600	70	280	778	10,210	7.10	430	2390	1.536	0.4
Osaka-Kumamoto	600	11,200	60	240	743	10,260	5.41	341	940	1.421	−14.4
Osaka-Oita	453	8600	55	265	689	8860	5.27	327	−260	1.234	−16.9
(Cities in Shikoku)											
Tokyo-Matsuyama	861	15,900	85	235	979	11,430	9.07	547	4470	2.328	48.8
Tokyo-Kochi	698	15,100	120	270	944	11,330	8.57	537	3770	1.989	0.4
Osaka-Matsuyama	453	8600	55	265	426	5620	5.55	355	1080	1.340	−9.0

Notes: (1) Access time calculated on the basis of ***Koku Ryokaku Dotai Chosa*** (Air Passenger Movement Statistics, Nov. 1975), published by the Ministry of Transport. (2) Access time required to each airport (in min): Tokyo 90, Nagoya 120, Osaka 90, Hiroshima 60, Ube 60, Kita Kyushu 60, Fukuoka 60, Nagasaki 120, Kumamoto 90, Oita 120, Kagoshima 90, Kochi 60, Matsuyama 60.

TOURISM

In tourism, the Shinkansen economically affects local communities in many ways. It increases the number of incoming sightseers. Tourism thrives when people are prosperous. When the Shinkansen was opened to Okayama, in 1972, the Japanese economy was growing and there was a rush of tourists to the environs of Okayama and the Sanin districts. However, when the Shinkansen was opened down to Hakata, in 1975, a recession had set in, triggered by the oil crisis, and the attraction of the Shinkansen was not strong enough to promote a tourist boom.

Nevertheless, the Shinkansen does encourage sightseers. According to a survey on reasons for traveling, conducted before and after the opening down to Hakata, the proportion of 15% for sightseeing before the opening rose to 25% afterwards. In most of the prefectures along the Shinkansen and those nearby the number of people coming from other prefectures also increased from the year before after the opening in 1975, as seen in Table 9.6.

As the number of tourists to the prefectures not listed in Table 9.6 has declined from the year before, it may well be concluded that the Shinkansen has some effect in encouraging tourists.

Another notable change is that the Shinkansen has shortened the tourists' travel schedule. Before the opening, for a distance of 301-400 km, for instance, 13% of the visitors returned on the same day and 44% after one or two days' stay. This increased to 34% and 45%, respectively, after the new line was opened down to Hakata [2]. This shows, on one hand, that tourists are trying to cut expenses because of the recession and, on the other hand, reflects

TABLE 9.6. *Influx of visitors to the prefectures along the Shinkansen after its opening in 1975*

Prefecture		Total no.	Outside visitors	Inside visitors	Lodging visitors
Along the line	Hiroshima	26,370	16,818	9552	6044
		(7.9)	(13.2)	(-0.2)	(14.0)
	Yamaguchi	19,914	13,771	6143	4111
		(1.3)	(13.8)	(-11.6)	(3.1)
	Fukuoka	52,247	21,128	31,119	4463
		(11.8)	(31.6)	(1.4)	(-19.9)
Hinter-land	Shimane	16,472	11,572	4900	2534
		(-6.5)	(6.5)	(-6.6)	(-10.8)
	Saga	17,351	11,113	6238	
		(5.7)	(5.5)	(6.1)	NA
	Nagasaki	20,019	10,855	9164	
		(4,3)	(4.6)	(4.1)	NA
	Kumamoto	22,914	13,650	9304	6399
		(8.0)	(7.0)	(10.1)	(2.4)
	Oita	32,794	23,250	9544	7628
		(-0.4)	(1.0)	(-3.9)	(0.2)
	Miyazaki	8018	4,846	3172	
		(-2.8)	(-6.8)	(4.0)	NA
	Kagoshima		7545		
		NA	(-8.2)	NA	NA

the time saved in traveling by the Shinkansen and the improvement in transfer facilities.

Tourists no longer visit only established and well-known places, but also those of historical and scenic interest in the hinterland — even on remote islets. Northwestern Kyushu and central Yamaguchi, close to the Sanin, which were not formerly taken seriously as places for sightseeing, are now becoming popular, as shown in Table 9.7. This may be partly due to a change in the class of sightseers (age, income level, etc.), but the great contribution of the Shinkansen cannot be ignored. These new localities lie mainly in the economically retarded areas, so the greater influx of tourists has benefited the residents economically.

Some cities along the Shinkansen line have seen a big drop in the number of visitors because the trains do not stop there. A typical example is Onomichi City, which has many old temples and shrines and notable beauty-spots and served as an important port for ferries plying between Honshu and Shikoku. In 1964 the city had as many as 1,764,000 visitors and this dropped to 1,605,000 (by almost 10%) in 1975, the year the Shinkansen was opened.

The growth of tourism, however, was not without problems; for instance, smaller places could not always provide lodging for all their visitors. Hotels in large cities were often booked up in advance. In Fukuoka City, where the

TABLE 9.7. *Growth of number of tourists from other prefectures to principal new places of attraction, 1975*

Source: *Kanko* (Sightseeing), Japan Tourist Association, Nov. 1976.

	Visitors from other prefectures (thousands)	Increase over preceding year (thousands)	Rate of increase (%)
Hiroshima Prefecture			
Hiroshima City	7156	2459	52.3
Miyajima, Ono	2797	438	18.5
Fukuyama City	570	10	1.8
Mihara City	119	35	41.6
Etajima	163	11	7.2
Onomichi City	1605	−179	−9.0
Yamaguchi Prefecture			
Iwakuni City	2113	245	13.1
Yanai City	110	12	12.2
Tokuyama City	258	29	12.3
Yamaguchi City	1147	83	7.8
Akiyoshidai	2095	282	15.5
Nagatokyo	411	33	8.7
Hagi City	1810	216	13.6
Nagato City	1209	88	7.9
Susa	71	20	39.2
Toyoura	380	43	12.8
Toyokita	279	38	15.7
Shimane Prefecture			
Saginoya Hot Spa. (Yasuki City)	117	48	69.5
Kiyomizudera (Yasuki City)	154	9	6.2
Sanbesan (Ota City)	365	24	7.0
Omori Ginzan (Ota City)	61	6	10.9
Masuda, Banryuko	318	70	28.2
Tsuwano	1194	85	7.7

TABLE 9.7. *Continued*

	Visitors from other prefectures (thousands)	Increase over preceding year (thousands)	Rate of increase (%)
Fukuoka Prefecture			
Fukuoka City	7468	3608	93.5
Tsuyazaki Town	358	192	122.4
Shingu Town	26	7	36.8
Maebaru, Itoshima	644	94	19.1
Dazaifu Town	2794	311	12.3
Chikushino Town	204	53	35.1
Soeda Town	310	230	287.5
Buzen City	90	10	12.0
Yukuhashi City	25	12	92.3
Tagawa City	73	43	141.7
Kurume City	520	38	7.8
Amagi City	345	274	385.9
Yanagawa Town	180	28	18.4
Saga Prefecture			
Saga City	1637	51	3.2
Yamato Town	193	54	38.8
Hamatama Town	423	21	5.2
Karatsu City	2210	377	20.5
Chinzei, Genkai Town	368	74	29.6
Arita Town	612	27	4.6
Ureshino City	971	11	1.1
Nagasaki Prefecture			
Nagasaki City	3296	192	6.2
Sasebo City	1720	130	8.2
Hirato City	895	94	11.7
Obama Town	2298	69	3.1
Takaki Town	70	19	37.2
Iki	333	7	1.8
Goto	294	14	5.0
Kumamoto Prefecture			
Kumamoto Town Sphere	4593	221	5.1
Aso Area	3232	194	6.7
Amakusa Area	2119	41	1.9
Tsuedate, Oguni Area	302	42	16.1
Kikuchi Area	890	58	7.1
Hitoyoshi, Kuma Area	560	198	54.5
Uki Area	385	278	259.8
Oita Prefecture			
Beppu City	12,035	48	0.4
Takeda City	593	63	11.8
Kunisaki Peninsula	394	18	1.3
Yabakei	2004	74	3.8

Shinkansen terminates, hotel construction boomed in anticipation of an influx of tourists and businessmen, and the number of hotel rooms had doubled by 1975, as shown in Fig. 9.5. However, statistics indicate that the number of visitors staying overnight has decreased since the Shinkansen was opened, and there is keen competition today among the hotelkeepers there.

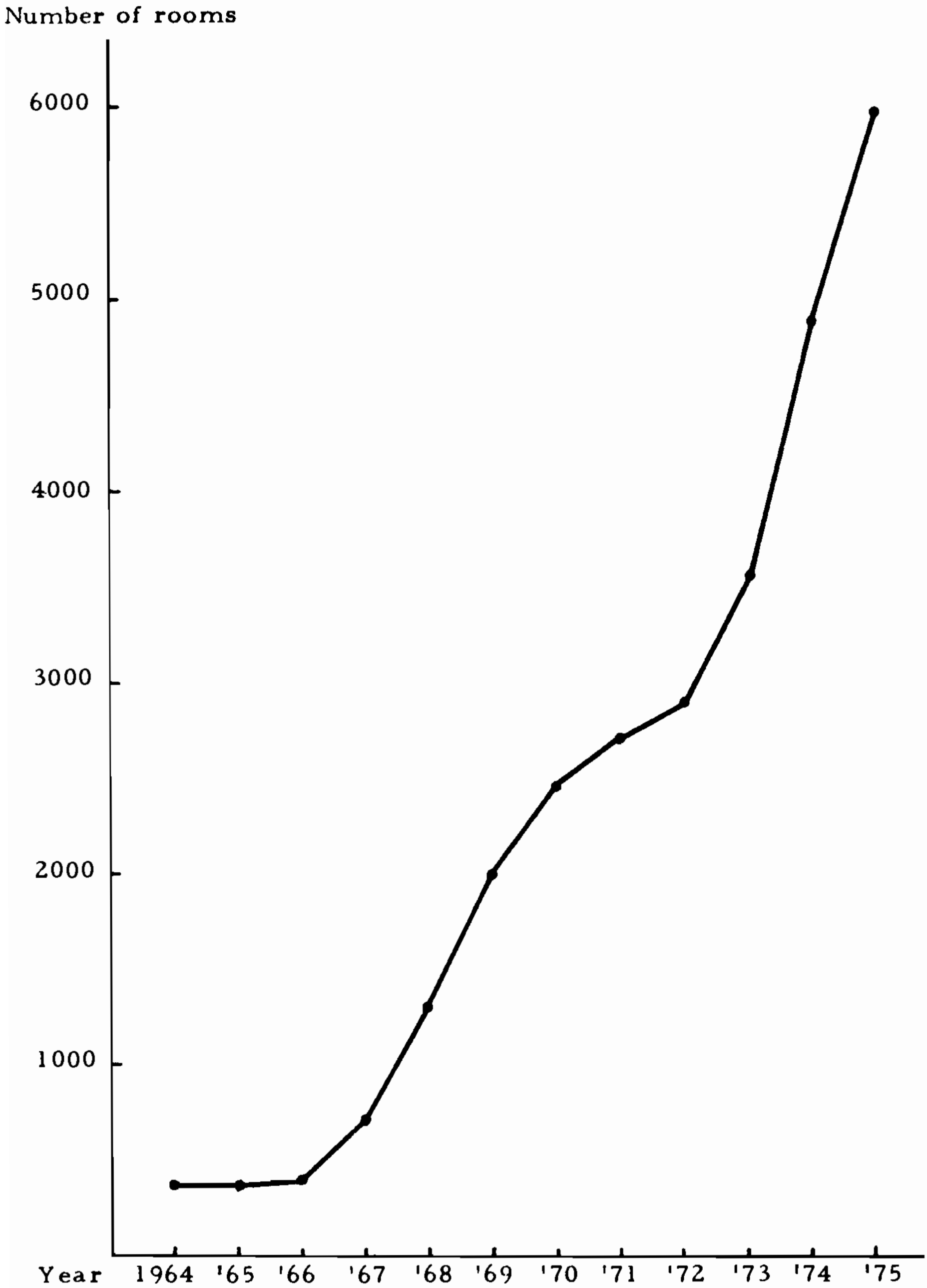

Fig. 9.5. Increase in hotel capacity in Fukuoka City (report by Fukuoka City Government).

MORE INTENSIVE USE OF LAND

The introduction of the Shinkansen and other trunk modes of transport has been a visible and invisible incentive to city and regional development. As far as the Shinkansen is directly concerned, development took place around a station, in its plaza, underground shopping center and surface shopping centers. This construction started a chain reaction — existing shopping centers in other parts of the cities were improved and the shopping centers in cities where the Shinkansen does not stop were redeveloped and extended.

Examples of the effect of the Shinkansen combined with the expressways under construction are the development of leisure resorts in the Inland Sea and Okayama Prefecture, the housing projects planned in anticipation of the future prosperity of the Shinkansen "train-stopping cities", the construction of distribution centers and large-scale diary farms.

Returning to city development around Shinkansen stations, the idea of city rehabilitation was taken up in almost all the Shinkansen train-stopping cities. Most enthusiastic was the City of Okayama, which produced a rehabilitation project for the district around the station. As early as 1970, the plan to expand the plaza in front of the Okayama Shinkansen station has been decided and the earthwork started. In the course of work, the idea of building an underground shopping center was conceived. The outline of the plan is shown in Table 9.8.

In Fukuyama, elevation work has already been completed around the station and the renewal of the station front is now under way. In Mihara, since the city has gained importance as a Shinkansen station and transfer station for Shikoku, a redevelopment plan is under way, centering on the 1.1-hectare city-owned land where the old Monopoly Corporation used to be. The total area covers about 2.7 hectares. At a cost of some 6400 million yen, construction of two buildings, 4500 m^2 in area (for shops, offices, hotels, amusement parlors and homes), and of a pedestrian deck linking Mihara station and the Mihara Inner Port, is planned and is about to be implemented.

Creation of these commercial nuclei centering on stationfront development exerts considerable impact on the local economy, particularly on retail businesses in the city.

TABLE 9.8. *Outline of plan for renewal of Okayama station front*

Station Plaza: Expand it from 12,500 m^2 to 19,700 m^2
Construct sidewalks, car roads, parking lot, taxi stops, bus stops, green belts
Use part of the land of the former Okayama Freight Station
Cost, about 100 million yen, to be shared equally by the city and JNR
Underground Shopping Center
Two underground floors, 23,800 m^2
To house 120 to 130 shops on the first underground floor
Center operator: Okayama Station Center, a joint stock company, registered in April 1972
Stockholders: JNR, Retired Railway Workers Welfare Work Association, Railway Hall Co., Commerce & Industry Chambers of Okayama Prefecture and City, local financiers
Construction cost, 3800 million yen
Opening day, 1974 year end

There are, however, many cities where no development is in progress. At Shin-Kurashiki, Shin-Iwakuni, Ogori, Shin-Shimonoseki, for instance, the new Shinkansen stations are built away from the city centers or at the back of existing stations. While there are many ideas for development, little work has been done on the station plaza, and wide-scale development is not yet ready to begin.

Haste is not always the best policy, but the problem of small-scale land ownership must be solved, and rising land prices checked so as to clear the way for development.

EFFECT ON CITY FUNCTIONS AND STRUCTURE

Distribution and setup of extensive economic functions. A city is a conglomerate of political, economic and cultural units. Cities can be classified, by the extent of their functions, into national cities, block nucleus cities, and local central cities. Here, in order to see the setup of cities along the Sanyo Shinkansen, the concentration of economic organizations will first be explained.

In Table 9.9 distribution is shown by city of head offices, branch offices, branch stores, business offices, and sub-offices of those companies listed in the First Section of the Tokyo Stock Exchange. The table shows that most head offices are concentrated in Tokyo, and then in Osaka and Nagoya. These three cities have the greatest number of branch offices and sub-offices.

The next rich in number of branch offices and stores are the local nucleus cities, which have a wider jurisdiction than business offices and sub-offices and act as block-control organs. Thus, the local nucleus cities clearly have a high degree of concentration of extensive economic functions. Moreover, the extensive functions of these cities are not confined to economic activities; the central government offices also have their block-control organs distributed among them.

Hiroshima and Fukuoka are the two biggest central cities in the regions through which the Sanyo Shinkansen runs. How big is the territory controlled by the economic functions of these two cities? In Hiroshima City, 13% of the branch offices there have control over only Hiroshima Prefecture, 13% over only a part of the Chugoku Region, and 73% over all the Chugoku Region [3] In Fukuoka City, 74% of the branch offices control the whole Island of Kyushu [4].

In comparing the two cities some allowance must be made for the fact that the surveys were not made at the same time and different methods were used. To see more clearly the territory controlled by the extensive economic functions and to grasp the interterritorial relationships, use should be made of Figs 9.6 and 9.7, which show the location of the exchanges where large numbers of telephone calls originate and the exchanges at which such calls are concentrated. It is seen from the figures that in Kyushu the large number of calls from local offices are taken first by the exchange offices in Kagoshima, Kumamoto, Nagasaki, Sasebo and Kita-Kyushu and then by the Fukuoka exchange office, and, from there, even to Shimonoseki. This indicates that

TABLE 9.9. *Establishment of branch offices and stores, business offices and suboffices in principal cities*

		(Number of offices)								(%)					
		No. of head offices		Branch offices & stores		Business offices & suboffices		Total of branch offices, etc.		Branch offices & stores		Business offices & suboffices		Total of branch offices, etc.	
		1964	1972	1964	1972	1964	1972	1964	1972	1964	1972	1964	1972	1964	1972
National total		561	718	1900	2898	1385	2717	3285	5610	100	100	100	100	100	100
Three biggest cities	Tokyo	305	509	389	520	95	158	484	678	20.5	17.9	6.9	5.8	14.7	12.1
	Osaka	94	116	336	456	67	86	403	542	17.7	15.7	4.8	3.2	12.3	9.7
	Nagoya	23	23	234	335	119	139	353	474	12.3	11.6	8.6	5.1	10.8	8.5
	(Total)	422	548	959	1311	281	383	1240	1694	50.5	45.3	20.3	14.1	37.8	30.2
Other principal cities	Yokohama	10	17	46	77	39	83	85	160	2.4	2.7	2.8	3.1	2.6	2.9
	Kyoto	12	12	18	24	19	51	37	75	1.0	0.8	1.4	1.9	1.1	1.3
	Kobe	15	13	50	61	35	71	85	132	2.6	2.1	2.5	2.6	2.6	2.4
	Kawasaki	9	12	8	12	6	9	14	21	0.4	0.4	0.4	0.3	0.4	0.4
	Kita Kyushu	7	6	67	61	51	73	118	134	3.5	2.1	3.7	2.7	3.6	2.4
	(Total)	53	60	189	235	150	287	339	522	10.0	8.1	10.8	10.6	10.3	9.3
Local nucleus cities	Sapporo	1	2	144	205	104	136	248	341	7.6	7.1	7.5	5.0	7.6	6.1
	Sendai	2	2	89	151	79	129	168	280	4.7	5.2	5.7	4.8	5.1	5.0
	Hiroshima	2	2	85	162	84	151	169	313	4.5	5.6	6.1	5.6	5.1	5.4
	Fukuoka	3	4	153	225	106	137	259	362	8.1	7.8	7.7	5.1	7.9	6.5
	(Total)	8	10	471	743	373	553	844	1296	24.8	25.6	26.9	20.4	25.7	23.1
Other cities	Takamatsu	1	1	35	64	47	97	82	161	1.8	2.2	3.4	3.6	2.5	2.9
	Saga	–	–	2	1	1	1	3	2	0.1	0.0	0.0	0.0	0.0	0.0
	Nagasaki	–	1	11	10	18	30	29	40	0.6	0.3	1.3	1.1	0.9	0.7
	Kumamoto	–	–	2	5	9	31	11	36	0.1	0.2	0.6	1.1	0.3	0.6
	Oita	–	–	2	5	1	31	3	36	0.1	0.2	0.0	1.1	0.1	0.6
	Kagoshima	–	–	2	3	10	28	12	31	0.1	0.1	0.7	1.0	0.4	0.6
	(Total)	1	2	54	88	86	218	140	306	2.8	3.0	6.2	8.0	4.3	5.5

Notes: (1) Enterprises: those listed in Tokyo Stock Exchange First Section, but not including insurance and banking business. (2) Source: compiled from the *Stock Company Annual* published by the Nihon Keizai Shimbun

Fukuoka City has close connections with all of Kyushu except the eastern part, and with the western part of Yamaguchi Prefecture.

In the Chugoku Region, with the major call-origin zone cut into the south and north, the Hiroshima Exchange is slightly weaker in the central function than the Fukuoka Exchange and the territory it covers is somewhat smaller.

There are more differences between the two cities. The greatest number of out-of-territory calls to the Fukuoka Exchange, for instance, originate in Tokyo and the next in Osaka and Shimonoseki. Hiroshima Exchange's greatest number of out-of-territory calls are from Takamatsu, and then Osaka and Matsuyama. Hiroshima City thus has a peculiarity in its extensive economic functions: its close link with the cities along the Inland Sea coast of Shikoku.

The Shinkansen will no doubt also have some effect on this territorial situation.

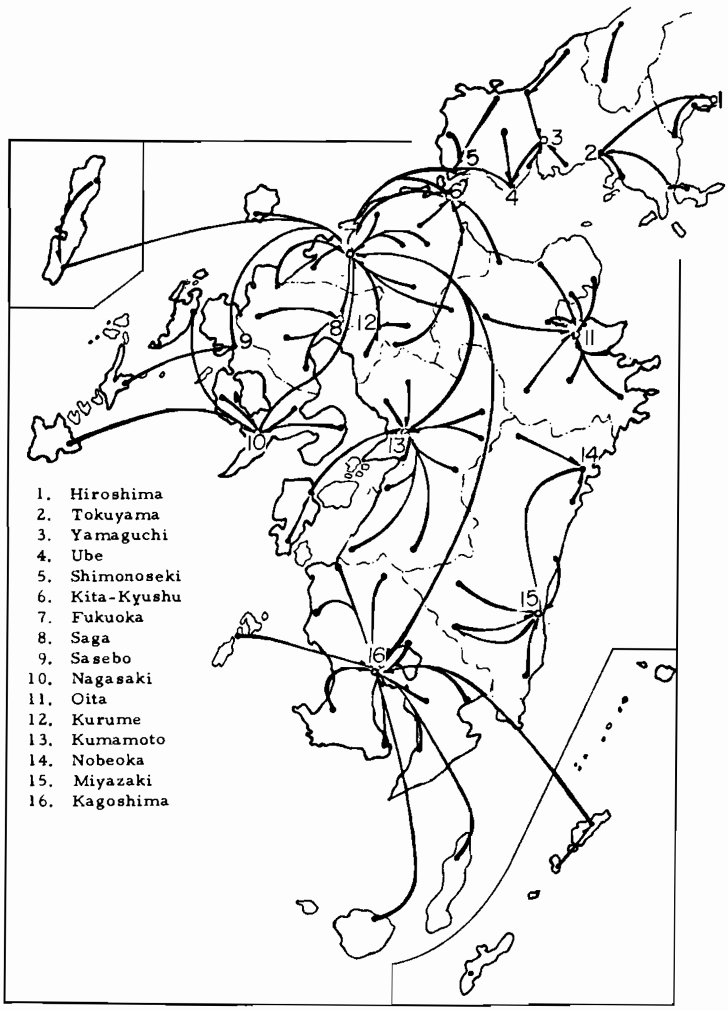

Fig. 9.6. Origin and concentration of telephone calls by telephone exchanges in Yamaguchi Prefecture. Note: Automatic direct calls, based on volume of long-distance calls per day-time peak hour. Source: Data of the Nippon Telegraph and Telephone Public Corporation.

Effect on retail business. Among the cities along the Sanyo Shinkansen where retail trade is highly concentrated (excluding Osaka) are Kobe, Fukuoka, Kita-Kyushu, Hiroshima, Okayama and Himeji; in other cities the sales figures are far less, as shown in Table 9.10.

The effect of the Shinkansen on the retail trade in these cities is diverse. Direct favorable effect, however, especially rapid growth of sales, is extremely restricted. According to an investigation made in 1975 [5] the cities in which 10% or more of the shops reported a rise in sales after the Shinkansen opening were only Yamaguchi (43.1%), Ogori (21.4%), Hagi (12.5%) and Tokuyama (11.3%). Of these, only Ogori and Tokuyama are located along the Shinkansen; the rest are tourist resorts in the hinterland. In Hiroshima,

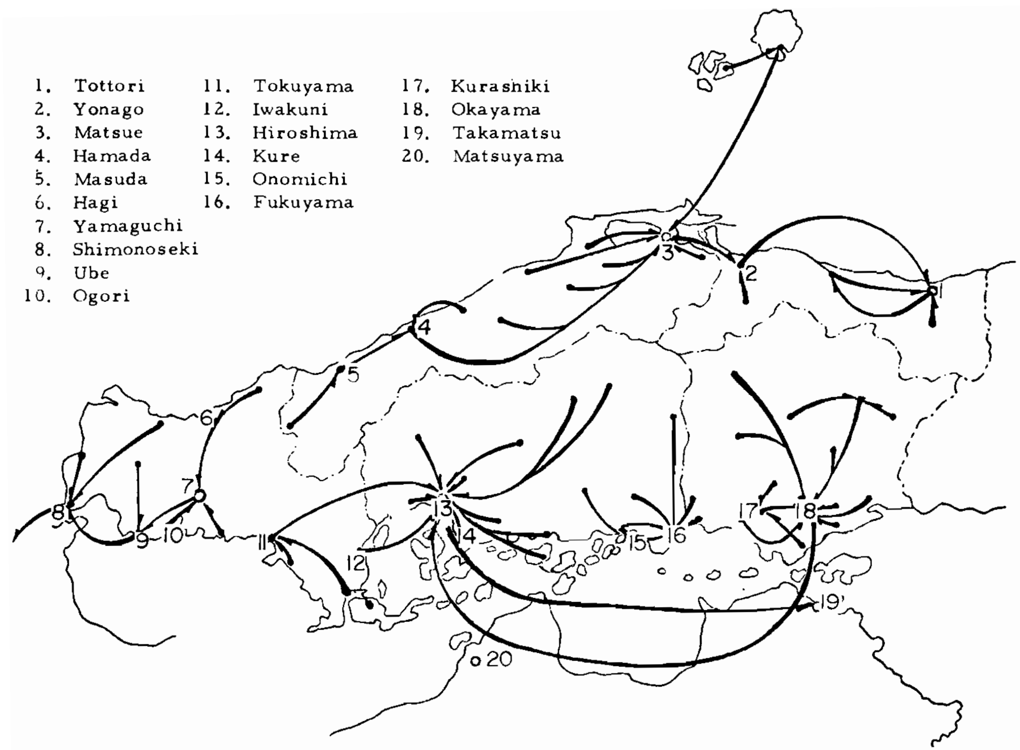

Fig. 9.7. Origin and concentration of telephone calls by telephone exchanges in Chugoku Region. Note: Automatic direct calls, based on volume of long-distance calls per day-time peak hour. Source: Data of the Nippon Telegraph and Telephone Public Corporation, May-June 1972.

TABLE 9.10. *Retail sales in cities along the Shinkansen*
Source: Commercial statistics.

	Sales (in million yen)				Sales per head of population (in 1000 yen)	Sales per retail shop (in 1000 yen)
	1970 (a)	1972	1974 (b)	Rate of increase (b)/(a) %		
National total	21,773,483	28,292,696	40,147,810	84.4	366.4	25,958
Tokyo	2,880,000	3,586,756	4,818,177	67.2	568.5	40,943
Osaka	1,188,989	1,478,065	1,919,807	64.1	696.0	37,439
Kobe	341,310	455,507	618,661	81.2	472.1	33,298
Akashi	40,790	55,362	79,634	106.4	352.8	26,722
Himeji	113,208	152,753	208,710	84.3	487.5	32,909
Aioi	11,706	15,869	23,523	85.6	376.8	29,693
Okayama	133,578	166,096	253,666	89.9	512.9	26,828
Kurashiki	74,009	98,607	156,992	112.1	405.3	22,631
Fukuyama	72,431	90,426	125,476	94.7	446.0	36,951
Mihara	20,382	24,981	36,786	80.4	431.2	26,753
Hiroshima	185,477	255,624	408,936	120.4	544.1	39,495
Iwakuni	28,336	35,016	46,420	63.8	424.0	25,491
Tokuyama	31,443	41,707	60,459	92.2	580.6	36,553
Yamaguchi	24,420	29,298	44,356	81.6	434.0	29,809
Shimonoseki	58,244	74,999	99,539	70.9	384.6	25,167
Kita Kyushu	228,504	338,327	425,190	86.0	404.6	27,652
Fukuoka	262,022	342,976	482,933	84.3	532.0	35,452

competing with Fukuoka City in retail sales along the Sanyo Shinkansen, sales are reported [6] to have risen only by some shops in its central shopping center (10.7%) and the shopping district in front of Hiroshima station (9.2%). Elsewhere, the rise in sales is negligible. Others (9.9%) in the central shopping center reported a decline, this being more conspicuous (34.2%) in the district in front of the station.

This implies that the opening of the Shinkansen does not immediately lead to a growth of retail sales in the train-shopping cities, and that, even when a growth is noted, it is only by some of the retail shops in front of the station; many others, even in the same district, find their sales declining due to keener competition.

The effects or the incentives in a wider sense are quite large. The following trends are likely to affect the retail trade in the cities along the Shinkansen:

1. The Shinkansen speeds up the arrival of new fashions in clothes from the principal cities. Stores selling women's clothes that are out of fashion, particularly juvenile clothes, are soon ignored.

2. What flows in is not only new fashion. Shorter time-distance facilitates business liaison, interchange of personnel and collection of information. Speciality retail chain stores, department stores and supermarkets begin to make aggressive inroads into the Shinkansen train-stopping cities. Half the shops in the underground shopping center of Okayama station are branches of large retail stores in Tokyo, Osaka and other cities. Enlarged and newly built department stores in the cities along the Shinkansen after its opening down to Okayama are shown in Table 9.11. The greatest inroads have been in cities with over 300,000 inhabitants.

3. In the Shinkansen train-stopping cities, the districts in front of the stations are being redeveloped and shopping centers constructed. When

TABLE 9.11. *Establishment and enlargement of department stores in principal cities (after 1972)*

City	No. of stores	Sales floor space (m^2)
Kobe	4	80,362
Himeji	2	27,309
Okayama	3	33,807
Kurashiki	1	6966
Fukuyama	1	8532
Hiroshima	2	41,022
Tokuyama	1	5000
Ube	1	6244
Yamaguchi	1	5724
Shimonoseki	1	12,948
Kita Kyushu	4	68,978
Fukuoka	5	93,346
Total	25	383,238

completed, these will present a challenge to local retail shops. In front of Okayama station an underground shopping center produced a department store, a supermarket and 130 speciality shops after the Shinkansen was opened down to Okayama. This has changed the course of the shoppers' flow in the existing central shopping center (Omotemachi) to the underground shopping center in front of the station, and has exerted a delicate influence on the location of shops.

Thus, the Shinkansen has the effect of inducing the capital of outside retailers to the principal cities located along the line and creating a new commercial nucleus within those cities. Moreover, it speeds up the popularization of new fashions and refines the taste and preferences of the customers.

Local retailers have to cope with these impacts. To keep up with new fashions, they have to link up with designers or stores in larger central cities. To satisfy increasingly refined tastes, they must keep a rich assortment of goods in stock and even remodel their shops. When a new commercial nucleus emerges or when the flow of customers changes, they may have to consider moving out or opening a new shop. According to the investigation [3] in Hiroshima City, the number of shopkeepers planning to enlarge, remodel, move out, or open new shops was as high as 50.2% in the central shopping districts, and for the city as a whole, it reached 45.8%. In Yamaguchi Prefecture the figure reached 40%, as disclosed by the Yamaguchi Prefectural Commerce and Industry Association.

Impact on wholesalers. The Shinkansen opening has also affected wholesalers in the cities along the Shinkansen, as shown in Table 9.12. Among the cities along the Sanyo Shinkansen, those where wholesalers are concentrated are Osaka City, which serves a nation-wide commercial area, and Fukuoka and Hiroshima Cities, which have extensive wholesale functions. The impact on other cities varies, depending on the degrees of wholesaler concentration, and the varying size and characteristics of the cities.

When the Shinkansen opened down to Okayama, the city retailers (in fabrics, stationery, machines, etc.) tended to order stock directly from Osaka

TABLE 9.12. *Wholesalers in cities along the Shinkansen*
Source: Commercial statistics.

	No. of shops (1974)	Sales amount (in million yen)			
		1970	1974	Rate of growth '74/'70 (%)	Sales per capita in 1974 (thousand yen)
National	292,254	88,330,893	173,671,813	96.6	1585
Tokyo	54,642	31,695,404	58,758,717	85.3	5183
Osaka	26,574	17,746,093	34,172,054	92.5	12,389
Kobe	4227	1,212,855	2,253,655	85.8	1719
Akashi	349	46,419	78,011	68.0	345
Himeji	1807	307,243	603,870	96.5	1410
Aioi	52	3374	9654	186.1	230
Okayama	1563	398,176	782,559	96.5	1582
Kurashiki	1020	214,417	417,680	94.7	1078
Fukuyama	1108	153,704	357,130	132.3	568
Mihara	219	15,744	48,462	207.8	1266
Hiroshima	4296	1,403,115	3,355,001	139.1	4464
Iwakuni	263	31,561	57,096	80.9	521
Tokuyama	515	94,654	243,317	157.0	2336
Yamaguchi	171	19,988	55,752	178.9	545
Shimonoseki	952	159,414	270,286	69.5	1044
Kita Kyushu	2876	701,191	1,096,444	56.3	1044
Fukuoka	5586	2,618,240	5,114,265	95.3	5634

and Tokyo, and this tendency was followed by retailers in the cities around Okayama. As a result, some wholesalers in Okayama, especially fabric dealers, registered a decline in sales. An investigation conducted before the Shinkansen opened to Hakata has also revealed that the retailers in Hiroshima Prefecture intended to order much of their stock from Tokyo and Osaka after the opening [4], as shown in Table 9.13.

These changes may have been only temporary and transitional phenomena before and after the opening. However, when considering the reduced time-distance, only 1 hour between Okayama and Osaka, 1 hour and 35 minutes between Fukuyama and Osaka, 1 hour and 56 minutes between Hiroshima and Osaka, it may well be that local retailers would tend to purchase more and more stock from Tokyo and Osaka. Apart from this inclination toward the large central cities, retailers in many cities will change their wholesalers, and

TABLE 9.13. *Changes expected in places of purchase due to the Shinkansen*
Source: Investigation on effects of Shinkansen opening, association of Chambers of Commerce and industry in Hiroshima Prefecture.

	Total	Purchases from Tokyo will increase	Purchases from Osaka will increase	No change likely	Others
Prefectural total	480 (100.0)	49(10.2)	62(12.9)	362(75.4)	7(1.5)
Fukuyama	84(100.0)	11(13.1)	14(16.7)	58(69.0)	1(1.2)
Onomichi	134(100.0)	9(6.7)	5(3.7)	120(89.6)	0(0)
Mihara	47(100.0)	2(4.3)	5(10.6)	38(80.8)	2(4.3)
Kure	141(100.0)	16(11.4)	23(16.3)	99(70.2)	3(3.2)
Hiroshima	74(100.0)	11(14.9)	15(20.3)	17(63.5)	1(1.4)

this will no doubt adversely affect wholesale businesses in the small and medium cities along the line who depend on supplying their local areas.

This impact varies in degree from city to city. It depends to some extent on how the local wholesalers cope with the situation caused by the Shinkansen. Their counter-measures are to strengthen their organizational setup, especially sales and information departments, to diversify or to specialize in their line of business, and to deal in higher-class goods. In brief, they will have to hold on to their clientele by being attractive wholesalers. Another problem is whether they will be able to keep their original areas of commercial activity. What is interesting here is the fact that the wholesale businesses in Okayama, the city that has been brought much closer to Osaka by the Shinkansen, has continued to grow after the Shinkansen opening. This is because they have retained the demand in their city and at the same time developed new markets in the districts along the Hakubi Line, seizing the opportunity of its improved train service.

The effects on Fukuoka City, which has the greatest wholesale concentration of all the cities along the Shinkansen, and which serves as the Shinkansen terminal in Kyushu, are as follows [4]:

Of the 317 wholesalers investigated in Fukuoka City, 110 (or 35%) reported a gain from the Shinkansen; 44 (or 14%) were unfavorably affected, and 172 (or 51%) did not know. When asked about sales, nine wholesalers reported a considerable increase, and 41 reported a slight increase (16% altogether). As many as 246 wholesalers (78%) reported "no effects felt". Nine (3%) reported that sales had gone down. This means that the Shinkansen has neither sharply increased nor decreased sales in Fukuoka City. The general effects of the Shinkansen are varied. Favorable effects reported are: frequent liaison between head office and branches increased human contact, opportunity to enlarge businesses, easier collection of information, easier location of enterprises along the Shinkansen, as pointed out by 149 (47%) of the 317 wholesalers approached. An adverse effect, reported by 49 wholesalers (16%), is keener competition among themselves and with large enterprises moving in from the central cities. Six wholesalers (2%) pointed out rising land prices and wages.

In the final analysis, the Shinkansen has brought new benefits to Fukuoka City which enjoys the advantage of being the terminal of the Sanyo Shinkansen. Since the city wholesalers purchase their goods from Tokyo and Osaka and sell them extensively throughout Kyushu, they are undoubtedly helped by the Shinkansen.

Although it is too soon to know in detail how wholesale business will be affected, the following may be pointed out. First, the extensive wholesale businesses in Fukuoka and Hiroshima Cities could become even more concentrated. Second, if the wholesalers in the small and medium cities along the Shinkansen are to continue to grow, the Shinkansen stations ought to be junctions to other lines, since there is an extensive hinterland for commercial activity. Third, cities where the Shinkansen trains do not stop, even those with traditionally strong commercial characteristics, will probably see their wholesale business gradually dwindle.

Conclusion

The Sanyo Shinkansen has, by the changes it has brought about in transportation, had diverse effects on local communities along the line. These are not effects that have an immediate and direct bearing on income level, but rather, the kind that alter the city structure and functions and the relationship between regions and cities. These effects must be correctly assessed and proper steps taken to cope with them, otherwise, city functions might deteriorate or be lost.

Important in this connection is the policy to be taken to develop the station front of such cities as Shin-Kurashiki, Shin-Iwakuni and Shin-Shimonoseki, which are located far from the city center. The cities of Iwakuni and Shimonoseki, in particular, whose stations have already been moved several times, are now cities of very little charm because their centres are so dispersed. Development of their station fronts should be encouraged with this in mind.

Another important point is the necessity of strengthening the relationship between the cities along the Sanyo Shinkansen and the hinterland. Fortunately, the Chugoku Highway (Osaka–Shimonoseki) is under construction to stimulate development of the hinterland. The highway is helping to induce to the hinterland some of the economic activity and population distribution of the Sanyo Region that has tended to concentrate on the Inland Sea coast. This is interesting, as it suggests the advantages of combining an expressway with the Shinkansen and developing the land two-dimensionally. Moreover, the cities along the Sanyo Shinkansen should make every effort to secure the means of transport to the inland cities to keep them within their spheres of influence. That is the only way for the small and medium-sized cities along the Shinkansen to expand their areas of activity.

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10. *Socio-Economic Impact Models as Tools for Aiding Decision-Making Assessments*

J. OWSINSKI

The impact of a certain action undertaken as a result of policy decision should be analyzed with regard to the initial goals of the undertaker. Two classes of undertaking realization effects may be distinguished. The first is related to direct goal definition and evaluation measures which were applied by some decision-making body in choosing this particular policy. The second are more general, outside the scope of evaluation and choice mechanisms of the above decision-maker, more difficult to evaluate quantitatively, but which must necessarily be considered at some higher level of decison-making.

Two distinct assessment questions arise (see Figs. 10.1 and 10.2):

What was the undertaking's *performance* with respect to its specific goals and evaluation measures?

What were the undertaking's *impacts* on more general socio-economic processes and how are they (can they be) evaluated?

It is obvious that the really best action can be chosen when the predictions of the performance (and impact) are uniformly close enough to an actual situation. These predictions refer, first of all, to the development of the situation in the sense of changes brought about by implementation of an action. Furthermore, as the attitudes and values evolve over time, so will the goal formulations, and therefore they should also be predicted with sufficient accuracy to ensure the positive outcome of the policy, whatever form of action it specifies: project, program or other.

Images

The predictions are based upon images which the decision-making body has of the system being the decision object (national economy, transportation system, JNR) and of the goals. These images and their interplay define to a large extent the decision-making procedure (as shown in Fig. 10.3), which provides a generalization of various loops from Fig. 10.1, and in Fig. 10.4, which is a deployed version of the loop.

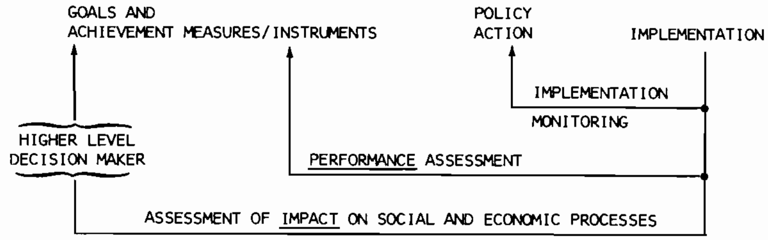

Fig. 10.1. Effects of policy implementation and their assessment.

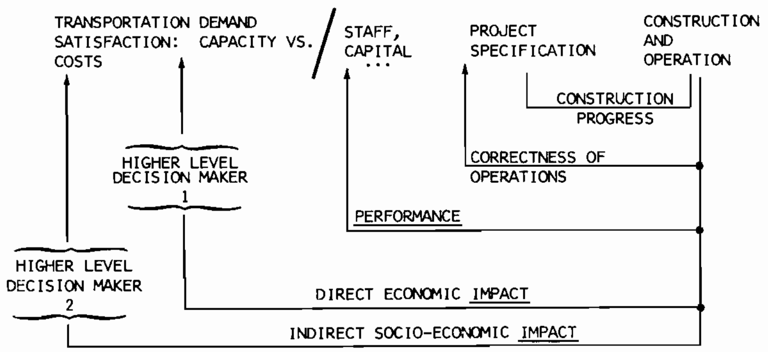

Fig. 10.2. Transportation system development policy: effects and their assessment.

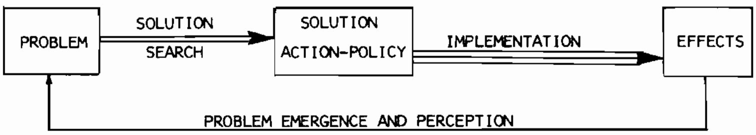

Fig. 10.3. Decision procedure loop.

Decision Process

Both types of assessment lead to the recognition of a decision *problem,* whenever there is a discrepancy between the state of the *object system,* as perceived through its model image, and the *goals* of the *decision-maker,* together with their quantitative achievement measures, as made explicit in a certain model or planning approach. The *solution search* is initiated by the decision-maker, and it consists in specification of various policy *instruments* alternatives, estimation of their influence on the object system, and choice of the best on the basis of goal achievement measures. The search is in general an iterative process which finally produces a *solution,* i.e. an action specification in the form of a policy statement. The policy is then *implemented* through activation of real *controls* operating on the object system.

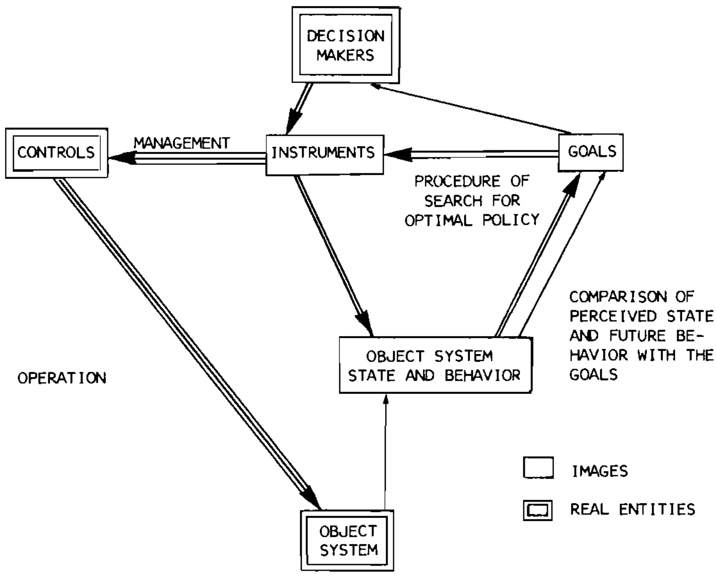

Fig. 10.4. Decision process elements and their functioning in the loop.

Performance and impact assessment therefore represent the closures of the loop effected on two different levels. The lower-level loop is shaped by the higher-level loop through influence on goals, controls and object system assignment.

Interests

Within this area of the study, analysis is focused on images (computerized or just formalized models, or less structured representations). It is interesting to see how the different elements of the decision-making procedure are represented and what their relations are in the functioning of the procedure. Are all the necessary image-type elements available? Do they correspond to each other? Can they form a functioning solution search procedure? These are the questions to be asked.

In many cases the decision-maker has (potentially) at his disposal more than one model for an element. The question then arises whether the models or other images do represent the same real entity, in which case a classification or even choice must be made among them (through validation, etc.) to arrive at the best representation, or whether they correspond to different entities (objects, aspects), in which case they should rather be combined to form a more comprehensive image.

The models for various effects should be constructed in recognition of the different types of effect that implementation of policies may have, and then subsequent various types of appropriate assessments, as mentioned before. These models would reflect the hierarchical structure of organizing decision-making processes within the management system. The questions here are: can the existing models be assigned to various levels of effects and evaluation and, if so, what would be the connections between subsequent loops?

Functioning of the Decision Procedure

The decision procedure loop from Fig. 10.3, and especially the solution search working iteratively over time, moves from the problem definition phase to the solution determination phase. In this process the structure of goals and their measures, as well as of policy alternatives, are first established, and then appropriate decisions are chosen (see Fig. 10.5). The interplay of deployment of goal achievement measures and policy instruments into achievement *conditions* and *alternatives* is of the utmost importance, because it results in policy statement and it shapes the lower-level decision procedure. The images-models should therefore also be analyzed from the point of view of the deployment spectra which they provide (what are they?, how are they generated?) and from the point of view of mutual correspondence of deployments, both within individual procedures and between the levels (whether the subgoals and subpolicies actually realized do correspond to explicitly stated higher-level goals and policies?, can the latter be reconstructed?).

Shinkansen

In Fig. 10.6 some of the notions introduced so far are exemplified for the Shinkansen. Of the levels already mentioned, monitoring and control aspects

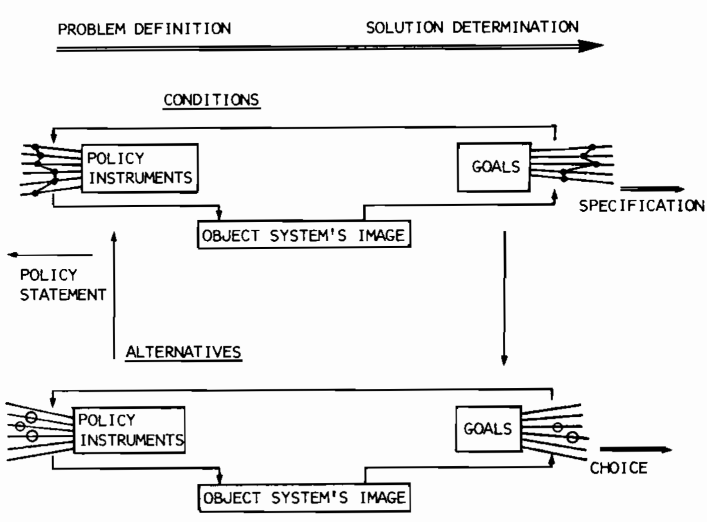

Fig. 10.5. Deployment into conditions and alternatives in the decision procedure functioning.

	PROBLEMS, SOURCES (NEEDS, OPPORTUNITIES)	GOALS	ACHIEVEMENT MEASURES	POLICIES	EFFECTS
INDIRECT SOCIAL IMPACT ASSESSMENT (SOCIAL STRUCTURE)	*MIGRATION *STAGNATION OF HINTERLAND *OVERPOPULATION OF AGGLOMERATIONS	*PROVIDE ACCESSIBILITY *INCREASE EQUITY *HINDER DECAY	*ACTIVATION/DISACTIVATION OF AREAS ALONG LINE *TOTAL INVESTMENT	*TRANSPORTATION SYSTEM DOWNSTREAM *STOPPING LOCATIONS *INTENSITY	*CHANGES IN URBAN FUNCTIONS *ENVIRONMENTAL EFFECTS
DIRECT ECONOMIC IMPACT ASSESSMENT (ECONOMY)	*LOWER TRANSPORTATION COST	*INCREASE OUTPUT	*PRODUCTION AND SERVICE VOLUME CHANGES *TOTAL INVESTMENT AND OPERATION COST	*OPERATION LEVELS *RATES	*STRENGTHENING OR WEAKENING OF ECONOMIC LINKS
PERFORMANCE ASSESSMENT (TRANSPORTATION SYSTEM)	*SATURATION OF TOKAIDO LINE *TECHNOLOGICAL (LATENT) POTENTIAL	*SATISFY DEMAND *(IMPROVE PRESTIGE)	*TRAFFIC CHANGES *COSTS TO USERS/ REVENUE *CAPITAL AND OPERATIONAL EXPENSES	*CHOICE OF PROJECT(S) AND TIMING	*CHANGES IN DEMAND

Fig. 10.6. Exemplification for Shinkansen of some notions introduced.

have been dropped. To the elements of decision procedure, "problem sources" are added reflecting these factors in the object and management system (differing for various levels) which make the specific goals appear. Problem sources are usually the superposition of lingering effects of previous action, changes in exogenous variables of the object system and shifts in goal and policy formulations at the higher levels.

Each entry represents in itself a problem for the modeller, a submodel or a separate model. Thus, for example, *achievement measures* within *performance assessment* may consist of a set of tables and graphs showing growth and shares of traffic, its cost and revenues. On the other hand, there might be a submodel in a transportation system model, showing changes in overall users' time and monetary cost (including shifts among modes), with breakdown into extrapolated and additional induced traffic, as weighted against revenues (depreciating investment and operations included), over time. For a longer time horizon, this projection would account for the growing marginal cost of carrying additional passengers (freight) or losses incurred by too low utilization of capacity. Such projections, generated for various transportation system configurations, could then be compared and evaluated.

In accordance with the meaning of Fig. 10.5, the goals and therefore also goal achievement measures on various levels, should be broad enough to enable the appropriate policy to be chosen. Thus, the imposing and costly technological project could not be chosen were it not for the sufficiently considered time horizon and such goals as the prestige of JNR or even Japan's image.

The paradigm behind the classification in Fig. 10.6 is the one that results from decision procedure requirements. An adequate image system must be formed that reflects the nature of the object system, management system and the goals pursued. This can be ensured by the creation of linkages between (consistent) levels and elements and by precise enough structuring of these elements. The models and analyses presented were regarded from this point of view.

Models and Analyses

In Fig. 10.7 models and analyses are placed against levels.

The SPAMETRI model spans a whole hierarchy of levels. It comprises a transportation submodel, mainly oriented at choice of transportation mode. Driving this submodel are economic and social potentials: regional inflows and outflows of commodities which have to be addressed, and regional populations and incomes creating interregional tensions. On the other hand, effective transported flows influence society and economy through the generalized idea of distance, which has its share in the shaping of production function values and of regional populations. The regional capacities and needs (investment, demand) are aggregated to produce national outputs. These are then allocated among regions. Regions in turn define their supplies and demands, so that the loop is closed. The model as a whole centers on economic considerations. Its main features to be analyzed are interconnections between levels, effected mainly through individual, aggregate variables of somewhat abstract character.

The trade pattern coefficient model does not contain an explicit national level. The economy "occurs" primarily as an interregional phenomenon whose parameters are directly shaped by costs and distances of the transportation system.

The mechanisms utilized in both models are, however, obviously not meant

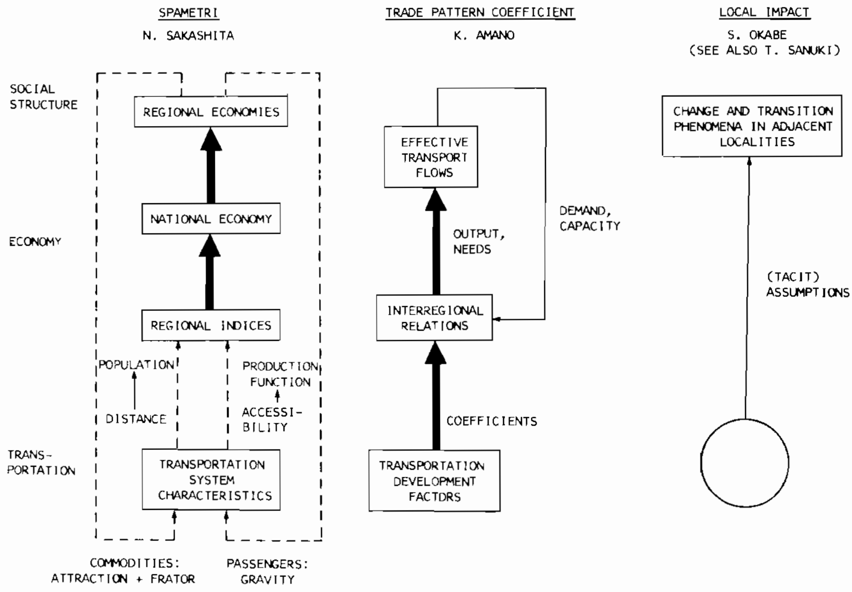

Fig. 10.7. Models and analyses against levels.

for the type of microanalysis which was illustrated in the paper on impacts on local communities. It is on this microlevel that the first-order social effects appear, connected with the flow of people and information, with accessibility to jobs, goods (in a broad sense) and service. Second-order effects would then include such by-produced phenomena as, for example, environmental impacts. In the third, and least measurable, order one would place inducement of technological progress as well as changes in attitudes towards development of the country and its character.

SPAMETRI

CONNECTIONS

As mentioned, connections are maintained through a limited number of aggregate variables. To estimate their role one should know:

Transportation system — economy and social structure) what are the relative weights of a_1ACC (a_1ACCP) — accessibility — in production function as compared to a_0?

What do they represent in terms of technical or other change? How does RKA (regional private capital stock in transportation) appear in production function, what is its weight, how does it develop over time (parameters of corresponding equation: a_{17}, b_{17} for various regions)?

How was the influence of flows themselves (and not only distances) on transportation investment accounted for in the model?

What changes in regional populations (RPOP) did the model predict, how do they relate to the changes delineated in, for example, T. Kuroda's paper?*

(National — Regional economy) What was the basis for adopting a fairly inertial national production allocation submodel, which highly influences equity indices?

(*Economy and social structure — transportation system*) What were the relative differences of gravity parameters a_{14}, b_{14}, c_{14} among various pairs of regions? How did these look compared to flow differences? What inducement could be observed for "Shinkansen" as compared to other simulative runs?

POLICIES

How does the distance (DIST) develop over time for a certain project, involving some government expenditure (RGINVA) and a steplike change in fare costs and time of travel? Should a separate submodel be run to account for the influence of RKA and flow changes?

Do fare rates only influence the model choice and not the effective volume? Where has the investment gone in case of reference simulation (if nowhere, then simulations are not comparable)?

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*For an example of additional material obtained during the Conference see the Appendix in the Summary of Discussion for this session.

GOAL-ACHIEVEMENT MEASURES

How can the total cost of meeting (given) demand be derived (like, for example, the submodel proposed here)?

PROJECTIONS

Small differences between the three projections illustrated — as compared to the divergence with relation to the actual growth curve — imply that the model should be utilized for longer ($\gtrsim$ 10 years) time horizons. It is not certain, however, whether even for such a time horizon the noise will not exceed or equal the policy effects (one year "noise" difference in a given example may exceed several years' sum of effects). On the other hand, establishment of technical parameters appropriate for this model for such a long time projection into the future may not give accurate results. Perhaps this level of assessment is not the right one for Shinkansen?

The econometric model SPAMETRI is obviously meant for general tracking of economic trends and, operating on the interregional basis, it can produce potentialities for interregional flows, and — from its model choice submodel — a share of individual modes. It is better adapted to absorb investments that are non-specific or broad in character than very specific and narrow ones. As the work on SPAMETRI's application to transportation projects has just begun, one must await future even greater accomplishments in the domain, mainly connected with policy formation, manipulation and sensitivity analysis, as well as the cost/benefit — more normative — side of the model utilization.

Trade-Pattern Coefficient Model

This model has a similar general methodological character to SPAMETRI, being a combination of econometric and I-O formulations. In the problems which arise, and which are exemplified below, a certain number of more general comparative considerations are included.

CONNECTIONS-EQUITY

There is a considerable difference between equity development predictions as provided by the two models. Some of this is certainly due to the national allocation mechanism of SPAMETRI, already mentioned, which is absent in the trade-pattern model, where economy — and ultimately also the allocation — is looked upon as an interregional phenomenon. There might be some further causes, like the more "linear" character of the influence of cost and time coefficients in the trade-pattern model than in SPAMETRI. In the latter there is a whole recursive mechanism involving congestion, private capital inducement, etc., influencing the distance variable which then appears in the population and production function submodels, and it can make the whole investment effect saturate very soon. With regard to the trade-pattern model, it is interesting to note that according to the Shinkansen network–highway network comparative study (see Appendix to the paper of K. Amano), Shinkansen lowers the equity, while the highway system enhances it. Why?

There is a more general question of the appropriate regions's size for catching all relevant economic and social phenomena. While it is true that the basic social changes along the Shinkansen occur at the prefecture level, these units cannot be directly treated in an economic model, for lack of data if for no other reason. On the other hand, it is often argued that break-down into units, each of which does not sufficiently weigh in national economy, would not give additional accuracy of a model's results. It can therefore be proposed that the major regions, especially those relevant to a given project, be subdivided, while others be kept as basic spatial units.

CONNECTIONS — TRANSPORTATION SYSTEM — ECONOMY

The trade-pattern coefficient model does not include (as SPAMETRI does) any direct capital influence on or inducement by transportation system characteristics. There is, on the other hand, a cost adjustment mechanism for cases of supply-demand imbalance. To what extent are these two approaches substitutive?

PROJECTIONS

It is difficult to assess on the basis of the paper whether the simulation runs performed are at all comparable. If they are, however, they yield a number of interesting results. Taking the Tohoku region as an example, we can see that not only is it under the relatively strong influence of the Shinkansen — although not directly affected by it — but that with the existence of the Tokaido Shinkansen it is economically more isolated than without it. What can be the rationale behind this result (centering of aligned regions on themselves)?

Conclusions

This short paper is not meant to provide any conclusions, as these can only be formulated after closer examination of the problems and further study. The increase in the number of model studies for evaluation of alternative policies (in transportation particularly) in Japan and elsewhere demonstrates that the question of adequate design of models for decision-making purposes is crucial.

11. *Discussion*

1. Model Types and Characteristics; Connections

(a) A very general question was raised and discussed which concerned the adequate *choice of models* (e.g. input/output as compared to scenario type) for various situations, and the *balance of possible techniques* to be used (related to the elements of the decision procedure introduced in a discussion paper — e.g. econometric compared to optimization).

(b) Concerning the *time stretch* covered by models it was stated that the SPAMETRI model as presented at the conference was expressly utilized for *ex-post* simulation, and that the runs reported in the paper are being extended to 1971 — the year of the Sanyo Shinkansen opening, and beyond. Previously, forcasting uses of the model were concerned with a macroanalysis of less specific governmental road investment allocation over regions. In general, however, forecasting has recently become more difficult for the Japanese economy because of the structural changes which the economy undergoes. The limits to the time horizon, which are set by changes in technical parameters and by policy horizons, are a subject for analysis in themselves.

(c) As far as the *data sources* for such complex modelling undertakings are concerned, the usual procedure in Japan is to utilize the official interregional input/output tables which are published every 5 years. The tables are used in a direct, aggregated, or disaggregated form. (The trade pattern coefficient model was based on the 1960 input/output tables. The 1965 and the 1970 tables are now available.)

An additional important source of data are the origin destination tables compiled for forty-six prefectures in Japan, published for passengers and commodities.

(d) The question of *model convergence* does not apply to the studies presented because they do not use simultaneous estimation techniques as a whole (only for some parts) and their deployment is to a large extent recursive.

(e) The *discount factor* of 7% used in the SPAMETRI model is an average of the credit rates of city banks over the simulation period.

(f) An illustration of the relative significance of *relations and parameters* used to connect different levels is shown in Table 11.1 of this summary. The table presents production functions of tertiary industries in the SPAMETRI model.

2. Adequacy to Object System

(a) Some discussion was devoted to the problem of the *boundaries of problem analysis,* in other words, the extent of the phenomena that was considered.

TABLE 11.1. *Production functions of tertiary industry for regions (estimated by 1961 ~ 1970 data)*

Region			R
1	RV (3.1) =	$e^{\underset{(-1.02)}{-3.97942}} \cdot \{u(3.1) \cdot RK(3.1)_{-1}\}^{\underset{(10.90)}{1.06139}} \cdot RN(3.1)^{\underset{(2.15)}{0.39984} + \underset{(0.59)}{0.91701}\, ACCP(1)_{-1}}$	0.9921
2	RV (3.2) =	$3^{\underset{(-188.13)}{-4.67414} + \underset{(4.60)}{2.80444} \cdot ACCP(2)_{-1}} \cdot \{u(3.2) \cdot RK(3.2)_{-1}\}^{\underset{(7.25)}{0.72241}} \cdot RN(3.2)^{\underset{(3.29)}{0.79373} + \underset{(2.32)}{0.04965} \log \frac{RSC(2)_{-1}}{RN(3.2)}}$	0.9997
3	RV (3.3) =	$e^{\underset{(-228.5)}{-3.64138} + \underset{(8.73)}{5.30902} \cdot ACCP(3)_{-1}} \cdot \{u(3.3) \cdot RK(3.3)_{-1}\}^{\underset{(36.96)}{1.01517} + \underset{(5.29)}{0.01416} \cdot \log \frac{RSC(3)_{-1}}{RK(3.3)_{-1}}} \cdot RN(3.3)^{\underset{(3.39)}{0.38030}}$	0.9999
4	RV (3.4) =	$e^{\underset{(-5.09)}{-1.46775}} \cdot \{u(3.4) \cdot RK(3.4)_{-1}\}^{\underset{(19.44)}{1.01771}} \cdot RN(3.4)^{\underset{(2.75)}{1.51425}\, ACCP(4)_{-1}}$	0.9999
5	RV (3.5) =	$e^{\underset{(-35.0)}{-2.23385}} \cdot \{u(3.5) \cdot RK(3.5)_{-1}\}^{\underset{(3.66)}{0.65499}} \cdot RN(3.5)^{\underset{(64.67)}{0.95630} + \underset{(2.51)}{0.35775}\, ACCP(5)_{-1}}$	0.9998
6	RV (3.6) =	$e^{\underset{(0.29)}{3.110836}} \cdot ACCP(6)_{-1}^{\underset{(0.27)}{1.07495}} \cdot \{u(3.6) \cdot RK(3.6)_{-1}\}^{\underset{(14.09)}{0.78563} - \underset{(-3.24)}{0.21699} \log \frac{RSC(6)_{-1}}{RK(3.6)_{-1}}}$ $\cdot RN(3.6)^{\underset{(2.57)}{0.33909} + \underset{(3.37)}{0.40706} \log \frac{RSC(6)_{-1}}{RK(3.6)_{-1}}}$	0.999
7	RV (3.7) =	$e^{\underset{(7.13)}{-7.02548} + \underset{(4.20)}{89.35534} \cdot ACCP(7)_{-1}} \cdot \{u(3.7) \cdot RK(3.7)_{-1}\}^{\underset{(17.02)}{0.87583} + \underset{(1.02)}{0.00803} \log \frac{RSC(7)_{-1}}{RN(3.7)_{-1}}}$ $\cdot RN(3.7)^{\underset{(5.92)}{0.91791} - \underset{(-2.10)}{0.050748} \log \frac{RSC(7)_{-1}}{RN(3.7)}}$	0.999
8	RV (3.8) =	$e^{\underset{(2.44)}{0.43801}} \cdot \{u(3.8) \cdot RK(3.8)_{-1}\}^{\underset{(10.22)}{0.82686}} \cdot RN(3.8)^{\underset{(9.53)}{5.62354} \cdot ACCP(8)_{-1}}$	0.9998
9	RV (3.9) =	$e^{\underset{(-135.80)}{-7.59058} + \underset{(1.68)}{2.70787} \cdot ACCP(9)_{-1}} \; u(3.9) \cdot RK(3.9)_{-1}^{\underset{(15.22)}{1.05167}} \cdot RN(3.9)^{\underset{(5.17)}{0.97745} - \underset{(-1.39)}{0.02362} \log \frac{RSC(9)_{-1}}{RN(3.9)}}$	0.9996

Note: u is the degree of capital utilization. The potential RV(RVP) can be obtained by setting $u = 1.00$.

(b) A related question of adequate *regional breakdown* was also raised. Although many societal processes induced by the Shinkansen occur on a prefectural basis, the economic models — especially those of the input/output type which use prefectures as basic units — may show too high a sensitivity to phenomena which is statistically negligible. From this point of view, a breakdown of Japan into nine major regions appears to be sensible. In addition, the amount of computation would increase dramatically if prefectures were used as the basic units for analysis — on the order of a factor of 25 to 30 for each matrix $(46/9)^2$. Reliable input/output and other tables already exist for a nine-region breakdown of Japan. The studies which incorporate this data, however, also include subregional considerations. The trade-pattern coefficient model, for example, initially included a total of twenty-four "zones" which were later aggregated into regions. For the purpose of Shinkansen analysis, it was suggested that those regions that lay along the Shinkansen lines could be divided into two or three "sub-regions" in order to obtain a more beneficial analysis.

3. Projections and Policies

(a) A question of *comparability of policies* which were analyzed was raised for general discussion. The specific example of analyzing the proposed highway in comparison with the Shinkansen was raised. It was mentioned that highways may be more environmentally and socially disruptive than a railroad system, in part due to the larger amount of land needed, increased pollution load, and highway death rates. It was emphasized by several delegates that these extraneous effects of highway construction are often not entered into a comparative analysis, thus inducing a false bias for highway construction.

(b) The level of sensitivity of the model results to *changes in policy formulation* turned out to be much higher for regional growth allocation than for summary output indices. This sensitivity can be easily derived from the results cited in the papers. In addition, the sensitivity to endogenous changes in policy variables was greater than the sensitivity to manipulation of exogenous variables.

For computation of model results with respect to interregional changes an illustration is given (see Appendix) of changes in regional populations according to both models.

(c) *Shinkansen* was defined in the SPAMETRI model as a *new mode* of transportation (see Table 11.2) utilizing the same parameters but incorporating differing dependent variables.

(d) The relationships of *time and monetary costs* for both the SPAMETRI model and the trade pattern coefficient model are shown in Tables 11.2 and 11.3.

(e) The *inducement level* of Shinkansen as predicted by the trade-pattern coefficient model was about 10-20%; the entire system was accounted for. The figure of 6% given in the paper "Impact of the Sanyo Shinkansen on Local Communities" refers to the actual situation on the Sanyo line. The 20-30%

TABLE 11.2. *SPAMETRI: Relation of monetary and time cost of passenger transportation*

Modal Choice Model for Passengers (Modes: (1) Railway; (2) Automobile; (3) Shipping; (4) Aviation)

$$\mathrm{RATIOP}(M,N,R) = \alpha_1(M,N)\cdot Q_1 + \alpha_2(M,N)\cdot Q_2 + \alpha_3(M,N)\cdot Q_3 + \alpha_4(M,N)\cdot Q_4 + C(M,N)\cdot P(M,N,R) + T(M,N)\cdot q(M,N,R)$$

$$P(M,N,R) = \{\mathrm{COSTP}(M,N,R) - \overline{\mathrm{COSTP}(M,N,R)}\} / \overline{\mathrm{COSTP}(M,N,R)}$$

$$q(M,N,R) = \{\mathrm{DISTP}(M,N,R) - \overline{\mathrm{DISTP}(M,N,R)}\} / \overline{\mathrm{DISTP}(M,N,R)}$$

$$\overline{\mathrm{COSTP}(M,N,R)} = \tfrac{1}{4}\sum_{R=1}^{4} \mathrm{COSTP}(M,N,R) \qquad \overline{\mathrm{DISTP}(M,N,R)} = \tfrac{1}{4}\sum_{R=1}^{4} \mathrm{DISTP}(M,N,R)$$

Q_1, Q_2, Q_3, Q_4: Dummy variables corresponding to the transport modes

A portion of [α] table

O*D	α_1	α_2	α_3	α_4	C	T	R^2
1-1	0.13260	0.31405	0.28292	0.27043	0.06557	0.34636	0.9976
	(2.883)	(2.657)	(3.115)		(-2.760)	(3.136)	
1-2	0.97772	0.02471	0.02044	-0.01587	0.01361	-0.01459	0.9998
	(4.681)	(0.702)	(0.562)		(0.699)	(-0.506)	
1-3	0.42254	-0.25861	-0.09701	0.93308	-0.26000	0.16181	0.9933
	(3.670)	(-1.135)	(-0.378)		(-1.825)	(0.911)	
1-4	0.93330	-0.06485	-0.07828	0.20983	-0.10922	0.03094	0.9999
	(4.683)	(-1.907)	(-1.807)		(3.302)	(1.201)	
1-5	0.80954	-0.26761	-0.11012	0.56819	-0.24795	0.13783	0.9993
	(4.580)	(-2.198)	(-0.705)		(-2.507)	(1.397)	
1-6	0.88284	-0.11356	-0.04570	0.27642	-0.10946	0.06376	0.9999
	(4.678)	(-0.897)	(-0.897)		(-3.251)	(1.722)	

Notes: (1) The figures in parentheses mean T-values. (2) The traffic assignment ratios for the O*D combination for which no estimated values of coefficients are available were estimated by the extrapolation of trend. (3) Estimated by 1961-1970 data. (4) α_4 is estimated by the relation of $\alpha_4 = 1 - \alpha_1\ \alpha_2\ \alpha_3$. *O = origin; D = destination.

TABLE 11.3. *Trade pattern coefficient model: relation (λ) of monetary cost to time cost of commodity transport.*

λ_i (yen/time)	Sector
35.1	Agriculture, fishery
18.0	Mineral industry
28.2	Textile industry
20.0	Chemical industry
31.0	Metallurgical industry
31.0	Machine industry
28.2	Miscellaneous

inducement rate for the Tokaido Shinkansen also refers to actual conditions during the line's first period of operation.

(f) The *pay-off period* for Tokaido Shinkansen investment was estimated by the trade pattern coefficient model as approximately 7 years in terms of national output. The actual pay-off period for the Tokaido Shinkansen, without taking into account external factors, was 5 to 6 years.

4. Goal-Achievement Measures

The type of simple cost/benefit analysis performed by SPAMETRI was the first attempt to use this model in such an analysis. In future studies the analysis will be extended to include such items as the range of policies and the comprehensiveness of measures; for example, in the determination of environmental costs, the cost of noise insulation, etc., would be included.

Appendix

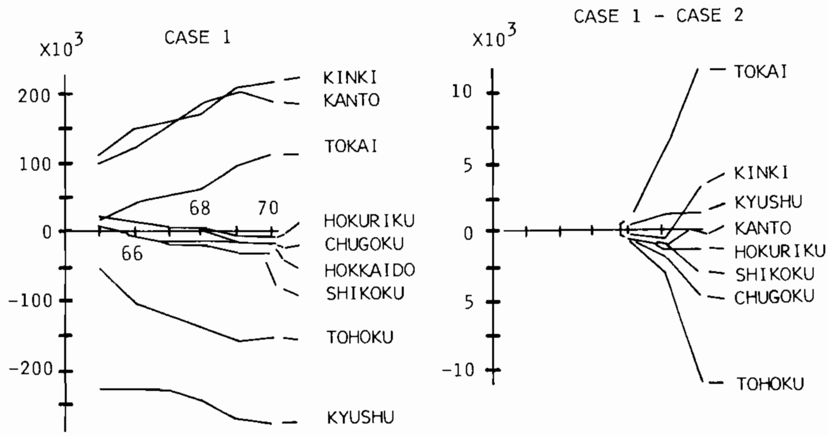


Fig. 11A.1. Regional population growth: trade pattern coefficient model.

TABLE 11A.1. *Actual and predicted regional population changes in SPAMETRI (thousands)*

Region		1963	1964	1965	1966	1967	1968
1	Actual	5125	5169	5205	5221	5229	5242
	Predicted	5113	5131	5150	5170	5192	5216
2	Actual	11,601	11,580	11,531	11,497	11,457	11,387
	Predicted	11,596	11,549	11,502	11,456	11,411	11,367
3	Actual	27,528	28,144	28,846	29,521	30,089	30,568
	Predicted	27,536	18,158	28,787	29,415	30,049	30,692
4	Actual	10,611	10,799	10,996	11,155	11,262	11,405
	Predicted	10,572	10,728	10,886	11,048	11,213	11,380
5	Actual	2763	2763	2767	2768	2761	2757
	Predicted	2761	2759	2756	2752	2748	2744
6	Actual	15,030	15,396	15,738	16,051	16,299	16,380
	Predicted	14,984	15,264	15,547	15,834	16,126	16,422
7	Actual	6896	6868	6877	6873	6874	6866
	Predicted	6891	6866	6845	6829	6819	6813
8	Actual	4022	3998	3979	3959	3945	3872
	Predicted	4011	3981	3952	3925	3899	3875
9	Actual	12,578	12,456	12,366	12,343	12,280	12,179
	Predicted	12,584	12,501	12,421	12,345	12,267	12,188
Total	Actual	96,154	97,173	98,305	99,388	100,196	100,856
	Predicted	96,047	96,937	97,846	98,775	99,725	100,697

Environmental Problems Associated with the Shinkansen

12. *Introduction and Framework for Assessing the Environmental Impacts of the Shinkansen*

D. FISCHER

IIASA studies of the Shinkansen and other large-scale development programs are undertaken in order to place the development environment interface into a systems perspective. As a possible environmental management framework linking the development and environment systems, Fig. 12.1 and 12.2 have been prepared. It is a suggested approach to the problem of forming a comprehensive and integrative environmental management system to respond to the development on the environment.

Figure 12.1 shows the basic structure of the above framework and provides an introduction to the papers that follow. Figure 12.1 is divided into two separate programs, a development program and an environment program. The key interface between these systems comes first from the development side as a set of development activities impinge on the environment as a set of impacts accompanied by development responses to those impacts. The second aspect of this development–environment interface comes from the environmental side to influence the development activities. This influence occurs through several

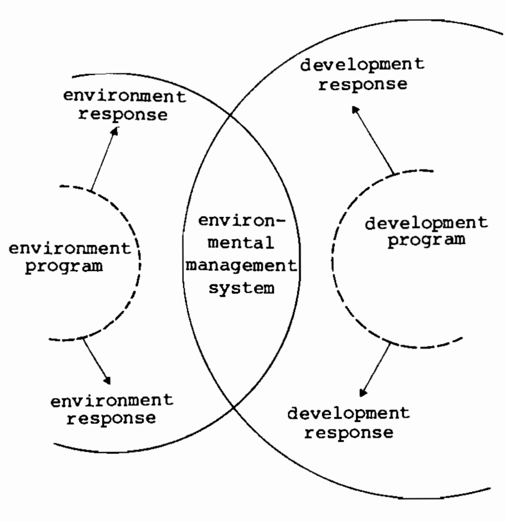


Fig. 12.1. The dual responses necessary for creation of an environmental management system.

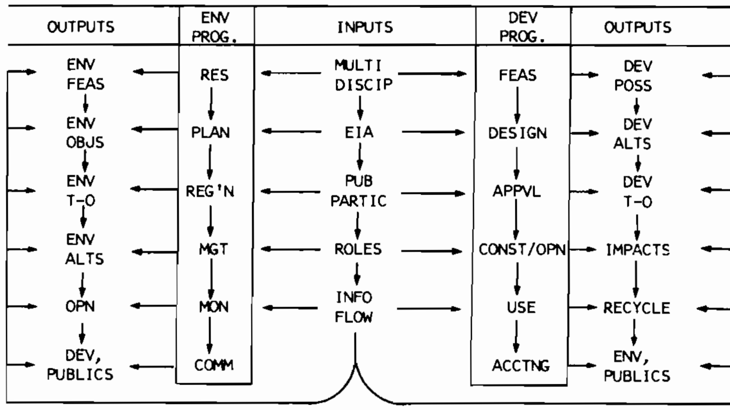


Fig. 12.2. Elements of a comprehensive and integrative environmental management system.

approaches including standards, sanctions, impact assessment, monitoring, etc. Both the environmental response and the development response are involved in mitigating or eliminating the environmental impacts of development activities. This dual response set comprises the environmental management system. The adequacy of this system is determined via the comprehensiveness of the responses and the degree to which they are integrated into the development system.

Together these policy variables comprise a system that is capable of responding to a set of impacts that affect the environment. One of the reasons the development program has grown so large is the set of positive development impacts that have been created and that propel the program over time. One of the reasons the environment program has evolved is the set of negative environmental impacts from these development activities that have given rise to the creation of a program to offset such development pressures. The scope of our studies is to ascertain the nature of the development and environment responses connected with the large-scale development programs. In particular, there is an interest in determining the linkages characterizing the interface between the development and environment systems. These linkages would comprise interprogram connection which could be joint responses envolving into a comprehensive and integrated environmental management system.

The first figure contains the two programs of environment and development, into which are embedded the essential variables of actors, their values and responses that are activated by the potential impacts from the development program. Each program is explicitly defined as shown in Fig. 12.2 with each stage briefly listed in the figure.

Figure 12.2 has a set of inputs which appear to be a necessary ingredient for interfacing specific development and environment programs. The first input is a multidisciplinary team to both environmental research and development feasibility studies which provides a basis for determining a wide range of environmental feasibilities and development possibilities, respectively. This information then feeds into the next stage as an input. The second input is an environmental impact assessment to both the environmental planning and the development design stages. This input provides a basis for forming environmental objectives and development alternatives and is created from the multidisciplinary input preceding it. The third input is public participation from a wide range of publics that stems from the impact assessment and feeds into the regulation and development approval stages to provide responses to environment-development trade-offs. The fourth input consists of the reticulist roles necessary to operate the interface as environmental management and development construction and operation actually occur over time and as conflicts arise. Public participation is an additional basis for generating environmental alternatives to expected and unexpected environmental impacts from the development. The fifth and final input is the flow of information from the reticulist roles into the monitoring of the environment and development, including the users and users of the development itself. The results of this information flow is to secure the operation of these environmental alternatives and of the recycling, conservation and environmental efforts of the developer. This information flow also provides the basis for the communications and accounting flows for each of the programs and to the publics as well as for each of the outputs associated with each of the programs.

While the above description of Fig. 12.2 is quite brief, it does suggest the outline of an environmental management system. It is the suggested approach of our IIASA study team based on the models used and the information collected for each part of our efforts.

Because of these major impacts associated with the Shinkansen, the environmental management aspects have become important. The basic activities in Fig. 12.2 comprising such an environmental program to meet these impacts are shown below:

Research. The capability of identifying environmental problems, providing the research design and analyses and communicating the results in a practical format.

Planning. The capability to perceive and plan for mitigating long-term effects of planned developments to the environment including the possibility of eliminating the development altogether or proposing viable alternatives thereto.

Regulation. The capability of controlling the construction, operation and abandonment of the development with appropriate measures and sanctions.

Management. The capability of managing the residual unmitigated adverse impacts and integrating them into a general management program for the environments options.

Monitoring. The capability of identifying the origins of impacts, their environmental effects and the changes induced in the environment from the development as well as the capability to translate these findings into suitable inputs to support the other environmental activities listed above.

Communications. The capability of translating and transmitting useful environmental information to the traditional users, the publics, the developers and the other environmentalists.

These activities, when taken together and when merged with development responses, comprise the essential elements of an environmental management system.

The adequacy of this combined response system can be assessed through the criteria of comprehensiveness and integrativeness. Comprehensiveness can be defined in two ways:

a comprehensive set of actor groups involved and assessing the adequacy of the environmental management system, and

the full range of environmental program activities necessary to regulate the development are included, such as research planning, regulation, management, monitoring and communication.

Integrativeness can be equally defined in two ways:

an integrated set of relationships between development and environment actor groups, and

an integrated communication and decision pattern giving similar weighting to environmental information generated.

How the environment is considered in the Shinkansen program sets the stage for many of the impacts emanating from it. If it is narrowly perceived as simply pollution control then important environmental factors can be missed. Such factors include not only the wider set of social environmental impacts that are often difficult to perceive but also the set of environmental planning opportunities available for restructuring and protecting the larger environment of a specific extension of the system.

The basic approach to the study of large-scale systems was the premise that environment and development are not always fundamentally incompatible. In other words, there is often an environmentally sound way to develop a technological system. This premise attempts to bring environment and development together rather than allowing them to segregate into separate conflicting compartments. Over time a growing convergence can often be seen rather than conflict between environmental and development goals, activities, strategies and actors involved. The conflict resolutions process is difficult because of major problems in attempting to integrate the seemingly disparate factors of environment and development. The assessment processes underlying such conflicts and integration attempts are of interest through their linkage of varying actors, goals and issues. The criteria underlying this approach are designed to ascertain the possible convergence between development and environment policy systems. This approach has as its purpose the understanding of the Shinkansen development-environment case for application of a systems view and subsequent analysis.

The purpose of this approach is to move from a set of isolated and non-comprehensive environmental functions housed in different agencies and to bring them together in a comprehensive way so that a holistic look at the environment is obtained for merging with a development program. A development is already brought together because of the necessity of achieving some set development goals, such as time-saving for the Shinkansen. The two programs are integrated so that finally a development program is created complete with an environmental program which is both comprehensive and integrated into that development program. This approach then is the generalized framework evolved at IIASA for studying large-scale development programs.

13. *Environmental Problems and the Shinkansen*

T. YORINO

Environmental Problems in Japan and Government Policy

THE BEGINNING OF ENVIRONMENTAL PRESERVATION ADMINISTRATION

The deterioration of the environment in Japan became increasingly serious in the course of high economic growth, but some improvement is being made in certain areas as a result of counter-measures. The problems remain serious, and they are becoming more diversified and complicated.

The first case of environmental pollution was noted in the latter half of the 19th century when the smoke and liquid waste from mines damaged agricultural products. The nation as a whole, however, showed little concern about environmental problems until the end of World War II. As early as the last half of the 1940s, pollution began to be a problem, related to the progress in economic recovery, in the Keihin (Tokyo and Yokohama) and Hanshin (Osaka and Kobe) districts, leading Tokyo to issue the Ordinance for the Prevention of Environmental Pollution by Factories, and other local authorities followed suit. These Ordinances, however, were concerned with air and water pollution, dealing only with the procedure for obtaining permission to build plants and workshops. No quantitative standards were set for the discharge of smoke and liquid waste.

Environmental pollution became a national concern around 1955, when the Japanese economy had finished its recovery period and entered into the remarkable growth period. During the 18 years from 1955 to 1973, the Japanese economy continued to grow at a rate unprecedented in the world, and the real gross national product rose 5.4-fold. This was also the period when environmental pollution spread to national proportions.

SYSTEMATIZATION OF ENVIRONMENTAL PRESERVATION ADMINISTRATION

In 1967, to clarify the common principles, targets and setups of environmental preservation administration that had become diversified among various ministries and agencies, and in order to coordinate efforts, the Basic Law for Environmental Pollution Control, based on a 2-year government study, was promulgated to cope with aggravated environmental pollution.

This law listed six environmental pollutions: air pollution, water pollution, soil pollution, noise vibration, ground subsidence and offensive odor. Factory operators and the state and local authorities were obligated to do their part in prevention of these pollutions.

The environmental quality standards called for under the Basic Law for Environmental Pollution Control were set out in 1969/1970 for sulfuric oxide, carbon monoxide, cadmium and mercury, and this was followed by the smoke and liquid-waste discharge standards for national application. The regulations on water quality, smoke, underground water pumping, etc., were also formulated. In 1968 the Noise Pollution Regulation for the control of workshop and construction noise was enacted, followed by the Vibration Pollution Regulation in 1976.

ESTABLISHMENT OF THE ENVIRONMENT AGENCY AND DEVELOPMENT OF ENVIRONMENTAL ADMINISTRATION

Along with the progress of legislation for preservation of the environment in the second half of the 1960s, the establishment of an overall administrative organ for this purpose was keenly desired, and the Environment Agency was set up in 1971 to take over all the environmental administration work that had been diversified among various ministries.

In 1972 an agreement was reached at a Cabinet meeting that in carrying out various public works their effects on the environment should be studied before-hand to avoid environmental deterioration, and that an environmental assessment should be conducted. Various methods of assessment were then studied in accordance with this Cabinet agreement. The Environment Agency has recently made preparations for legislation to institutionalize environmental assessment for application to all large-scale projects before their commencement, and this is being discussed with the authorities concerned.

The history of environmental pollution in Japan and measures taken to control it are given in Table 13.1, which shows that the Shinkansen environmental problem appeared late and is a part of the diverse environmental problems.

Laws Controlling Environmental Pollution

Laws controlling environmental pollution, gradually put in order since 1890 when the Mining Ordinance was promulgated, are shown in Fig. 13.1. As is shown, legislation is now almost completed, and much is expected of the adequate application of these laws and regulations.

Current Problems of Environmental Pollution

The environmental pollutions complained of in Japan today are shown in Tables 13.2-13.4. Complaints rose rapidly in number, reaching the peak of about 80,000 cases in 1972.

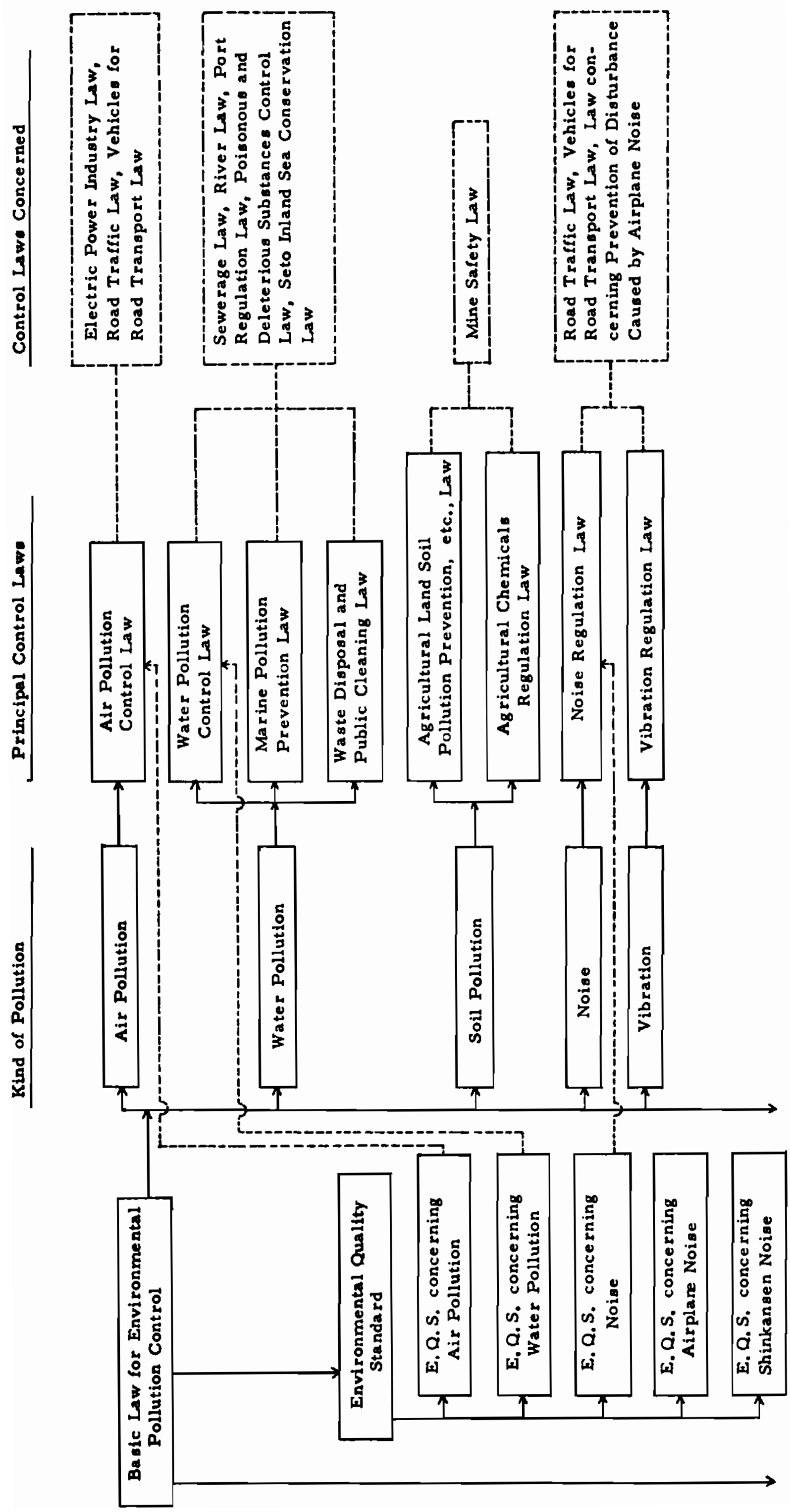
TABLE 13.1. *History of environmental pollution legislation*

1956	"Minamata" disease (organic mercury poisoning) becomes a social problem
1959	Construction of the Shinkansen begins Water-quality Preservation Law Numerous asthma cases in Yokkaichi City (petrochemical complex)
1962	Smoke and Soot Regulation Law
1964	Environmental Pollution Section set up in the Ministry of Health and Welfare Shinkansen opens between Tokyo and Shin-Osaka
1967	Basic Law for Environmental Pollution Control Law for the Prevention of Noise at Public Airports Lawsuit concerning Air Pollution in Yokkaichi City
1968	Air Pollution Control Law Noise Regulation Law
1969	Lawsuit concerning "minamata" disease Lawsuit against noise at Osaka International Airport
1970	Amendment Basic Law for Environmental Pollution Control
1971	Environmental Quality Standards for Noise (in general district) Environment Agency set up Central Council for Control of Environmental Pollution set up
1972	UN Environment Conference Nature Conservation Law Recommendations of Urgent Steps on Shinkansen Noise Abatement
1973	Environmental Quality Standards for Airplane Noise
1974	Lawsuit at Nagoya against Shinkansen Noise and Vibration
1975	Environmental Quality Standards for Shinkansen
1976	Recommendation of Urgent Guidance Principles on Shinkansen Vibration Vibration Regulation Law

Among the complaints of environmental pollution, those of noise and vibration head them all, reaching 24,000 cases in 1974. Of these, 21,000 complaints were of noise and 244 of railway noise (about 1%). Complaints of vibration reached 4000, of which 350 were of railway vibration, or about 9%. Most of the complaints about railways were made of the Shinkansen.

Environmental Problems Involving the Shinkansen: Background

The noise and vibration and impairment of TV reception caused by Shinkansen trains have been complained of, individually or by group, since the opening in October 1964, and some complainers have demanded compensation. At the time of the opening, the train frequency was 30 round trips per day and the number of complaints was small, but as the number of trains raised and as more cars were put on each train (from twelve to the present sixteen) complaints against the noise and vibration began to mount annually. Organized movements started in various places along the line, the League against Shinkansen Pollution taking the initiative. Complaints rapidly increased and intensified among the residents along the line, so much as to become a social movement. By the end of 1975 the total number of complaints and petitions in writing had reached 550.


Kind of Pollution
Principal Control Laws
Control Laws Concerned
Basic Law for Environmental Pollution Control
Environmental Quality Standard
E. Q. S. concerning Air Pollution
E. Q. S. concerning Water Pollution
E. Q. S. concerning Noise
E. Q. S. concerning Airplane Noise
E. Q. S. concerning Shinkansen Noise
Air Pollution
Water Pollution
Soil Pollution
Noise
Vibration
Air Pollution Control Law
Water Pollution Control Law
Marine Pollution Prevention Law
Waste Disposal and Public Cleaning Law
Agricultural Land Soil Pollution Prevention, etc., Law
Agricultural Chemicals Regulation Law
Noise Regulation Law
Vibration Regulation Law
Electric Power Industry Law, Road Traffic Law, Vehicles for Road Transport Law
Sewerage Law, River Law, Port Regulation Law, Poisonous and Deleterious Substances Control Law, Seto Inland Sea Conservation Law
Mine Safety Law
Road Traffic Law, Vehicles for Road Transport Law, Law concerning Prevention of Disturbance Caused by Airplane Noise

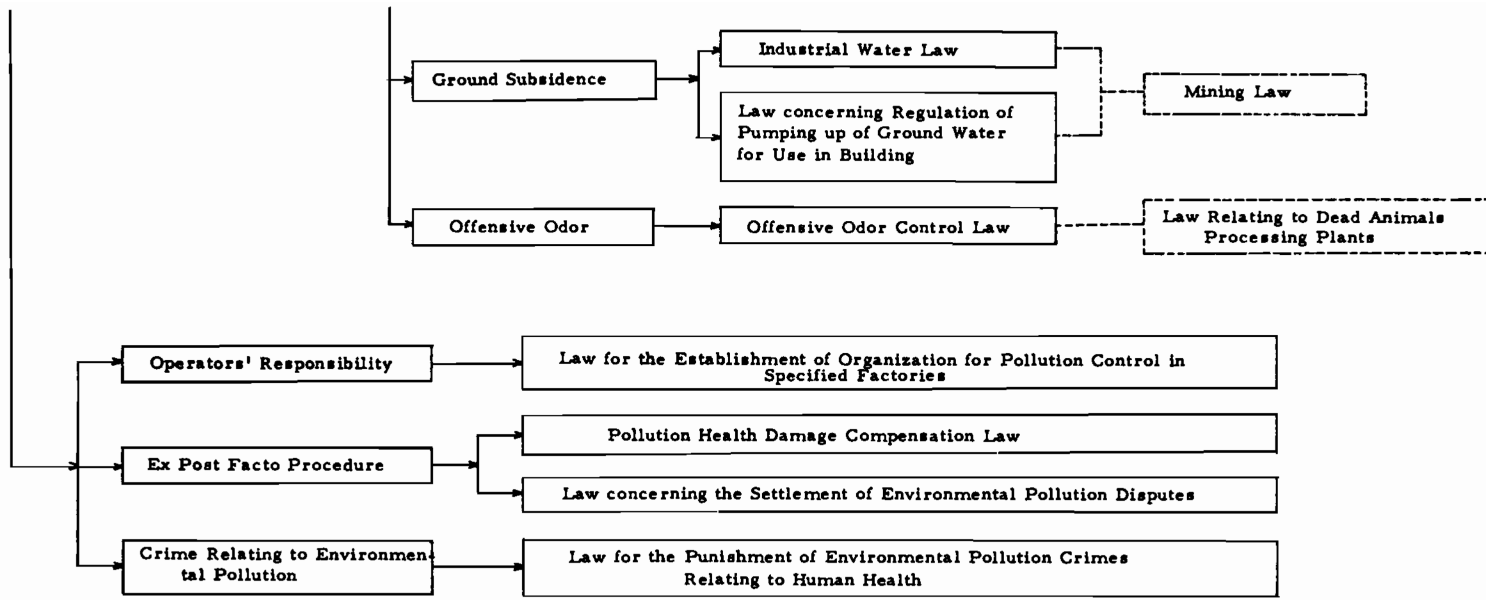


Fig. 13.1. System of laws controlling environmental pollution.

TABLE 13.2. *Number of complaints of environmental pollution by kind*
Source: Environment Agency, Environment White Paper, 1976.

Kind	1966	1967	1968	1969	1970	1971	1972	1973	1974
Air pollution	4962	5621	5843	7558	12,911	13,798	15,096	14,234	12,145
Water pollution	2197	3014	3782	4665	8913	11,676	14,197	15,726	14,496
Soil pollution	-	-	-	-	67	262	408	466	478
Noise and vibration	8833	12,205	12,110	17,786	22,568	25,591	28,376	28,632	24,195
Ground subsidence	31	41	41	13	11	937	74	93	84
Offensive odor	3494	5073	5622	7983	14,997	17,750	21,576	19,674	17,140
Total	19,517	25,954	27,398	38,005	59,467	70,014	79,727	78,825	68,538

Note: Investigated by the Environmental Dispute Coordination Commission.

TABLE 13.3. *Breakdown of complaints of noise*
Source: Environment Agency, Environment White Paper, 1976.

Year		Kind of noise							
		Work-shop	Con-struc-tion	Road traffic	Mid-night	Air-plane	Railway	Others	Total
1971	No. of cases	11,506	1983	479	720	341	63	3643	18,735
	%	61	11	2	4	2	1	19	100
1972	No. of cases	14,828	3619	527	1026	166	162	3653	23,981
	%	62	15	2	4	1	1	15	100
1973	No. of cases	14,908	3424	691	1205	249	144	3524	24,146
	%	62	14	3	5	1	1	14	100
1974	No. of cases	12,567	2647	819	1179	265	244	3251	20,972
	%	60	13	4	6	1	1	15	100

Note: Investigated by the Environment Agency.

TABLE 13.4. *Complaints of vibration throughout Japan in 1974*
Source: Environment Agency, Environment White Paper, 1976.

	Kind of noise								
		Con-struc-tion	Road traffic		Railway				
	Workshop	tion work	High-way	Others	Shin-kansen	Other	Air-plane	Others	Total
No. of	2179	986	26	378	273	77		176	4095
cases	(64)		(1)				(17)	(28)	(110)
%	53	24	1	9	7	2	-	4	100

Notes: Investigated by the Environment Agency. The numbers in parentheses represent those of low-frequency aerial vibration, not included in total.

The complaints and petitions mainly desired the establishment of a buffer zone between the rail line and built-up areas, prompt execution of work on abatement of noise and vibration, compensation for pollution, and the slow-down of trains. In extreme cases, the residents along the line in the Nagoya area instituted lawsuits demanding the banning of Shinkansen noise and vibration intrusion. Social trends had made residents aware of their right to protect themselves against environmental pollution and complaints were steadily increasing.

The Shinkansen, however, was created to benefit human life. It is reasonable to expect it to meet the transport demands and carry out its service in the most efficient way. But how could a rail line of such vital importance as the Shinkansen be constructed in a narrow land like Japan, with its population and economic centers distributed as they are, and be completely free from environmental pollution?

The question is how to keep a balance between the convenience of the Shinkansen and the environmental deterioration. The problem can be solved only on a national scale with the realities of the situation understood and with the cooperation of residents along the Shinkansen line. Here, it is particularly important to understand the nature of environmental deterioration. Noise and vibration, unless at especially high levels, unlike air and water pollution, are not directly linked to health harm. They are linked rather to mental harm or annoyance to daily life. Hence, the balance between the influence on the personal environment and the public nature or convenience of the Shinkansen must be considered. Room is thus left for the factor of human endurance. There is also the question of who is to bear the cost of environment preservation and to what extent, and therefore a hasty conclusion should not be drawn.

BACKGROUND TO THE SOCIAL PROBLEM

The public today reacts more sensitively than formerly to environmental problems. In extreme cases, there is a tendency to think that mankind is even imperiled.

Japan is a country high in population density, GNP, crude steel production, electric power generation and motor-car ownership. Moreover, less than 30% of Japan consists of flat land. In the region called the Tokaido Megalopolis, which lies along the Shinkansen, nearly half the Japanese population and about 70% of the national industrial output is concentrated. It is one of the most thriving regions in the world, densely populated and industrially productive (see Fig. 13.2). In such a region, a mass transport system like the Shinkansen is vitally necessary. Indeed the traffic on the Shinkansen speaks for itself, and justifies its existence.

For the convenience of users and to facilitate a transportation network, it was desirable to build a Shinkansen station close to the existing station, well inside the urban district. Hence, the route had to pass through densely populated areas in the vicinity of the station. Even when the route avoided these areas, new houses would be built along the line after it was opened. The Shinkansen trains forced their way into the existing urban districts to reach their stations. It was not easy to provide a proper buffer zone between the line and dwelling houses.

There is not much affinity between the Shinkansen and the residents along the line, as the residents do not use the Shinkansen trains as often as the conventional narrow-gauge line. This is one reason why many complaints are made against the noise and vibration of the Shinkansen although the noise and

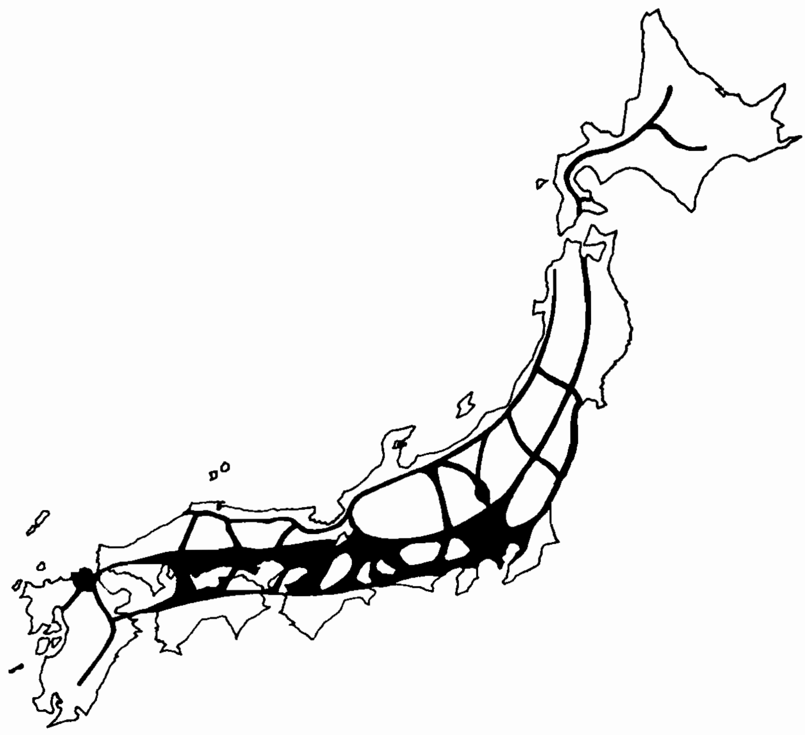


Fig. 13.2. Megalopolitan Japan. Source: Kenzo Tange, *Image of Japan in the Future.*

vibration levels are almost the same as those of the conventional narrow-gauge line.

Most of the houses are made of wood and paper and cannot shut out noise and vibration.

All these circumstances combine to make a serious environmental problem. Most of them appear to be peculiar to Japan, as do most of the environmental problems concerning the Shinkansen.

Environmental Quality Standards on Shinkansen Noise: Guidance Principles on Vibration

Having decided that counter-measures must be taken against the Shinkansen noise and vibration, which had become a social problem, the Environment Agency recommended in December 1972, first of all, urgent steps on Shinkansen noise abatement along the line, based on suggestion by the Central Council for Control of Environmental Pollution. In July 1975, the Agency formulated environmental quality standards for noise control, and in March 1976 recommended guidance for vibration. That these recommendations were made outside the framework of the Noise and Vibration Pollution Regulations in expectation of active efforts by the state and JNR was, presumably for the following reasons:

The operating body of the Shinkansen is JNR, a public corporation, and the recommendations are directed to a specific body, unlike the case of road transport where the persons to be regulated are unspecific; the technology for prevention of noise and vibration at the source is well advanced; and the impact of the regulations would be very great and it would not be easy to balance the various interests.

RECOMMENDATION OF URGENT STEPS ON NOISE ABATEMENT

The urgent steps for noise abatement recommended in December 1972 were as follows:

1. Take countermeasure at the sound sources, so that the Shinkansen noise level is below 80 phons (A) in the residential area along the line.
2. For dwelling houses and others in an area where the noise level persists at 85 phons (A) or more after countermeasures are taken at the sound sources, take steps to remove the nuisance, so that daily life is not too much impaired.
3. Give special consideration to schools, hospitals and other institutions that particularly need to be quiet.
4. For areas suffering from damage due to vibration, consider methods to ease the suffering.
5. During night-time track maintenance work, endeavor to reduce the noise level by improving the method of job execution.

ENVIRONMENTAL QUALITY STANDARDS CONCERNING NOISE

The main points of the environmental quality standards for noise from the Shinkansen, made public in June 1975, are shown in Tables 13.5 and 13.6.

Policy for execution of noise abatement

1. In executing the countermeasure, give priority and weight to Area A of Table 13.6.
2. For Areas B and C of Table 13.6, determine the execution method to be taken, taking into account the progress of work execution on Area A.

TABLE 13.5. *Standard values for noise*

Classes of area	Standard values
I. Mainly residential	70 phons or below
II. Commercial and industrial, but must be kept suitable for living in	75 phons or below

TABLE 13.6. *Target period of attainment of noise standards*

	Classification of areas along Shinkansen	Target period of attainment: Shinkansen already in operation	Shinkansen under construction	Shinkansen to be constructed
A	Area of 80 phons or more	Within 3 yr	At the time of opening	
B	Area above 75 phons (a) and under 80 phons (b)	Within 7 yr Within 10 yr	Within 3 yr after opening	At the time of opening
C	Area above 70 phons up to 75 phons	Within 10 yr	Within 5 yr after opening	

The area (a) of B refers to the place corresponding to the Class 1 area or is an extension of it, and the area (b) to places other than the area (a).

BASIS OF ENVIRONMENTAL QUALITY STANDARDS CONCERNING NOISE

The main points of the basis on which the environmental quality standards were determined, as reported by the Experts' Committee of the Central Council for Control of Environmental Pollution, are as follows:

Assessment unit

The elements to be specially considered in determining the assessment unit are train frequency, peak level and duration. Among the assessment units for noise, covering these three elements are Leq, expressing the quality of energy, and ECPNL, used as the assessment unit of aeroplane noise. In the case of the Shinkansen, the peak level alone is used at present, as no differences due to train frequency can be noted in the degree of nuisance complained of by the residents in their answers to questionnaires, and as the desirability of using Leq or ECPNL has not yet been fully studied.

Standard value

Conceivable effects of noise are: the effect on hearing, the physiological effect on pulse and blood constituents, the psychological effect, commonly expressed as nuisance, and the effects on daily life, such as sleep and conversation.

The effect on hearing and the physiological effect are produced by a level of noise considerably higher than that which produces the psychological effect and the effects on daily life. The range of levels of the Shinkansen noise, except in special cases, is no higher than that causing the psychological effect and the effects on daily life.

The psychological effect of annoyance and the effects on daily life, such as sleep and conversation, have been studied from answers to questionnaires sent in from residents along the Shinkansen, and the noise level has been set at a point where the rate of the residents' complaints about some of the relevant effects would be less than 30%. The noise level at which less than 30% of the

TABLE 13.7. *Residents' reaction to Shinkansen noise*
Source: Experts' Committee Corcerning Noise, Central Council for Control of Environmental Pollution, *Basis of Environmental Quality Standard Concerning Shinkansen Noise*, March 1975.

Item	Rail line	Investigated by	Ratios of positive reaction					
			60%	50%	40%	30%	20%	10%
Prevention of falling asleep	Tokaido Shinkansen	Tohoku Univ.	87	84	82	80	77	75
	Sanyo Shinkansen	Tohoku Univ.	82	78	75	71	67	-
Disturbance of restful sleep	Tokaido Shinkansen	Tohoku Univ.	87	85	82	79	76	73
	Sanyo Shinkansen	Tohoku Univ.	80	77	74	71	69	66
Telephone interference	Tokaido Shinkansen	Environment Agency	80	78	76	73	70	66
		Tohoku Univ.	81	79	77	74	72	69
	Sanyo Shinkansen	Tohoku Univ.	79	76	73	70	67	64
Conversation interference	Tokaido Shinkansen	Environment Agency	79	77	74	71	66	55
		Tohoku Univ.	80	77	75	73	71	69
	Sanyo Shinkansen	Tohoku Univ.	77	74	72	70	67	65
Being startled	Tokaido Shinkansen	Tohoku Univ.	88	85	83	80	77	75
	Sanyo Shinkansen	Tohoku Univ.	84	81	77	74	71	68
General assessment	Tokaido Shinkansen	Environment Agency	80	79	77	73	68	-

Notes: (1) By "positive reaction", is meant: (a) according to the Environment Agency, "Occasionally experienced" + "Rather frequently" + "Frequently"; (b) according to Tohoku University, positive reaction by Likert measure. (2) The noise level is the average value of noise level at the time the train passes the measuring point. (3) The Environment Agency has also investigated, item by item, but the relation between the noise level and complaints has not been sought for disturbance of sleep, etc., as the analysis revealed that there are many contributing factors other than noise involved in the complaints.

residents complain of some effects is roughly calculated as 70-75 phons, as may be seen from Table 13.7.

The psychological effect and the effect on daily life vary with residents' varying environmental conditions and ways of life. Thus the standard value of a mainly residential area, where more quiet is desired (a Class I area), is set at 70 phons, and that of other areas (Class II) at 75 phons. These values were decided after a comparative study of environmental quality standards for road traffic and aeroplane noise.

DOUBTFUL POINTS OF THE ENVIRONMENTAL QUALITY STANDARDS

The environmental quality standards are stipulated under Article 9 of the Basic Law for Environmental Pollution Control. They are formulated by the Government with the object of protecting man's health and preserving his environment in good condition. In this respect the standard values are of a somewhat different nature from the regulation values set for poisonous materials injurious to health. This characteristic of being the target value gives rise to a sort of intrinsic ambiguity in the meaning of its numerical value. Conflicting opinions are therefore inevitable. One opinion holds that the numerical value is difficult to attain but it must be set as high as possible; the other insists that it is necessary to set an administrative target, i.e. with a highly realizable value kept in mind. This ambiguity seems not to have been properly clarified at the discussion of environmental quality standards for the Shinkansen noise. Other problems that seem not to have been properly studied are: the definitive way of attaining the value; the impacts on the national economy; whether the tempo of the investment to be made on the environment preservation is reasonable or not in the light of the prevailing economic situation; how far other kinds of noise are controlled; the effect on the country's standard of living.

URGENT GUIDANCE PRINCIPLE RECOMMENDED ON VIBRATION

The main points of the guidance principle on the Shinkansen vibration recommended in March 1976 are given below.

Standard value

1. For the areas where the corrected acceleration level of the Shinkansen vibration exceeds 70 dB, consider as promptly as possible counter-measures against vibration sources and prevention of the nuisance to houses.

2. For the areas with hospitals, schools, and institutions that need to be quiet, give special consideration and take proper steps as soon as possible.

Steps for the attainment of the standard value

1. As a counter-measure against vibration sources of the Shinkansen, provide a means to reduce the vibration of structures. Even when such measures have been taken, there may be occasions where it is not easy to reduce the vibration with the presently available technology. Technical development must be immediately undertaken, therefore, to devise the means for the vibration-proofing of structures and for vibration interception.

2. Compensation for house moving and financial housing aid for reconstruction or reinforcement are to be provided in the areas affected, beginning with the area suffering most from vibration. In particular, technical development should be undertaken as soon as possible for the vibration-proofing of houses and steps taken to ease the nuisance of vibration by repairing houses, and so on.

BASIS OF URGENT GUIDANCE PRINCIPLE ON VIBRATION

The main points of the basis on which the standards were determined, as reported by the Experts' Committee of the Central Council of Environmental Pollution, are given below. •

Assessment unit

For the assessment unit, ISO-2631 on exposure of human body to vertical vibration (see Fig. 13.3), is applicable and the vibration level unit dB is used.

In the case of ground surface vibration, the vertical vibration is larger than

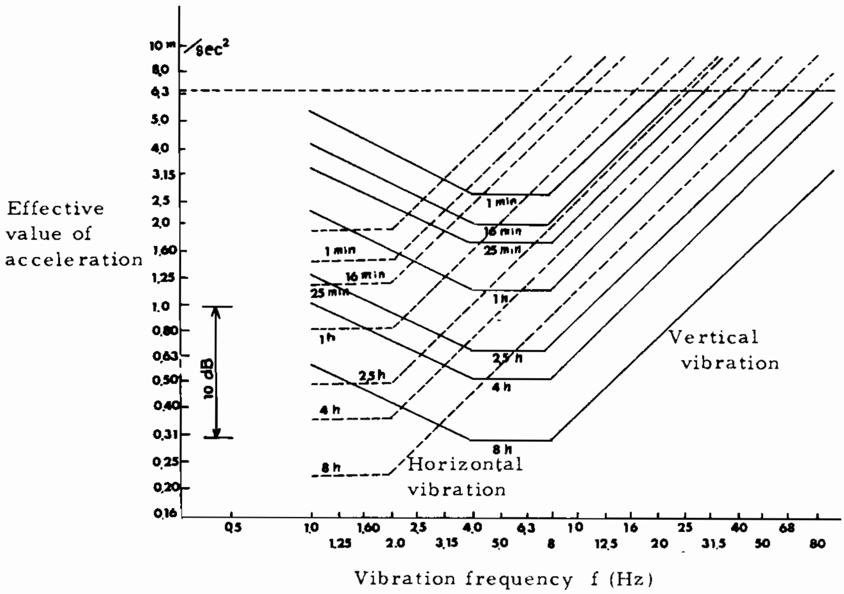


Fig. 13.3. Standards for vibration exposure (ISO-2631). Note: 1. The solid line represents the standards for vibration exposure to vertical vibration at the industrial place of work (the efficiency diminution limit due to fatigue), the broken line, that to horizontal vibration. 2. The durability limit is 6 dB higher than the standards; the comfort diminution limit is of a value 10 dB lower. 3. The standard for exposure to vertical vibration lasting 8 hours corresponds to 90 dB when converted into corrected acceleration level. Source: Experts' Committee Concerning Vibration, Central Council for Control of Environmental Pollution, *Basis of Urgent Guidance Principle on Shinkansen Vibration* (ISO-2631) March 1976.

the horizontal vibration in many instances. Since, in the vibration frequency zone related to pollution, the human body feels the vertical vibration more strongly, this vibration alone is taken note of in order to accept vibration as an environmental pollution.

Standard value

The basic thinking in setting the standard value is that the value be set so as not to impair health or hamper daily life during the day and not to disturb sleep at night. For this, the results of studies on physiological and psychological effects and the effect on sleep, as well as the answers of the residents to the questionnaire on vibration, have been used as reference in the discussion. Also used as reference were the results of investigations on the actual state of various kinds of vibration, the studies on the present state and future prospects of the technology of vibration-proofing and the standards adopted by local authorities. For the Shinkansen, the effect of disturbed sleep is not considered as no trains run on it late at night.

The conditions considered in setting the standard value are given below.

House-vibration characteristics

The relation between the ground-surface vibration and indoor vibration is affected by the house vibration characteristics. Depending on the frequency, the vibration is amplified or damped, which makes the assessment complicated. Using the results of various investigations as reference, the standard for vibration amplification is set at 5 dB.

Physiological and psychological effects

A variety of experiments have disclosed that the vibration exerting significant effects on health are those over 90 dB (ground surface value about 85 dB) which is a very high level. In the ISO standards, the comfort-diminishing limit is given as 80 dB (75 dB on the ground surface). This is a value for 8 hours' exposure at the industrial place of work. The standard value of vibration in the house must be set below that level.

Investigation of residents' reaction

An example of residents' reaction to workshop vibration, road traffic vibration, and Shinkansen vibration is shown in Table 13.8.

Physical damage

The vibrations that inflict physical damage on ordinary houses at one stroke, such as an earthquake, are presumed to be of a level higher than 85-90 dB. In the case of vibration as environmental pollution, the vibration is of long duration and the frequency of occurrence is high. Therefore, the conditions under which damage occurs are quite different from an earthquake. The actual physical damage from vibration is not definitely known at present, since there are various factors to be considered, such as the forms of vibration, the age of the house, structure of the house, the foundation, etc. The investigation of residents' reaction has revealed a notable correlation between the number of complaints about the damage and the corrected acceleration level. When the vibration level exceeds 70 dB, the feeling of damage is expressed but in most cases the damage done is as slight as ill-fitting doors.

TABLE 13.8. *Residents' reaction to vibrations from three different sources*
Source: Experts' Committee Concerning Vibration, Central Council for Control of Environmental Pollution, *Basis of Urgent Guidance Principle on Shinkansen Vibration* ISO-2631, March 1976.

	Slightly sensed			Distinctly sensed		
	30%	40%	50%	30%	40%	50%
Workshop	50dB	55	59	60	65	69
Shinkansen	48	51	54	65	70	75
Road traffic	-	-	50	62	65	69

TABLE 13.9. *Standard values for workshop vibrations*
Source: Experts' Committee Concerning Vibration, Central Council for Control of Environmental Pollution, *Standard Values for Workshop Vibrations and Upper Limit Values of Road Traffic Vibration,* March 1976.

Classes of area	Day	Night
Mainly residential	Above 60 dB up to 65 dB	Above 55 dB up to 60 dB
Commercial and industrial[a]	Above 65 dB up to 70 dB	Above 60 dB up to 65 dB

[a]Where conspicuous vibration must be prevented in order to preserve environment.

TABLE 13.10. *Upper limit values of road traffic vibration*
Source: Experts' Committee Concerning Vibration, Central Council for Control of Environmental Pollution, *Standard Values for Workshop Vibrations and Upper Limit Values of Road Traffic Vibration,* March 1976.

Classes of area	Day	Night
Mainly residential	65 dB	60 dB
Commercial and industrial[a]	70 dB	65 dB

[a]Where conspicuous vibration must be prevented in order to preserve environment.

After all these points were considered, the conclusion was reached that it is desirable to set the ground-surface value below 70 dB for the Shinkansen. For reference, the standard values discussed at the same time for workshops and road traffic are shown in Tables 13.9 and 13.10.

Method of Solution of Shinkansen Environmental Problems

REVIEW OF THE PROBLEMS

The greatest problem is the noise and vibration generated by running trains. The noise level of 90 to 100 phons close to the Shinkansen track cannot be helped, as steel sheels are running on steel rails at the high speed of 200 km/h. This noise is, however, reduced by a sound-barrier wall for viaducts and embankments and by sound-proofing work on steel girders, to slightly over 80 phons at a point 25 meters from the track center.

Vibration caused by a running train is generated by wheels of about 17 tons axle load, run at 200 km/h. This also cannot be helped. The effects of vibration on the surroundings vary widely with the conditions of structures and foundation. When a rigid-frame viaduct is on an ordinary foundation, the level is 70 dB at a point 10 meters from the track center. When a rigid-frame viaduct is on an extremely soft foundation, the level exceeds 75 dB beside the track, and even at a point 50 meters from the track center it sometimes exceeds 70 dB.

Besides the noise and vibration, complaints are made of impairment of TV reception and obstruction of sunlight. But all these environmental "pollutions" are not so serious as to directly injure man's health. They are complained of as annoyances or as adverse effects on living environment. It is desirable to cope with them as such.

Suggested methods of solving the environmental problems associated with the Shinkansen are:

Technical

The best way, undoubtedly, is to abate the noise and vibration at source. The noise, however, comes from many sources; the contacting surface of rail and wheels, the carbody, the contacting surface of contact wire and pantograph and the structures. It is still extremely difficult to reduce the noise to below 80 phons in areas along the Shinkansen. Analysis of the generation of vibration and its propagation mechanism has only just begun. From now on, technical development will have to be expedited to abate noise and lessen vibration. Counter-measure (theoretically) proven effective must be put to practical use.

Economic

So far as the environment problems of the Shinkansen are complaints about annoyance, attempts should not be made to restrain the working of the Shinkansen, for instance by reducing the train speed, even when the standards set cannot be met in a short time by sound-proofing at the sources. However, when the residents along the line desire reconstruction of their houses to alleviate annoyances from noise and vibration, or, in worse cases, move out to a locality less affected, financial aid should be given as occasion demands. This will effectively settle the complaints.

Political

In the long term, it is desirable to move dwelling houses that are easily affected by Shinkansen noise and vibration away from the line and leave the places empty for the location of workshops and warehouses that are less vulnerable, or for green belts, parks and roads which would make life more pleasant. For this, the environmental problems concerning the Shinkansen need to be solved as part of national land development and city planning projects, so that the strips of land along the line could be turned into buffer zones provided with public facilities.

As houses will continue to be built along a newly laid railway line in spite of the effect of passing trains, some legal restrictions are needed to ensure at least that new houses along the line are highly sound-proof and vibration-proof.

14. *Environmental Preservation and the Shinkansen*

T. YORINO

Environmental Problems

Although the Shinkansen was acting splendidly as the main traffic artery of Japan, when it was opened the residents along the line unexpectedly began to complain about the noise and vibration, and the complaints have gained momentum with the rising voice of the public against environmental pollution.

How to keep a balance between the increased convenience the Shinkansen provides and the environmental nuisance it causes is a problem to be solved only in the national context, supported by the intelligent understanding and cooperation of the residents in the affected areas, pointed out in my previous paper in these Proceedings.

Complaints in writing received since the opening of the Shinkansen are as shown in Table 14.1. The subjects of the complaints are diverse, as is shown, but the main complaints are of noise and vibration. These are the two focal points in this paper, the problem is localized to the Tokyo–Shin-Osaka section of the line, where most of the complaints originate.

Environmental Problems and Counter-Measures Considered When the Shinkansen was Planned and Constructed

The environmental problems that the Shinkansen trains would give rise to were carefully deliberated when the line was planned. The growth of the problem to its present scale, however, was quite beyond expectations. At the planning stage, it was considered that complaints about noise and vibration

TABLE 14.1. *Petitions and complaints received annually (Tokyo–Shin-Osaka)*
Source: JNR Shinkansen Administration, *Ten-Year History of the Shinkansen.*

	Year													
Complaint	1964	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	Total
Noise	9	13	16	6	2	2	1	2	3	6	5	12	13	90
Vibration	11	16	19	9	3	5	1	2	5	1	6	9	0	87
Noise and vibration	10	13	7	10	5	3	3	17	8	16	36	41	6	175
Wind pressure	2	4	1	1									2	10
Interference with TV, and others	1	4	4	6	6	1	6	6	1	1	11	10	10	67
Total	33	50	47	32	16	11	11	27	17	24	58	72	31	429

would not be very serious when levels could be reduced to those of the conventional narrow-gauge lines. The target, therefore, was to keep the noise and vibration down to that of the narrow-gauge line trains.

STUDIES ON NOISE AND VIBRATION

Noise and vibration on the narrow-gauge lines have occasionally been measured, on a small scale. After 1960 the noise and vibration was taken as reference for the Shinkansen construction. The following steps were taken:

In September 1960 the noise level was measured of narrow-gauge line trains running at speeds of 100 km/h or less.

In November 1960 tests were conducted with limited express trains running on the narrow-gauge line at high speeds, over 160 km/h. The results of the test were to be used in determining the details needed to design the track, rolling stock, overhead wiring and signalling system for the Shinkansen. A study on noise and vibration was included in these tests. Checks of the noise and vibration on narrow-gauge lines at various places followed.

From 1963 to spring 1964 the noise and vibration caused by trains running at 200 km/h were studied, using part of a line laid for tests to confirm the stability of Shinkansen trains.

Around 1955 tests to confirm the noise-abating effect of side walls set up on a viaduct were conducted.

These tests and experiments revealed two points. First, that although the noise level rises as the speed of the train increases, the growth of noise considerably slackens when the speed is over 120 km/h. Second, even when speed is increased to about 200 km/h, it is possible, by appropriate design of rolling stock, track and structures, to keep down the noise and vibration levels to that of a narrow-gauge line train run at speeds of 100 km/h or less.

MEASURES TAKEN

On the basis of the results of these numerous studies, the following countermeasures were taken. Their effects were ascertained by tests on the model line.

Track. Adoption along the whole line of heavy long-welded rails (53 kg/m, as compared with 50 kg/m for the narrow-gauge lines), movable nose turnout and rail-fastening devices using rubber pads.

Rolling stock. Adoption of light-weight carbody, a new type air-spring bogie, and equipment of carbody skirt.

Structures. Adoption of sidewalls, about 1 meter high, made of concrete blocks, on viaducts in urban areas.

Routes. When planning routes, urban areas were avoided as much as possible. Consequently the extension of tunnels reached a considerable length. Of the 515 km between Tokyo and Shin-Osaka, 13%, or 68 km, consisted of tunnels.

Noise and Vibration after Shinkansen Opening

The noise level of the Shinkansen is shown in Table 14.2, and for comparison, that of conventional narrow-gauge lines is shown in Table 14.3.

The vibration levels of the Shinkansen and conventional narrow-gauge lines are shown in Tables 14.4 and 14.5, which show that there is not much difference in the noise and vibration levels between the Shinkansen and the narrow-gauge lines, as far as physical quantity is concerned. Nevertheless the Shinkansen has given rise to numerous complaints (the reason is explained in Chapter 13).

TABLE 14.2. *Noise levels on the Tokaido Shinkansen*

Source: Technical Committee for Prevention of Shinkansen Noise and Vibration, Committee data.

Structure	Track	Sidewalls	Noise level dB (A) 70 80 90 100
Embankment	With ballast	None	
		1.9 m	
Viaduct	With ballast	None	
		1.9 m	
Steel girder bridge	With ballast	None	
		1.9 m	
	Without ballast	None	
		With soundproof work	

Note: Measurements were taken outdoors 25 m from center of track 1.2 m above the ground.

TABLE 14.3. *Noise levels on conventional narrow-gauge lines*

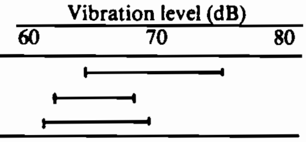
Source: Technical Committee for Prevention of Shinkansen Noise and Vibration, Committee data.

Line	Structure	Track	Side walls	Noise level dBA 70 80 90	Remarks
Tokaido Main Line	Embankment	With ballast	None		Electric railcar 80 km/h
Hankyu Private Railway	Embankment	With ballast	None		Electric railcar 100 km/h
Chuo Line	Viaduct	With ballast	1.1 m		Electric railcar 80 km/h
Joban Line	Viaduct	With ballast	1.4 m		Electric railcar 70 km/h
Subway Tozai Line	Viaduct	With ballast	1.6 m		Electric railcar 80 km/h
Kisei Main Line	Viaduct	Direct fastening	1.0 m		Diesel railcar 60 km/h
Sobu Main Line	Prestressed concrete bridge	Direct fastening	1.0 m		Electric railcar 60 km/h
Kagoshima Main Line	Steel girder bridge	Without ballast			Electric railcar 60 km/h
Hankyu Private Railway	Steel girder bridge	Without ballast			Electric railcar 80 km/h

Note: Measurements were taken outdoors 25 m from center of track 1.0 m above the ground.

TABLE 14.4. *Vibration levels on the Tokaido Shinkansen*
Source: JNR survey.

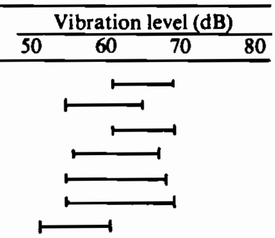
Type of structure	Vibration level (dB) 60–80
Viaduct (rigid frame type)	
Viaduct (beam type)	
Embankment	



Note: Measurements were taken on the ground 25 m from center of track.

TABLE 14.5. *Vibration levels on narrow-gauge lines (measurement by Environment Agency)*

Line	Structure	Vibration level (dB) 50–80
Takasaki		
Chuo		
Tobu Private Railway		
Meitetsu Private Railway	Level ground	
Tokaido Main Line		
Kansai Main Line	Embankment	
Kintetsu Private Railway Nagoya		



Note. Measurements were taken on the ground 25 m from center of track.

Counter-Measures Taken after the Opening

Since the opening of the Shinkansen, JNR had been studying the best methods to satisfy the complaints that began to come in from residents along the line and had sought the advice of theoretical and practical experts. The results of these studies were all successively put into practice.

In the meantime, the public was becoming increasingly concerned about environmental pollution and the Government began to urge JNR to speed up its counter-measures.

GOVERNMENT GUIDANCE

The Government issued the following:

1. Partial modification of regulations on Shinkansen structure (1971, 1977). Provisions for the prevention of noise and vibration were added to the Regulations on the Shinkansen Structure by the Ministry of Transport Ordinance.

2. Recommendations on Urgent Steps for Noise Abatement, by the Director of the Environment Agency (December 1972). For details of this and items (3) and (4), refer to my previous paper (Chapter 13) in these Proceedings.

3. Public Notice on Environmental Quality Standards Concerning Noise (July 1975).

4. Urgent Guidance Principles Recommended on Vibrations by the Director of the Environment Agency (March 1975).

5. Main Points of Counter-measures against Shinkansen Noise (as approved at Cabinet Meeting in March 1976). In this document the national

policy as decided by the Government in accomplishing the environmental quality standards on noise is formulated. The main points are:

Steps to be taken on sound sources

Technical development of every kind must be continued on a well-planned basis and effective use made of their results.

"Nuisance-prevention" on houses

When it is still deemed impossible to accomplish the Environmental Quality Standards during the target period by taking counter-measures on sound sources, "nuisance-prevention" work shall be done on the dwelling houses, schools and hospitals located along the line.

For removing the nuisance, noise-abatement work shall be executed. However, in those zones where the noise level still exceeds 85 phons after counter-measures on sound sources that are reasonable at the time have been taken, the demand for relocation of houses may be complied with when it is found that the noise-abatement work is inadequate.

These stipulations are applicable to those houses and buildings standing on 9 March 1976 along the part of the Shinkansen already in operation and others standing when the Shinkansen now under construction opens its commercial service.

In executing the counter-measures, priority shall be given to dwelling houses in those zones where the noise level exceeds 80 phons. On those schools and hospitals located in zones where the noise level exceeds 70 phons, the work shall be executed as soon as possible.

JNR shall exert its utmost efforts in building up a system of nuisance-prevention for houses. It shall also endeavor to seek the cooperation of the local authorities concerned.

Utilization of land along the Shinkansen

The state and local authorities, in planning for the utilization of land along the Shinkansen and in building public buildings and facilities, shall give due consideration, where possible, to the preservation of the environment along the Shinkansen.

Others

To the zones where the vibration generated by running trains is conspicuous, adequate counter-measures shall be taken in conjunction with the work to be done for noise abatement.

NOISE-PREVENTION COUNTER-MEASURES AT SOUND SOURCES: TECHNICAL DEVELOPMENT

Of the technical achievements on noise abatement accomplished by JNR, the main points are as follows:

Noise sources can be roughly divided into two groups, as shown in Fig. 14.1. The distribution of noise level, as transversely measured on typical viaducts, is shown in Fig. 14.2. The noise level varies from one kind of structure to another. An example is shown in Table 14.2. The duration of the noise peak level when a train runs through is about 7 seconds. Even the duration of its effect is as brief as 10 seconds or thereabouts.

To produce a thorough counter-measure, it is necessary to discover the elements contributing to noise at the sound source and their characteristics. These are summarized in Table 14.6.

Technical development and practical use of achievements

In the initial period of service, the greatest emphasis in the studies of counter-measures was placed on the sound-barrier wall and sound-proofing work on ballastless steel girders. Rolling stock, track, and structures were next in importance. The main results of these studies were as follows.

1. Rolling stock

(a) *Vibration-proof wheels.* Vibration-damping material was applied to the wheels from the sides.

(b) *Resilient wheels.* Vibration-damping material such as rubber was partly inserted in the wheels.

Both these types of wheel diminish noise by 1 to 2 phons where there is no sound-barrier wall. With a sound-barrier wall, there is no apparent effect. The

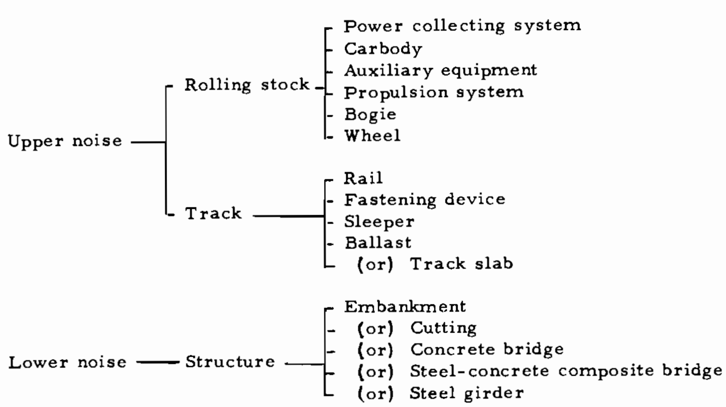


Fig. 14.1. Noise-generating components.

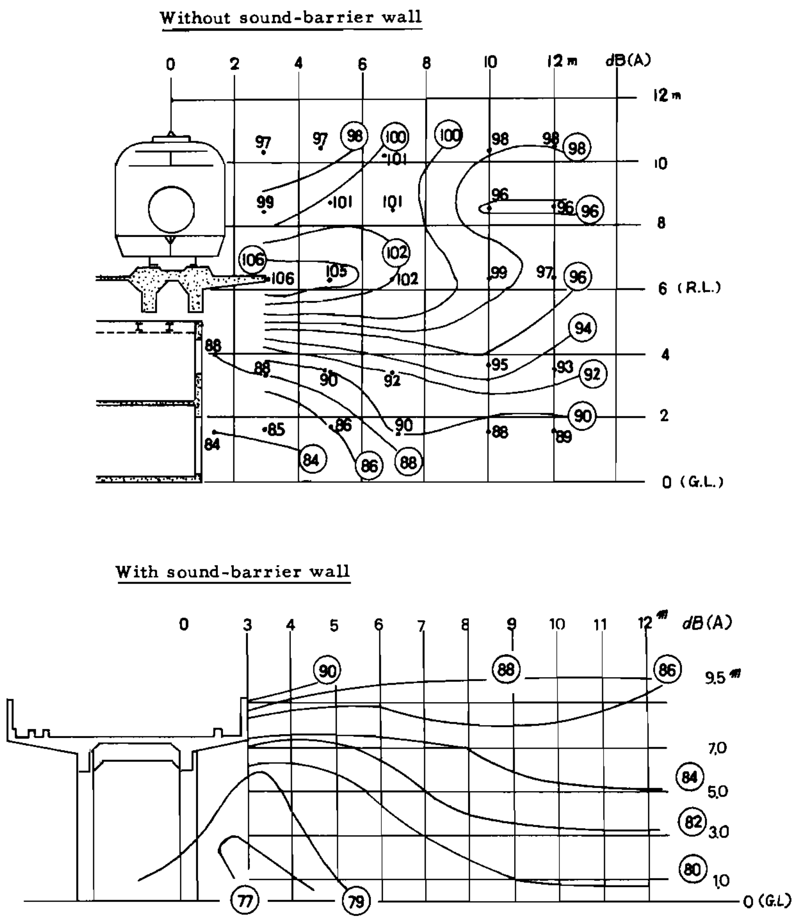


Fig. 14.2. Distribution of noise level around viaduct. Source: Technical Committee for Prevention of Shinkansen Noise and Vibration, Committee data.

resilient wheel, in particular, has some deficiency in strength and requires further improvement.

(c) *Lengthening body skirt on bogie side.* The lower part of the rolling stock sides (body skirt) is lengthened to shut off the noise generated at the contacting part of the rail and wheel. This has some effect when there are no sound-barrier walls. With the walls, however, there is no apparent effect.

(d) *Improvement of pantograph insulator.* The whistling sound caused by the wind hitting the pantograph was eliminated by changing the shape of the insulator, and this was done on all the pantographs.

2. Track

(a) *Non-vibratory rail.* Vibration-damping material was applied on the side surface of the rail. Though there is some diminution of noise, the effect is not felt when the sound-barrier wall is set up. Further improvement is needed.

TABLE 14.6. *Contribution to noise by sound source: counter-measures studied*

	Item	Initial contribution	Counter-measure intended	Essential measures taken and their effectiveness
A	Rail-wheel shock and friction sound	Greatest	1. Difficult to suppress generation, effect of steps taken is small 2. Sound-barrier wall, most effective	1. Vibrations of bogie, wheel and track components damped 2. Effective sound-barrier wall set up Average 86 phons reduced to 80 phons
B	Secondary noise from structures caused by propagation of vibration into solid form	Greatest, next to A, especially great effect on immediate neighbor	1. Suppression of radiating energy by vibration damping 2. Damping by sealing the lower portion	1. Laying mats 2. Noise-proofing work on bridge In case of ballastless steel girder, 10-15 phons reduction
C	Pantograph-trolley line sounds generated by current collecting	Smaller than A and B	1. Difficult to suppress 2. Pantograph and trolley wire to be improved	Improvement of the noise generating mechanism of pantograph and trolley wire under study
D	Aerodynamic noise of carbody	Smaller than A and B	1. Difficult to suppress 2. Improvement from the standpoint of carbody aerodynamics	Improvement under study

(b) *Ballast mats and slab mats.* Rubber mats were inserted between the lower surface of the ballasted track or slab track and the upper surface of the viaduct slab to shut off the downward vibrations. Both methods have considerable effect directly under the viaduct and are now in use. No effect, however, is felt at a point away from the track. Also, it is difficult to place a large number of mats under the track while trains are running.

3. *Structures*

(a) *Ordinary sound-barrier walls.* These are upright concrete walls 10-15 cm wide. Between Tokyo and Shin-Osaka, flexible boards are used owing to restrictions on structural strength and construction. The noise level of trains running on the track near the measuring point varies somewhat depending upon whether the wall is put up on the embankment or on the viaduct. At a height of 1 meter, the wall has a diminution effect of about 5 phons and at 2 meters high, about 7 phons, although the effect on the trains running on the opposite track is rather less. By combining mats and walls, a decrease of nearly 10 phons can be expected. The effect of raising the wall height to more than 2 meters is strong enough to withstand the winds, to say nothing of the "sunshine obstruction" problem this would create.

(b) *Sound-barrier wall with overhang.* This is a roofed upright wall reaching close to the carbody. As compared with the upright wall, this diminishes the noise level by 2 to 3 phons in some places. A wall of this type is erected between Okayama and Hakata, where slab track is mostly laid, though not between Tokyo and Shin-Osaka, where the viaduct is not strong enough. Some of the sound-barrier walls have sound-absorbing material fitted to their inside surface, but the effect of this has not yet been ascertained.

(c) *Sound-barrier wall as close as possible to the train.* The sound-barrier wall could be put up as close to the train as the construction gauge permits. Although this has the same effect as the sound-barrier wall, it is not desirable from the standpoints of safety and maintenance, and it is therefore not used.

(d) *Sound-proofing work on ballastless steel girders.* The secondary noise level due to vibration is high in the case of steel girders. Especially when ballastless, the vibration is directly transmitted to the girder and the noise level goes up, since there is open space under the girder. To check this, sound-insulating material with non-vibratory support to the steel girder from its under-surface is used, and the sound-barrier wall is put up to diminish the noise of wheels and rails. By this method the noise level has been brought down by 15 to 20 phons.

(e) *Bridge hooding.* Here a fulcrum is set on the top of a steel truss, and a sound-barrier hood is hung down. This was tested on certain bridges. The hooding reduces the noise level to about 70 phons. For practical use, however, it has many drawbacks: The hooding obstructs sunshine, spoils scenic beauty and is not desirable from the viewpoints of maintenance work and structural strength.

4. *Most effective results*

The most effective of the counter-measures described above is the high-quality sound-barrier wall. By using mainly this, the noise level previously close to 90 phons has been reduced to an average of 80 phons, excluding ballastless steel girders. The decrease by distance is shown in Fig. 14.3.

5. *Targets for future technical development*

As the result of the studies on the contribution of sound-source components to noise, which were carried out at the same time as the studies described

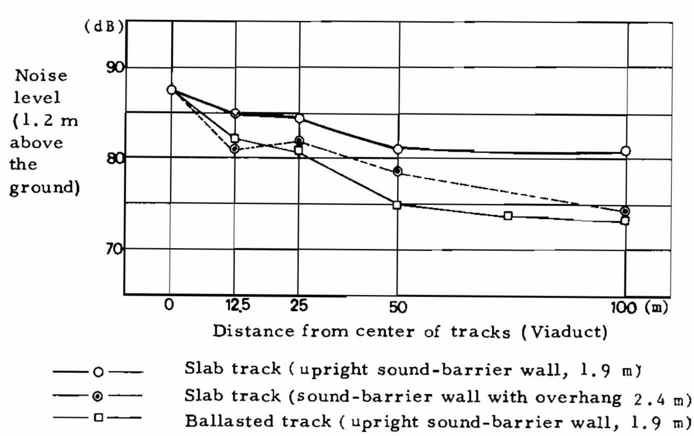


Fig. 14.3. Example of noise diminution by distance.

above, the remarkable level of noise arising between the running parts of the rolling stock and the track components, previously reaching 90 phons, has been reduced to 80 phons. Now that the levels of noise coming from the four main sound-source components, as shown in Fig. 14.4, are almost the same, it appears safe enough to conclude (a) that no better result can be obtained unless the levels of noise from all four components are equally reduced and (b) that an attempt to bring down the level of noise from a single source would not be satisfactory.

The targets for future technical development are: (1) in order to bring down the total noise level, technical developments should be continued for the improvement of all the sound-source components at the same time and the effect of the whole ascertained; (2) as future counter-measures will call for highly complicated technology, emphasis should be placed on the studies of safe operation of trains, durability, and execution of work. For this, experiments and tests will have to be conducted on the Shinkansen that is already in operation. As tests using the Shinkansen which is operated for commercial service are restricted, a part of the Tohoku Shinkansen now under construction will also have to be earmarked as a test line and completed as quickly as possible.

VIBRATION PREVENTION COUNTER-MEASURES AT VIBRATION SOURCES: TECHNICAL DEVELOPMENT

Railway vibration generation and propagation mechanism

In dealing with the vibrations caused by trains (unlike the case of noise) not only the sources but also the means of propagation must be analyzed. The

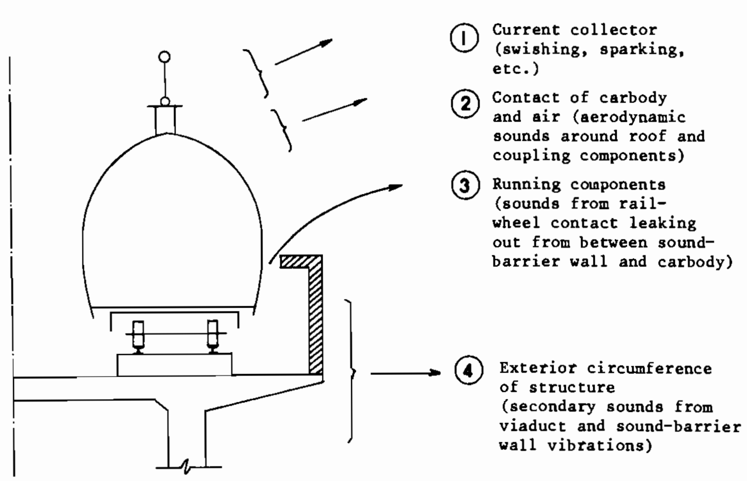


Fig. 14.4. Noise generated by running train. Source: Technical Committee for Prevention of Shinkansen Noise and Vibration, Committee data.

reasons for ground vibrations caused by running trains may be roughly grouped as follows:

(a) load repeated in a certain cycle due to axle arrangement;

(b) loading fluctuation stemming from flat tires, track irregularities, rail joint, and variations in ground condition;

(c) vibrations peculiar to component elements concerned.

The vibrations caused by (a) and (b) are selected and amplified by (c).

The component elements concerned are rolling stock, track, structure foundations, and the ground (see Fig. 14.5). Much is still unknown about the part played by each of these elements.

The mechanism of vibration propagation from track to structure is comparatively easy to trace. Vibration propagation from structure to ground, or that in the ground, however, is complicated and varies according to the kind of structure foundation, the characteristics and structure of the ground.

Characteristic of ground vibrations

Measurements of wave frequency along the Shinkansen viaduct disclosed that 2-3 Hz and 15-25 Hz waves are predominant. The 2-3 Hz waves disappear at a point 10 meters from the viaduct, but the 15-25 Hz waves do not.

Rolling stock	Carbody Bogie Wheel
Track	Rail Rail fastening Sleeper, Ballast (mat) (or) Track slab (mat)
Structure	Embankment (or) Cutting (or) Elevated track on viaduct (or) Concrete bridge (or) Steel-concrete composite girder (or) Steel girder (or) Tunnel
Foundation	Direct foundation (or) Pile foundation (or) Caisson foundation
Ground	Dynamic characteristics of ground Local geological structure
Building	Wooden construction (or) Reinforced concrete construction (or) Steel frame concrete construction (or) Steel frame construction

Fig. 14.5. Factors giving rise to vibrations and their propagation.

Much is now known about the variations in vibration caused by train speed, kind of rolling stock, track, and other structures, as well as the varying geological conditions, but this is too technical a subject for this paper.

Vibration counter-measures

Less is understood about vibrations and their theoretical analysis, particularly their propagation mechanism, than about noise, and no precise way of reducing vibration has yet been found. Counter-measures that have been studied are as follows:

(a) ditches,
(b) increased volume of viaduct foundation,
(c) use of ballast mats,
(d) comparison of rigid-frame viaduct and girder bridge,
(e) comparison of different kinds of viaduct foundation.

Studies on (a), (b), and (c) are not yet complete, and further investigation is still needed.

What has been clearly shown is that the adoption of girder bridges and the driving of rigid piles down to the supporting ground have notable effects on damping vibration.

PROGRESS MADE IN IMPLEMENTING SOUND AND VIBRATION SOURCES COUNTER-MEASURES

Counter-measures against sound sources have been vigorously developed, and some of the most successful are already in use. Particularly effective are the sound-barrier wall sound-proofing work on steel girders, for which 90% and 75%, respectively, of the necessary work has been done.

No effective way of damping vibrations at their sources has been found. The use of heavier rails and ballast mats is assumed to be effective, and the progress made in carrying these out is 40% and 15%, respectively. Ballast mat-laying takes time and manpower, and the rate of progress is therefore not at all satisfactory.

"NUISANCE-PREVENTION" ON HOUSES

Although a wide variety of steps have been taken to diminish noise and vibrations at their sources, it must be admitted that the Environmental Quality Standards (below 70 or 75 phons) and the Recommendations on Vibrations (below 70 dB) are hard to achieve.

In the ordinary sections of embankment and viaduct of the Tokaido Shinkansen, the noise level has been reduced to 80 phons on average (at the standard point of 25 meters from the center of track) but many 80–82-phon sections remain. The area where the level is said to exceed 80 phons is assumed to lie within 30 meters from the track center in the case of a viaduct and 20 meters in the case of an embankment. Around the ballastless steel girder the noise level is kept to 86–87 phons.

Vibrations differ widely from one type of ground to another. On average, however, the vibrations are assumed to exceed the level of 70 dB along viaduct sections in alluvial deposit areas, within 25 meters of the track center, and, in diluvial deposit areas, within 10 meters of the track center. In an alluvial deposit tract, the area subject to over 70 dB lies within 10 meters of the track center along the embankment sections. In these cases, the steps to be taken on the dwelling houses located along the line are indicated by the Noise Quality Standards and the Recommendations on Vibrations (this is what is meant by "nuisance-prevention" on houses).

Noise-abatement work on houses

In the Urgent Recommendations on Noise of December 1972, by the Director of the Environment Agency, execution of nuisance-prevention on houses is demanded on dwelling houses in those districts where the noise level over 85 phons persists even after the counter-measures against noise at sound sources have been enforced, as in the environs of ballastless steel girders. On receipt of the Recommendations, JNR in April 1973 entrusted the Japan Railway Engineering Association (JREA) with the study on the method of executing noise-abatement work applicable to dwelling houses. In the spring of 1974 JREA, with cooperation from the Railway Architecture Association, produced a method that would almost serve the purpose. The study was as follows:

1. Investigation of the actual state of noise in buildings located along the Shinkansen.
2. Experiments on reconstruction of existing buildings.
3. Experiments with the method on test houses.

Vibration-damping work on houses

The amount and characteristics of vibration on houses vary considerably according to the ground on which the houses are built. Houses are of diverse structure, which makes it difficult to find the right method of vibration-damping on houses. Moreover, as little time was allowed for the development of the method, the result is not entirely satisfactory, and further improvements are essential.

Execution of nuisance-prevention on houses

In line with the Urgent Recommendation, methods of noise-abatement work on dwelling houses were first studied. Then, in conjunction with work on counter-measures for sound sources, the procedure for the execution of work on houses located in zones where the noise level was over 85 phons was decided on, and the work was executed in June 1974. Later, however, the Environmental Quality Standards on Noise and the Recommendations on Vibration were successively issued. A new procedure for nuisance prevention for houses was decided on and the work began in December 1976.

The procedure called for work on houses in those zones where the noise level reached over 80 phons, as stipulated in the Standards, and where the vibration level was over 70 dB, as prescribed in the Recommendations. The main points of the procedure were:

1. Eligible buildings and houses

(a) Buildings and houses existing on 9 March 1976 (for buildings and houses located along the Tohoku Shinkansen at present under construction, those existing on the day the section is opened for commercial service).

(b) Dwelling houses located in zones where the noise level is over 80 phons, and school and hospital buildings in zones where the noise level exceeds 70 phons.

(c) Dwelling houses and school and hospital buildings in zones where the level of vibration exceeds 70 dB.

2. Work to be executed

(a) Noise-abatement and vibration-damping work, in principle. When circumstances compel, relocation work is executed.

(b) Noise-abatement work on dwelling houses is divided into two categories, depending upon the noise level, and that on school and hospital buildings into four.

(c) The number of rooms of a dwelling house on which the noise-abatement work is to be executed depends upon the size of the family, but is limited to four at most.

(d) The vibration-damping work is executed in the manner described for the noise-abatement work.

3. Method of executing work

(a) Work is executed by the owner, and JNR grants financial aid up to the limits calculated according to the standards it has set.

(b) Administration for financial aid may be entrusted to the local authorities concerned.

Execution of nuisance-prevention work: setup and progress

The present number of buildings and houses on which nuisance-prevention work is to be done located along the Shinkansen between Tokyo and Hakata to which the work rules are applicable is estimated at 18,000 (where the noise level is over 80 phons). Although the work has to be accomplished within the target period of 3 years set by the Environmental Quality Standards, this is extremely difficult since the number of buildings to work on is so large.

For execution of the work, the Track and Structures Department was in charge at the Head Office, and the Environment Control Section of the Shinkansen Administration was in charge as the local organ. However, as the issue of the Environment Quality Standards on Noise and the Recommendations on Vibration expanded the area of work, an Environmental Preservation Department was set up in the Head Office in April 1976 to specialize in the administration, while branch offices of the Environmental Control Section, Shinkansen administration, were newly set up for all local blocks. The Construction Divisions, which are in charge of large-scale construction and improvements, are also doing part of the work. The setup is shown in Fig. 14.6.

However, as the administrative capacity of JNR itself is still inadequate, it is planned to entrust a considerable part of the execution of the noise-abatement work on dwelling houses and school and hospital buildings in the areas of 80-85 phons wherever possible to the local authorities concerned.

OTHER ENVIRONMENTAL PROBLEMS

So far, mainly noise-abatement and vibration damping have been dealt with. There are, however, other environmental problems concerning the Shinkansen:

Interference with television reception

The opening of the Shinkansen gave rise to complaints about interference with TV reception. Based therefore on the investigation made by the NHK (Nihon Hoso Kyokai-Japan Broadcasting Corporation), JNR in cooperation with NHK executed improvements in some 9000 households during 1965 to 1966. The same complaint has been received in great numbers since about

Head Office	Local organs
Environmental Preservation Dept.	Shinkansen Administration — Environment Pollution Countermeasure Sec. — Branch Offices
	Construction Div. — Shinkansen Environment Pollution Countermeasure Sec.
	Building Construction Div. — Shinkansen Environment Pollution Countermeasure Sec.

Fig. 14.6. Setup for nuisance-prevention work on houses.

1970. This is presumably because the frequency of trains has increased, color televisions sets have become popular, and the public's awareness of its rights has increased, and so, new complaints began to come in from districts where no such trouble had occurred before. JNR therefore enlarged the areas for improvement work in1972 and it is intended that all complaints will be dealt with in the near future. The households whose television reception is to be improved number as many as 150,000.

Noise generated during track maintenance work

As no intervals are available for track maintenance during the day, maintenance work is done at night. Initially, an engine generator was used as the motive power source in maintenance works. To lessen its noise low-voltage power-distribution circuits were set up for an electric generator. Efforts were also made to decrease the noise of multiple tie-tampers and other track maintenance machines. Some of the noise-proof contrivances developed are already in use, and with great success.

Sanyo, Tohoku, and Joetsu Shinkansen Lines

The Sanyo Shinkansen was opened between Shin-Osaka and Okayama in March 1972 and between Okayama and Hakata in March 1975. In the construction of this Shinkansen, experience gained from the Tokyo–Shin-Osaka Section (the Tokaido Shinkansen) was exploited. Since many newer technical developments were used on the Sanyo line, considerable improvement is noted over the Tokyo–Shin-Osaka Section in the noise and vibration levels. Noise, for instance, is below 80 phons along almost the whole line. Places where vibrations exceed 80 dB are extremely few. The items improved are:

Track. 60 kg/m rails are laid along the whole line

Structures. No ballastless steel girders have been used; heavier-weight structures have been constructed; upright or sound-barrier walls with overhang have been set up; foundation structures have been strengthened.

Others. Sidewalls and streets have been provided, in cooperation with local authorities.

The Tohoku Shinkansen (Tokyo–Morioka) and the Joetsu Shinkansen (Tokyo–Niigata) are under construction. In these, not only will the recent new technical achievements be introduced, but also the results of experiments to be conducted using a partially completed section of the Tohoku Shinkansen as the test line. Further improvement is thus expected.

Technical Development Setup

Well aware of the importance of environmental preservation, JNR is continuing its research, studies and development to that end. The organs engaged in technical development are listed in Table 14.7.

TABLE 14.7. *Setup for technical development*

	Item	Principal organs	Organs concerned
Policy	Basic policy	Technical Committee for Prevention of Shinkansen Noise and Vibration	Departments concerned
	Drawing up of basic policy	Environmental Preservation Dept. Technical Development Dept.	
	Introduction of new techniques	Railway Technical Research Institute Departments concerned Technical Committee	Technical Development Dept. Rolling Stock Design Office Structure Design Office
	Basic studies	Railway Technical Research Institute	
	Plan deliberation	Railway Technical Research Institute Technical Development Dept. Departments concerned	
Planning	Design and study	Rolling Stock Design Office Structure Design Office Construction Div.	Departments concerned
	Deliberation of plans drawn up	Departments concerned Technical Development Dept.	Railway Technical Research Institute Shinkansen Administration Construction Div. Departments concerned
Execution	Experiment	Shinkansen Administration Construction Div. Railway Technical Research Institute	
	Study on the outcome of experiments	Railway Technical Research Institute Departments concerned	
Overall adjustment	Overall adjustment of all plans	Technical Development Dept. Environmental Preservation Dept.	

The Railway Technical Research Institute is engaged in basic studies. Its internal setup, which has recently been strengthened, is shown in Fig. 14.7.

In the study of railway noise the subjects are diverse: rolling stock, track, structures, electric apparatus, and basic theories. A laboratory has been set up for each subject. Now that the level of noise generated by each component has become about the same, the study has reached the stage where improvements of all the components must be effected at the same time. Hence all the noise specialists have been gathered together from the laboratories into a Noise Analysis Project Research Laboratory.

Past and present technical committees deliberating on the course of technical development since the Shinkansen opening are the following:

RAILWAY TECHNICAL RESEARCH INSTITUTE,
DIRECTOR
DEPUTY DIRECTORS

- TRACK LAB
- TRACK MATERIALS LAB
- STRUCTURES LAB
- ARCHITECTURE LAB
- SOIL MECHANICS LAB
- GEOLOGY LAB
- DISASTER PREVENTION LAB
- TROLLEY LAB
- ROLLING STOCK STRUCTURE LAB
- ROLLING STOCK DYNAMICS LAB
- PHYSICS LAB
- NOISE ANALYSIS PROJECT LAB

Fig. 14.7. Railway Technical Research Institute organization chart (for noise and vibration).

1. Noise Study Group (1965 to 1969).
2. The Noise and Vibration Sub-Committee of the Shinkansen Construction Committee (1971-1972) was set up to consider the standards for construction of new Shinkansen lines.
3. Technical Committee for Prevention of Shinkansen Noise and Vibration (1972 to the present).

The first two committees consisted of JNR experts only. When the basic studies had been completed and the course of technical development set, the second committee was reorganized to form the Technical Committee for Prevention of Shinkansen Noise and Vibration, including outside experts, so that wider knowledge could be gained.

Future Targets

So much for the present state of environmental problems involving the Shinkansen and the steps taken to overcome them. The basic policy in dealing with these problems, past and future, may be summarized as follows:

1. To combine technical development with the aim of diminishing noise and vibration levels at their sources and to strive for the prevention of noise and vibration propagation.

Comment. If the lower limit of noise is to be kept down to 80 phons or thereabouts at the sound sources, as at present, it will certainly be difficult to attain the standard of 75 or 70 phons; and the reasonableness of this standard value is itself questionable. The zones where the noise level reaches 75 phons extend 75 meters each side of the track center (or 150 meters in the case of 70 phons) and the number of houses located within these zones is staggering, calling for huge amounts of money to execute the nuisance-prevention for houses on them all. A problem of national proportions will arise: that of making the most effective use of land in such a small and densely populated country as Japan.

2. To try to secure as much space as possible between the track and the houses.

Comment. This has to be considered when locating the route. By the nature of the primary mission of a railway, it is unavoidable that a railway line should run into existing built-up areas, at least near the stations, but apart from this, the environment should never be polluted. Hence, in selecting a route, its effect on the environment must be considered to the fullest extent along with the economic aspects.

In order to attract to places along the line such public establishments as streets, parks and green-belt zones that can act as buffers against environmental pollution, close cooperation with local authorities' planning is needed when coordinating JNR's plans.

If it becomes necessary, regulations to restrict the location of houses and buildings along the route must be considered. Since the Shinkansen commenced service, many houses were built even when the residents were well aware of the adverse effect of noise and vibration from trains. This may be thought very strange, but it does show that evaluation of the effect produced by the Shinkansen varies from person to person. However, if things are left as they are, there will certainly be more trouble in the future. It is my personal opinion that some regulations should be imposed which would ban the building of houses along the line or compel the owners to sound-proof their houses at their own expense.

3. To deal with the residents' complaints as promptly as possible.

Comment. Residents' complaints must never be treated with unnecessary suspicion. Residents must not be suspected of using complaints as a means to foment social unrest, a means of self-advertisement or of obtaining compensation money. Complaints must be dealt with; they must be listened to, investigated, and the situation rectified. Since there are many difficulties and restrictions it has been customary to avoid listening to complaints or to delay answering them properly. This has often fostered mistrust of JNR.

Blindly fulfilling the wishes of complainers will never do, either. They must be shown the basic policy and reasonable counter-measures and their understanding must be asked for. This is the duty of those engaged in operating public services.

15. *The Shinkansen as an Environmental Component of Japan*

H. UZAWA

I should like to congratulate Mr. Yorino on his excellent survey of the environmental problems of Japan in general and of the Shinkansen in particular. I would especially like to point out the impartial nature of his analysis and the accuracy of his assessments of the social and political implications of such a large public enterprise as the Shinkansen project. This is very difficult for one who is himself a party to this highly sensitive and potentially explosive dispute.

Since Mr. Yorino's papers deal with the problems of the environmental impacts of the Shinkansen so extensively and exhaustively, I do not think I have much to add to his analysis, either in the form of comments or as a critical appraisal. Instead, I would like to present an alternative approach to this highly complicated and delicate problem: namely, to regard the Shinkansen as one component of the "environment" in Japan, and to try to indicate a number of implications that can be obtained from such an analysis.

In his concluding section, on political aspects, Mr. Yorino notes that the environmental problems of the Shinkansen cannot be analysed independently of its relationship with the broader class of social and natural environments, such as urban infrastructures in general and housing environments in particular. I should like to take up this remark as a key to the following general problem.

The Shinkansen may be regarded as a component of the overall "environment" which forms the basic infrastructure of Japanese society and plays a fundamental role not only in the economic processes of resource allocation but also in shaping the cultural and social characteristics of the way people live in Japan. The environment in the broadest sense, as used here, includes all natural, social, and physical infrastructures underlying Japanese society; perhaps it is better to define it as social overhead capital, to borrow from the terminology commonly used in economic theory. Social overhead capital in economic theory is defined as all those scarce resources which are not to be appropriated to private individuals or institutions, either for technical or social reasons, but are to be owned and managed jointly by "society" as a whole. Social overhead capital thus comprises natural capital such as rivers, oceans, forests, and social capital such as roads, harbors, and urban infrastructures such as education, medical, and transportation capital. The Shinkansen, or the public transportation system in general, is a vital component of the framework of such social overhead capital, exerting a profound and permanent effect upon the mode of life and cultural pattern in Japan.

We have seen that the Shinkansen has already changed the methods of communication and travel between various cities; not only between the large urban centers directly involved, but also between many cities in the surrounding areas, and the pattern of urban development of Shinkansen cities has been markedly different from those observed for cities with only conventional railway stations. This is also shown in Mr. Okabe's paper on "Impact of the Sanyo Shinkansen on Local Communities".

The Shinkansen has made certain significant changes in the pattern of personal movements between major cities involved, resulting in significant increases in the amount of travel for business and personal reasons and for tourism.

The papers presented at this Conference have all eulogized the merits of the Shinkansen and the efficiency, safety, and modernity of its operation in the last 13 years. I do not want to dispute the main theme of their opinions, but, if we look at the Shinkansen as one component of social overhead capital in general in Japanese society and compare its function with other social and cultural components of social overhead capital, we would have an entirely different picture. We would be particularly struck by the extreme imbalance which exists in the various components of Japanese overhead capital, and this imbalance has accelerated during the period of rapid economic growth in the last two decades. The Shinkansen is one of the most glaring cases observed. That is to say, while the social overhead capital for the urban infrastructure, such as sewage systems, housing environments, medical and educational systems, was, from the start, extremely poorly endowed there have been no significant attempts in the last two decades to allocate scarce resources and human efforts to the increase and enrichment of such social overhead capital.

Another vital component of social overhead capital has also not fared well, as is suggested by the significant number of pollution diseases and the large number of environmental disruptions in the period of rapid economic growth. I do not have enough time to dwell upon the details of these phenomena, which will be discussed in another paper at the International Energy Agency World Congress, Tokyo, August 1977. I will only argue that the relative scarcity of this social overhead capital has been intensified in the last few years, and is approaching a point where a complete reassessment of the rationale of all the development policies in Japan should be considered. My opinion is that this is one of the most urgent and critical questions facing us in Japan.

16. *Environmental Problems**

N. SAKASHITA

I almost fully agree with Professor Uzawa when he points out that there is a large imbalance between the social overhead capital, mainly relating to industrial activities like Shinkansen, and that relating to the daily life of the people. However, Professor Uzawa did not mention the fundamental cause of the imbalance. Although I am sure he has a definite idea about it, I would like to discuss this problem because I believe the imbalance is not an accident.

What is the cause of the imbalance? Is it a fault of the capitalist system in general? Perhaps yes. However, the imbalance in Japan is much worse than in other capitalist societies in Western Europe or North America. I think a major reason is the overconcentration of public administration, political power, information and cultural activity in Tokyo, a single metropolitan capital in Japan. I have to go to Tokyo so frequently (150 times in the last 5 years!) in order to obtain scientific information, particularly in the form of "fresh" data, because it is not easy to obtain such material quickly, even in Osaka.

Nowadays, almost everything is concentrated on Tokyo, especially the great power of the central authorities in the form of "administrative guidance" *(gyosei shido)* on private economic and social activities. Accessibility to Tokyo is indispensable for the survival of local communities. People in the Aomori Prefecture, for example, are eagerly awaiting "their Shinkansen" in order to obtain better access to Tokyo, not in order to go to Sendai which is nearby.

If the administrative power in Japan is considerably decentralized, people in local communities may not wish to have another Shinkansen and may concentrate their efforts on improving their daily home-life. In this sense, my conjecture is as follows: the only effective way to restore a balance between the industrial infrastructure and the infrastructure of social life is to introduce federalism into the public administration of Japan, and to diversify the administrative power among local governments to the limit. Only by such a policy can the local communities of Japan regain their own social characteristics. When this is accomplished, the need for a giant network of Shinkansen or expressways would become much weaker and public capital can take other directions which would bring about the improvement of social and private life in local communities.

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*Comment on H. Uzawa, *The Shinkansen as an Environmental Component of Japan,* Chapter 15 in these Proceedings.

17. *Application of an Environmental Framework for the Study of the Shinkansen*

S. IKEDA and D. FISCHER

In this section dealing with the environment, we have had two papers by Mr. Yorino of JNR, and some very interesting comments by Professor Usawa of the University of Tokyo. These presentations have brought out important points of environmental considerations associated with high-speed mass transportation systems.

Mr. Yorino opened with a description of the general environmental protection situation in Japan and some background material on the environmental problems associated with the Shinkansen system. The main environmental problems are those of noise and vibration, and additional comments were made on the efforts of JNR and the Japanese Government to solve these technically and economically difficult problems. The policies designed to deal with the lowering of noise and vibration levels were then explained in terms of environmental standards and administrative guidelines along with possible future directions involved in seeking solutions for Shinkansen noise and vibration difficulties.

To facilitate the discussion, I would like to present some applications of a framework for studying the environmental management system, and show how we can apply this approach to the Shinkansen. Professor Fischer, in his introduction to this session, briefly explained the analytical framework we have used in the case studies of the Bratsk-Ilimsk Territorial Production Complex and the North Sea petroleum development program. This conference and the subsequent field study will aid us in collecting Japanese experience in creating and integrating the management of Shinkansen impacts. For this purpose, our approach to the Shinkansen will include the concepts of integration and comprehensiveness both in a retrospective and a prospective mode.

High-speed mass transportation can bring great benefits to passengers and to the regional economic systems in which they operate, provided that they offer rapid accessibility, reliable service, a high degree of safety, and are coupled with low operating expenses and relative energy efficiency. Noise has always accompanied such transportation means. In the past the attitude of people towards noise was reconciled with the social and economic constraints of their time. It has become evident, however, that along with the rapid growth of individual travel and the expansion of transportation facilities which are

TABLE 17.1. *Estimation of possible damage in OECD countries (European part)*

	Land use (km^2)	Noise (population)	Air pollution	Visual incompatibility	Ecological effect
Road	1260	4.4×10^6 65 dB L_{10}	13×10^6 tons/yr 0.8×10^6 tons/yr hydrocarbons	4300 km (9%)	No quantitative measure
Railway	680	1.3×10^6 67 dB CNEL	Indirect (electro-power)	4800 km (11%)	Main issues: Destruction of balance for flora and fauna Pollution from tourism
Airport	700	4.9 to 9.0×10^6 >67 dB CNEL	Indirect (access traffic)		
	0.1% of total 2.6×10^6	2% for road 0.6% for rail 2.5% for air		Visible to adjacent housing	

able to carry huge volumes of traffic, the industrialized nations of the world are experiencing a turning-point in terms of environmental quality. The deterioration of environmental quality is especially evident in noise and vibration levels, in air and water qualities, and in levels of amenities. In addition, in most of the industrialized countries, there has been very little incentive and few mechanisms to reduce noise and vibration. In this context, IIASA has great interest in the new Japanese experience of environmental policy and management applied to the future.

Generally speaking, we can divide the environmental elements associated with an interregional or intercity transportation system into six categories:

1. *Land absorption* — the transformation of land areas from traditional uses to transportation infrastructures, including such items as railways, roads, stations and parking lots.
2. *Noise and vibration.*
3. *Air pollution* — the result of road traffic, but indirectly affected by railroads and airlines.
4. *Visual incompatibility* — the loss of amenity of the inconvenience, direct or indirect, of being deprived of places or landmarks formerly used to obtain such amenities.
5. *Ecological change* — the construction or operation of a transportation system which results in damage to the natural ecosystem balance.
6. *Incidental effects* — the items of pollution caused by an unexpected increase in tourism, motorway congestion, and infrastructure changes.

An example of this type of evaluation of an interregional transportation system is shown in Table 17.1. This study was done by OECD and covers the European part of the OECD countries.* Estimation of possible damages is shown in this figure under the categories of land absorption, noise levels

*Personal communication with Steering Committee on European Intercity Requirements, OECD, Paris, 1976.

according to population, air pollution, visual incompatibility and ecological changes. These categories are distributed according to roads, railroads, and airlines. The total population subjected to traffic noise can be deduced as approximately 2% for roads, 0.6% for railroads, and 2.5% for air traffic. Visual incompatibility in this figure refers to the visible distances of roads and railways from adjacent housing. At present there is no definitive measure for ecological damage. The main question is how data of this type should be taken into account for the development of a system of environmental management.

Figure 17.1 illustrates the changes in public opinion concerning industrial development as opposed to accompanying pollution.

Figure 17.2 illustrates public reaction to the question of sharing noise-control costs. It shows that more than 60% of those asked about the Shinkansen and 80% of those asked about the automobile with regard to sharing noise-control costs were of the opinion that they should be entirely or partly charged to users. This change of people attitudes, together with the international movements for environmental protection, has caused great pressure on the Government to endorse some type of environmental program.

Returning to the environmental management problems of the Shinkansen system, Fig. 17.3 depicts the interconnections of the major environmental issues and shows the impacts on the environment of a Shinkansen development program. Some impacts occur at the national levels and others at the local level. The number of people subjected to noise and vibration is extremely small

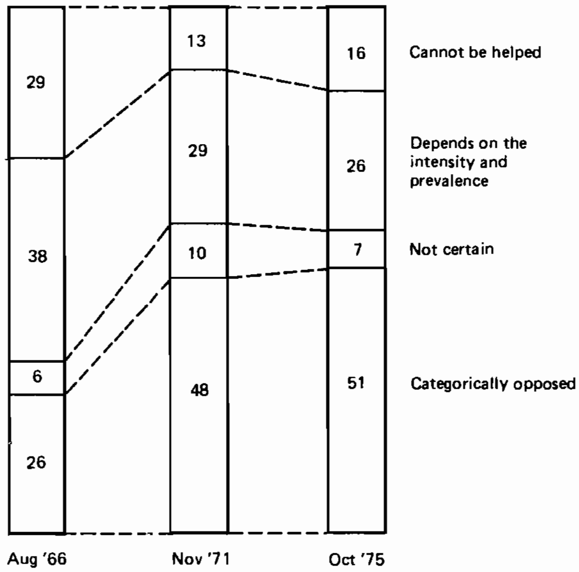


Fig. 17.1. Attitude of the public towards industrial development and pollution. Categories are answers to the following question: Must environmental pollution be tolerated to a certain extent for a nation's industrial development or are you categorically opposed to any form of environmental pollution? Source: Prime Minister's Office Opinion Poll, Japan.

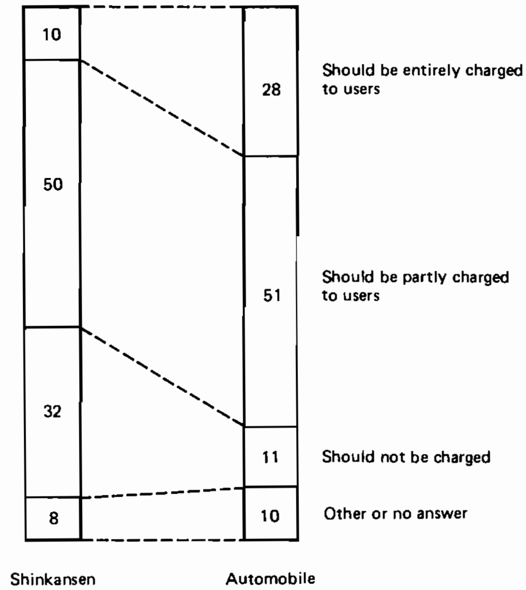


Fig. 17.2. Public reaction to sharing noise-control costs. Source: Environment Agency survey, Dec. 1974.

in relation to the number of users of the transportation system. In addition, the environmental damage, such as changes in landscape and ecosystems, may also be small. Nevertheless it appears that we are facing a conflict between the derived benefits for the community in general on one side, and the suffering minority and environmental preservation on the other side. Indeed, the larger the scale of development and the more concentrated and complex the project, the larger are the environmental changes which ensue, even after taking into account the wide range of economic benefits. This is why one of the major aspects of our studies dealing with large-scale development programs is concerned with studying the integration of environmental factors into the development system.

Table 17.2 and Fig. 17.4 depict the approach presented by D. Fischer as applied to the Shinkansen environmental management system. Table 17.2 shows a comparison of the development-environment system which leads to a classification of the environmental program into five basic activities necessary for a response to the possible impacts: research, planning, regulation, monitoring, and communication. According to their roles in environmental management, we can then determine the detailed elements that should be taken into account.

Figure 17.4 shows the elements of an environmental protection program for a transportation system.

Table 17.3 sums up JNR's development choices, indicating possible environmental issues and JNR's response to them. For example, the choice of separate line, high-speed, elevated track, and increase of transportation

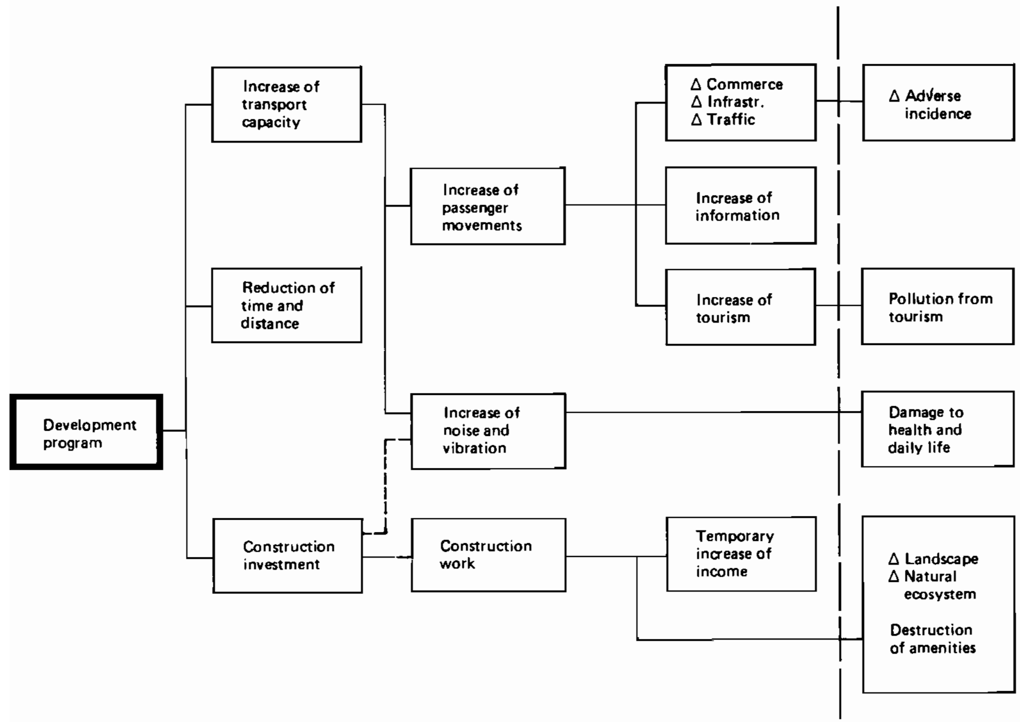
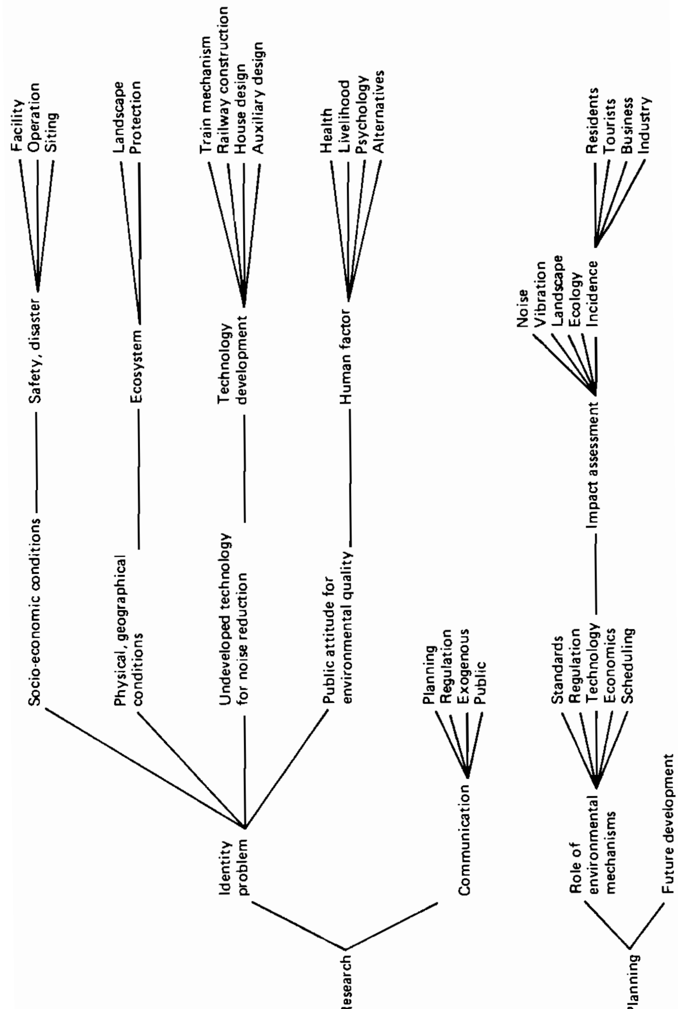


Fig. 17.3. Shinkansen environmental issues.


Research
Identity problem
Communication
Socio-economic conditions
Physical, geographical conditions
Undeveloped technology for noise reduction
Public attitude for environmental quality
Safety, disaster
Ecosystem
Technology development
Human factor
Facility
Operation
Siting
Landscape
Protection
Train mechanism
Railway construction
House design
Auxiliary design
Health
Livelihood
Psychology
Alternatives
Planning
Regulation
Exogenous
Public
Planning
Role of environmental mechanisms
Future development
Standards
Regulation
Technology
Economics
Scheduling
Impact assessment
Noise
Vibration
Landscape
Ecology
Incidence
Residents
Tourists
Business
Industry

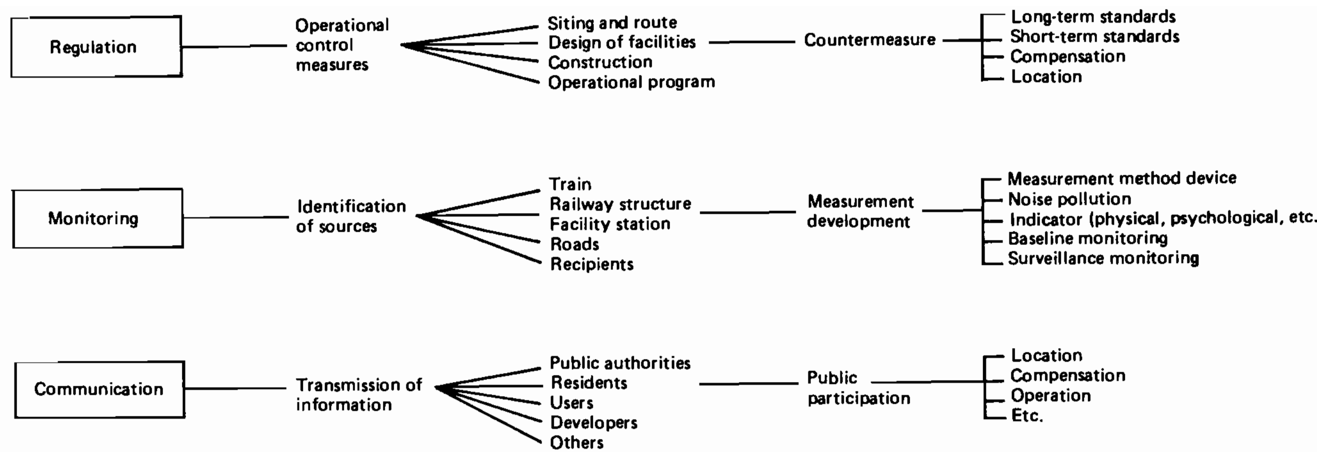


Fig. 17.4. Elements of an environmental protection program for a transportation system.

TABLE 17.2. *Development of environment program*

Elements	Role	Special features
Research	Identify problems, provide research design, do analysis and synthesis	*High density of population in urban areas *Narrow flat area *Housing condition *Disasters (typhoons, earthquakes)
Planning	Create goals, assess and mitigate short- and long-term impacts, propose alternatives	*No formal EIA procedure in 1960s *Strong demand for transportation
Regulation	Control construction operation	*Development-oriented systems
Monitoring	Identify origin of impacts, measure their effect and induced changes, provide data	*No standard measuring methods for psychological health effects
Communication	Transmit basic information to developers, users, public	*Citizens movement against pollution *Change of public attitude to environmental quality

TABLE 17.3. *Development choices of the JNR*

Development	Environmental issues	JNR responses	Environmental responses
Separate rail line	ΔIncidence	Avoid already congested area	Impact assessment, alternatives, public participation
High speed	High noise and vibration	Technology at source, compensate, relocate, sound-proof house	Standards, monitoring, buffer zones, speed-down
Elevated track	High noise and vibration, loss of sun	Technology at source, compensate, relocate, sound-proof house	Standards, monitoring, buffer zones
Frequent trains	High noise and vibration, all day	Time limits	Public participation, bans
Power source	ΔType and location of pollution	Not JNR problem	Impact assessment, alternatives
Control system	ΔPassenger flows	Increase safety automatic devices	Impact assessment, standards monitoring contingency plans
Rapid construction	ΔLandscape, Δplans, Δplans of residents	Condemn properties	Impact assessment, public participation
Night maintenance	Continuous noise	ΔJob technology	Standards, monitoring, public participation, bans
Extension of system	Incidence, Δlandscape	New lines, advance plans	Impact assessment, public participation, standards
Induced development	ΔIncidence, Δlandscape, commerce, traffic	New stations	Compensation in kind, impact assessment, public participation

capacity may result in specific environmental issues, i.e. increased noise and vibration. JNR's response to these environmental issues is avoidance of congested areas, technology development at source, sound-proof facilities, compensation, etc. The last column gives possible environmental responses which we would like to assess in the forthcoming field study.

The major questions associated with the environmental management of the Shinkansen can be summarized as follows:

How has the environment been perceived by all those impacted upon — either negatively or positively?

How have these perceptions been implemented into the environmental management systems?

What have been the actual responses of developers, public authorities, users, and residents?

How well have the environment and development responses worked in practice?

Are these responses comprehensive and are they well integrated into the Shinkansen development program?

18. *Discussion*

The discussion session that followed the presentations covered three main areas:

1. Possible solutions for those who are adversely affected by the development of large projects, and the determination of compromises among competing objectives.
2. Problems of noise generation and its control.
3. Environmental costs associated with noise suppression.

The presentation by H. Uzawa extended the idea of "environment"to include the socio-economic environment of Japan, and raised questions concerning the distribution of social overhead capital. This question of distribution of social capital was also raised in the section dealing with implications of national development in Japan, but no definite conclusions were reached on the priority to be allocated to projects on a national basis. The discussion that followed Uzawa's presentation was keynoted by an informal presentation from N. Sakashita. He explained what he believes to be the fundamental cause of the imbalance of social overhead capital in Japan. The text of his comments is included as an appendix to this discussion session.

Main Discussion Themes

1. The first main discussion theme dealt with the determination of compromises among competing objectives — specifically environmental objectives versus development objectives.

(a) It was commented that one can approach the problem of environment versus development by not treating them as separate entities but combining them in a new approach to environmental management, based on the thesis presented by D. Fischer in his presentation. A possible application of a new environmental management approach was also presented by S. Ikeda and D. Fischer and applied to the Shinkansen. The discussion centered on the type of approach that JNR could attempt in dealing with the environmental problems of the Shinkansen.

(b) It was stated that JNR took a radical approach to development when a totally new and untried system of ground transportation was chosen for the Shinkansen lines, and that the same spirit could perhaps be applied to the environmental problems associated with the Shinkansen.

(c) Several suggestions were raised concerning the type of response: a more equitable distribution of the revenues derived from Shinkansen — reserving part of the ticket price for environmental engineering and environmental solutions, compensation benefits for people adversely affected by the Shinkansen, etc.

(d) It was also pointed out that even with the introduction of new types of ground transportation systems such as the magnetic levitation process, new environmental problems may appear. High-speed transportation must be concerned not only with reliability and efficiency, but also with the interests of people who would not use such a system even if it were available. It is imperative to examine both environmental and developmental aspects of programs from the very beginning of the planning and formulation process — a comprehensive and integrated approach towards the environment–development interface.

2. The second theme of the discussion dealt with the problems of noise generation and environmental costs.

(a) The question was asked as to whether the use of 25-kV AC, semiconductor rectifiers, and perhaps the auxiliary motors for high-speed operation could induce large amounts of electromagnetic interference. The reply was that there was indeed some interference, but in the case of the Shinkansen this is almost exclusively limited to television reception. Interference with other types of communication has been effectively eliminated through the use of booster transformers and the autotransformer.

(b) An additional question was asked about the noise generated from maintenance activities, since maintenance on the Shinkansen lines is undertaken at night, when the trains are not running. In the Federal Republic of Germany, for example, the sound barriers along the tracks are 3 meters from the center of the track. The German experience is that the sound walls are too close to be effective, and they cause a wide distribution of the sound. On the Shinkansen lines, mechanical maintenance noise generation has been reduced through the use of electric motors for the maintenance vehicles and covers placed over tie-tampers. The Shinkansen noise barriers along the track have also proved less effective than desired, and tests are therefore being conducted on the use of overhead sound-depressing structures.

(c) The discussion on noise-absorbing structures led to a series of questions dealing with attempts to limit noise generation at the source, the contact of rail to wheel. The general conclusion reached was that in spite of the considerable scientific and engineering research being done at the Railway Technical Research Institute in Japan and in research institutes the world over, the results have proved unsatisfactory since there are too many unknown characteristics. It was suggested that one solution of the magnetic levitation system for guided transport, which avoids any physical contact with the guideway. This system could theoretically result in speeds of 500 km/h. This suggestion raised an additional comment that, at such speeds, noise may still be a major problem owing to the compression and decompression of air masses.

3. The last part of the discussion dealt with the problem of environmental costs associated with noise suppression. It was commented that the recommended standards for noise levels in Japan are extremely low in comparison to those of the UK, for example. If the Japanese standards were enforced in the UK, the railways would probably have to close. It was asked what factors caused JNR to accept such a low noise limit, and whether the costs of noise suppression were included in JNR discounted cash flows.

(a) It was generally agreed that the cost of noise suppression is heavy, but work is continuing towards solution of the problem by compensation payments and improved sound-proofing of housing structures near the Shinkansen line.

(b) The preceding comments provoked a general discussion of possible systems of charges for recovery of the environmental improvement costs. Several possible methods were suggested, such as passing on the costs to the passengers of JNR Shinkansen trains, that JNR should absorb the costs, or that residents who move close to Shinkansen routes after construction is completed should be charged.

(c) It was mentioned that in some regions of North America, similar problems are being encountered in residential areas surrounding airports: people move into airport areas and then complain of noise.

(d) This problem also occurs in Shinkansen areas but nothing has yet been done about it.

Implications of National Development in Japan

19. *Background of Development in Japan*

N. GLICKMAN

The history of postwar regional development in Japan is one of very rapid urbanization that occurred immediately after World War II, and involved a high level of concentration in major metropolitan areas. In papers written in 1976 (Glickman, 1976, 1977a, 1977b, 1977c) metropolitan areas, called Regional Economic Clusters (RECs), were defined which dominate urban life in Japan. These RECs are similar to the Standard Metropolitan Statistical Areas in the United States, and the SMLAs in the United Kingdom. The Tokaido region, for example, consists of several interrelated sets of regions, including Nagoya and Osaka. There is tremendous concentration along this Tokaido belt, along which the Shinkansen was built. In 1975 two-thirds of the total Japanese population resided in the eighty regions shown in Fig. 19.1. The figure also shows eight areas, heavily outlined, which are defined as Standard Consolidated Areas, and approximately one-half of the Japanese population resides in them.

During the course of the research it was found that the cities were becoming centralized over time. In other words, the large cities were growing at the expense of the smaller cities and the rural areas. This was particularly true between 1950 and 1970. Another important finding was that in comparison with developed countries in the West, there was relatively little suburbanization in Japan.

We recently had the opportunity to update some of this research by means of some of the data that Professor Kuroda has presented at this conference, and we indicated some of the events that took place between 1970 and 1975. The population percentage changed between 1970 and 1975, and the RECs grew by 6.2 million between 1970 and 1975 (of the 7.2 million growth in the whole of Japan) which is about 86% of the total population growth in Japan. The non-REC areas grew relatively slowly, only about 3.3% between 1970 and 1975 compared to 7.8% for the major metropolitan areas. (This is shown in detail in Table 19.1.)

The large regions of Tokyo, Nagoya, and Osaka also grew very fast. In spite of some of the "U-turn" phenomena that we have been hearing about, these major metropolitan areas continue to grow, and faster than the non-metropolitan areas.

What has also been happening in the 1970s is that most of the growth in these RECs is occurring in suburban areas: much more suburbanization has been taking place, especially in the larger metropolitan areas. The smaller

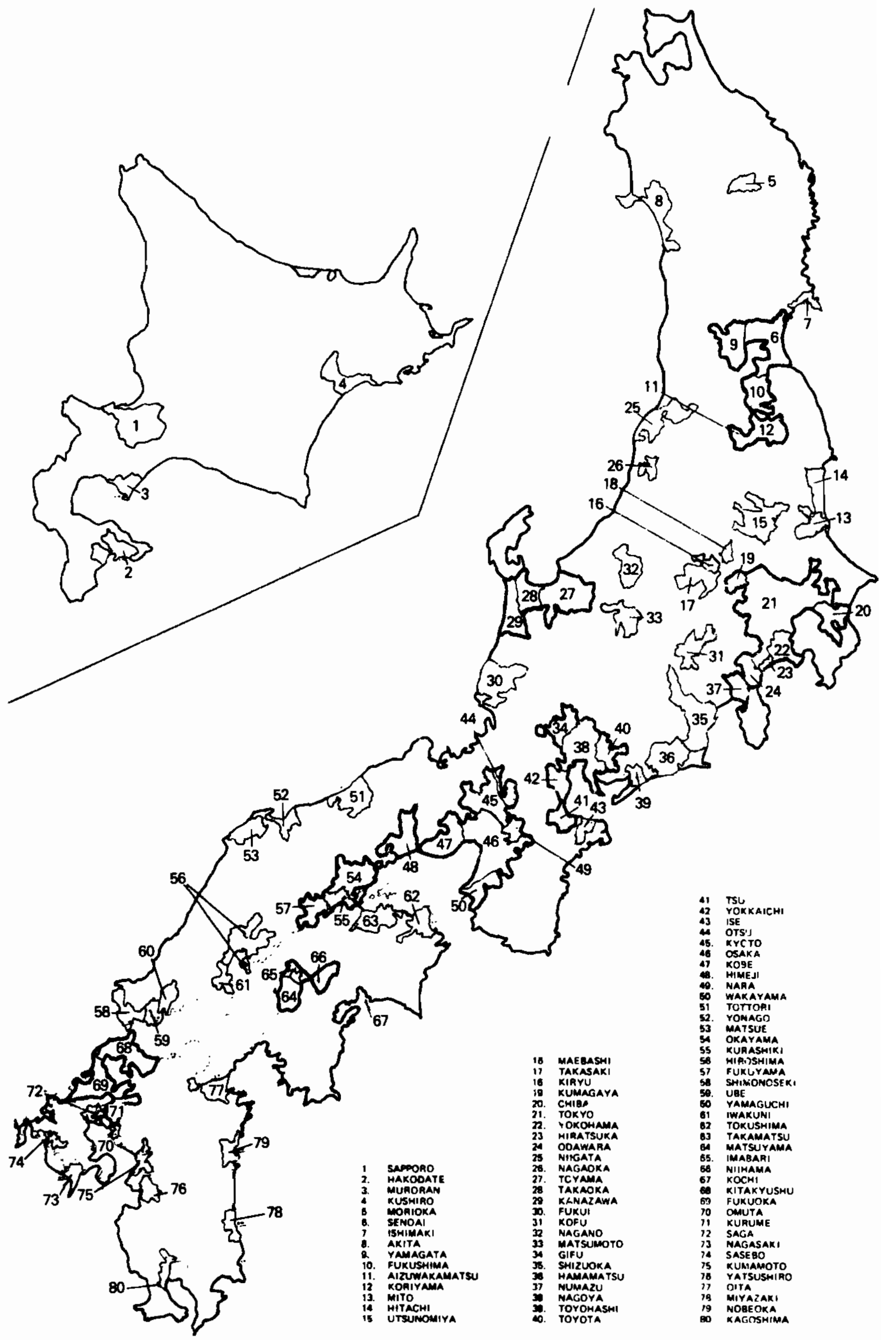


Fig. 19.1. Regional economic clusters and standard consolidated areas.

TABLE 19.1. *Growth of population of regional economic clusters, standard consolidated regions, and Japan as a whole, 1970-1975*

Area	Population (millions)		Percent change
	1975	1970	1970-1975
All Japan	111.9	104.7	6.926
All regional economic clusters	76.6	70.4	8.705
All standard consolidated areas	57.9	53.3	8.716
Tokyo, Nagoya and Osaka SCAs	48.0	44.2	8.659
All non-REC Japan	35.3	34.2	3.264
RECs as percent of Japan	68.42	67.30	—
SCAs as percent of Japan	51.73	50.89	—
SCAs as percent of RECs	75.61	75.63	—
Tokyo, Nagoya and Osaka SCAs as percent of all RECs	62.89	62.73	—

areas exhibit much less suburbanization. A third phenomenon, one which Professor Kuroda discusses, is that the middle-size regions are beginning to grow faster than the larger regions. In the 1950-1970 period, the large regions were experiencing rapid growth rates. Now it is the middle-size regions, 500,000-700,000 people, that appear to be growing fastest. The data to support this observation is rather limited because it is only reported in 5-year periods. To provide a better basis for argument, I looked at some of the data that Professor Kuroda also used. Table 19.2 shows the migration in various regions of Japan during the period 1954-1975. The first column shows the net migration into the three major metropolitan areas: Tokyo, Kanto — Osaka and Nagoya (Tokai) — and Kinki. Note that there was an increase in in-migration from 1954 to 1962, then there was a sharply decreased net in-migration. By 1975 there is very little in-migration, only 32,000 people.

In looking at the fourth column of Table 19.2, for the suburban prefectures we see in the early years a trend of out-migration, but after 1959 there is sharply increasing migration into these areas, peaking in 1970 and then declining. The figures after 1970 show that there is not as much in-migration to the suburbs as there used to be; more people are leaving the cores and going to the suburbs. This is shown in column 5 of the table, where in the later years there are the beginnings of positive in-migration. These results are complementary to what Professor Koruda has said, and I have tried to amplify his remarks.

The reason the data from the census in Glickman (1977a) shows a still increasing metropolitan growth is that the birth rate is much higher in metropolitan than in rural areas, owing to the age structure of the population. Migration to the cities is mainly by younger people of child-bearing age. Birth rates therefore continue to be high and are more than making up for the decrease in in-migration.

The major goal of regional development policy since about 1960 has been to decentralize the Japanese urban system. But regional planning has to be seen within the context of national planning. There have been ten national plans since 1955, the latest one issued in 1976. The major purpose of most of them is to stimulate economic development, usually accomplished through the

TABLE 19.2. *Annual net migration to Japanese regions, 1954-1975 (thousands)*

	(1) Kanta, Kinki and Tokai regions[a]	(2) Other regions[b]	(3) Core prefectures[c]	(4) Suburban prefectures[d]	(5) Exurban prefectures[e]	(6) Peripheral prefectures[f]	(7) Prefectures other than core, suburbs exurbs and periphery[g]
1954	265.3	-265.3	418.8	-35.1	-118.4	-59.2	-206.1
1955	242.2	-242.2	383.0	-27.3	-113.5	-53.0	-189.2
1956	279.5	-326.8	429.9	-24.4	-126.0	-50.8	-228.7
1957	371.2	-371.2	523.9	-10.7	-142.0	-65.1	-306.1
1958	294.7	-294.7	430.0	-3.6	-131.7	-50.3	-244.4
1959	370.4	-370.4	482.8	16.7	-129.1	-82.7	-287.7
1960	491.9	-491.9	552.3	43.8	-104.1	-121.0	-371.0
1961	572.6	-556.5	594.0	62.4	-83.8	-139.7	-432.9
1962	575.7	-575.7	539.1	112.4	-76.2	-128.1	-447.2
1963	557.1	-557.1	477.0	151.9	-71.8	-138.7	-418.6
1964	521.4	-521.4	421.2	166.0	-65.8	-108.2	-413.2
1965	426.1	-426.1	337.9	158.7	-70.5	-78.6	-347.5
1966	348.9	-348.9	251.0	174.2	-76.3	-61.0	-287.9
1967	374.7	-273.8	229.5	195.4	-50.2	-62.2	-312.5
1968	399.6	-399.6	231.3	208.5	-40.2	-60.2	-339.4
1969	430.5	-430.5	212.5	233.1	-15.1	-60.6	-369.9
1970	427.5	-427.5	147.3	265.0	15.2	-49.2	-378.3
1971	318.7	-318.7	77.4	231.7	9.6	-28.7	-290.0
1972	229.1	-229.1	-11.0	259.5	-19.4	-13.0	-216.1
1973	168.5	-167.5	-105.4	244.3	28.6	-5.8	-161.7
1974	78.2	-78.2	-152.8	202.7	28.3	6.0	-84.2
1975	32.2	-32.2	-151.6	172.2	11.6	19.6	-51.8

[a]Tokyo, Kanagawa, Chiba, Saitama, Tochigi, Ibaraki, Gumma, Yamanashi, Nagano, Shiga, Kyoto, Nara, Wakayama, Osaka, Hyogo, Shizuoka, Aichi, Gifu, and Mie prefectures.

[b]Prefectures not included in column (1); see footnote a.

[c]Tokyo, Osaka, Kyoto, Hyogo, Aichi, and Kanagawa prefectures.

[d]Gifu, Nara, Saitama, and Chiba prefectures.

[e]Gumma, Ibaraki, Tochigi, Shizuoka, Mie, Shiga, Wakayama, Yamanashi and Nagano prefectures.

[f]Miyagi, Fukushima, Okayama, Hiroshima, Yamaguchi and Tukuoka prefectures.

[g]Prefectures not included in columns (3) through (6); see footnotes c-f of this table.

stimulation of exports and investment. Regional development policy has followed the various stages of national development policy. Professor Miyazawa is quite correct in his discussion on some of the stages of growth policy, and it is important to consider regional development policy in this context. The important thing, of course, is the implementation of regional policy. The stated goal is to try to decentralize the population, and to some degree this has been reflected in the public investment patterns as seen for the different regions.

Data on the relative level of public investment for the major regions of Japan (Glickman, 1977b) show that most regions that were less favored in earlier periods (1959-1961) become more favored later on (1973). The Tohako region provides a good example of this trend. In Japan public investment can be seen to be highly centralized in the Pacific belt. To understand the

Shinkansen investment, one should look at it in the context of the investment policy during the late 1950s and early 1960s. A large amount of public investment was concentrated in the Tokaido region, and the Shinkansen was just one element of this investment, which included the development of ports, roads, conventional railroads, etc., which was going on during that period.

Reactions were observed in the late 1960s indicating that there was too much pollution and too much concentration of population. The data I have discussed indicates that the Government responded in some degree, to these reactions in the late 1960s and began to decentralize investment spatially.

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20. *Migration, Population Distribution, and Population Policy in Japan*

T. KURODA

1. Introduction

Migration of population is closely related to economic development; this can be fully documented by experience in the advanced countries. In the process of modernization, migratory movement of population tends to function as a movement which equalizes aggregate socio-economic disparities between regions [1], and also tends to mitigate regional population pressures by syphoning off excess population in one area into areas of greater opportunity which demand a labor force. In this sense, internal migration is a device for maintaining a social and economic balance for the nation among communities and is a mechanism of personal adjustment by achieving a more satisfactory selection of residence and job through migration [2].

In broad terms, Japan's modernization is not unique. In particular, the relationship between economic development and migratory movements of population in the postwar period was very typical. Population movement in postwar Japan has increased rapidly, with economic motives as the principal causal factor. However, it should be noted that migration, in addition to contributing greatly to rapid economic growth, has brought about a severe dichotomy of overcrowded and depopulated areas, creating new socio-economic and administrative difficulties in both areas. In the field of demography too, Japan has experienced an extraordinary change of regional vital statistics, resulting in overall higher birth and natural increase rates in all industrial-urbanized prefectures over all rural prefectures, amounting to more than 30.

However, there are clear signs of basically changing national patterns of migration and redistribution trends of population. This paper examines the historical change of migration and population distribution in relation to economic development, and, in particular, indicates a new migration dimension based on the mobility transition hypothesis [3].

2. Bifurcation of Population Concentration and Metropolitanization

Historically, the population distribution of Japan is basically characterized by bifurcation into Tokyo and Osaka. Even before the Meiji Restoration in 1868, these cities had been bifocal points of attraction to population as political or industrial cores. The rural-to-urban type of migration has in fact been a Tokyo–Osaka oriented movement. Rural-to-urban migration was on the increase even in the prewar period, but was not significant compared with the magnitude and pace of increase in the postwar period, particularly after about 1955, when rapid economic growth began after the postwar economic recovery. The average annual number of migrants in Japan was about 5 million for the second half of the 1950s, rising to more than 6 million in the first half of the 1960s, and 7.6 million in the second half of the same decade; finally exceeding 8 million per year in the first half of the 1970s.

There were three major sources of this enormous number of migrants in the postwar period. First, the very large number of repatriated and demobilized soldiers, young adults, looking for employment opportunities. Second, this inevitably brought about a marriage and baby boom. The average annual number of births amounted to about 2.7 million for the period 1947-1949, when the birth rate was roughly as high as 33-34 per thousand of the population. Although the birth rate began to fall very quickly, this baby-boom population contributed towards meeting the heavy demand for a young labor force later. Third, the remarkable decrease of the population engaged in primary industry, in which the agricultural population was dominant. Nearly half of the working population was engaged in primary industry in 1960. However, the numbers started to decrease rapidly to 33% in 1960, and 19% in 1970; a decrease from 17 million in 1950 to only 10 million in 1970. The population shift from primary to secondary and tertiary industries can be roughly and indirectly explained by migration estimates between urban and rural areas, because those population increases in secondary and tertiary industries are reasonably assumed to be out-migration from rural, agricultural areas, particularly from those in an earlier stage of economic development. Table 20.1 and Fig. 20.1 show how the migration trend has been strongly oriented to the Tokyo and Osaka metropolitan areas in the postwar period. Table 20.2 gives estimates of interregional net migration based on the vital statistics method.

It can easily be seen from Tables 20.1 and 20.2 that only two regions, Minami-Kanto and Keihanshin (the most urbanized areas centering upon Tokyo and Osaka cities), have continuously shown enormous net in-migration. In other words, Tokyo and Osaka and their metropolitan areas have been bifocal growth points, absorbing a very large population from all other regions in the country. This is clear from the fact that all remaining regions, excluding Chukyo, have continued to show net out-migration.

Even in the prewar period, both regions continued to absorb population through migratory movement from local regions. For example, Table 20.2 shows that the Minami-Kanto, i.e. the present Tokyo Metropolitan area, showed more than 600,000 net in-migrants for each 5-year period since 1920. The Keihanshin region, i.e. the present Keihanshin Metropolitan area, also has net in-migrants comparable to the Tokyo Metropolitan area. However, it should be noted that the Tokyo Metropolitan area has exerted a much stronger population-absorbing capacity than the Keihanshin Metropolitan area. Table 20.1 shows that net in-migrants in the former exceeded 1 million in each 5-year

TABLE 20.1. *Interregional net migration in postwar Japan (thousands)*
Source: *Annual Report on Internal Migration Derived from the Basic Resident Registers,* Bureau of Statistics, Prime Minister's Office, Japan.

Region	1955-1959	1960-1964	1965-1969	1970-1974
1 Hokkaido	+ 23	− 151	− 199	− 223
2 Kita-Tohoku	− 160	− 298	− 250	− 215
3 Minami-Tohoku	− 280	− 361	− 219	− 125
4 Kita-Kanto	− 285	− 201	− 90	+ 247
5 Minami-Kanto	+ 1442	+ 1854	+ 1452	+ 899
6 Hokuriku	− 245	− 254	− 212	− 122
7 Tosan	− 222	− 137	− 87	− 49
8 Chukyo	− 70	+ 311	+ 157	+ 111
9 Keihan-Shuhen	− 57	− 34	+ 22	+ 124
10 Keihan-Shin	+ 633	+ 929	+ 526	+ 44
11 San-In	− 87	− 115	− 93	− 50
12 San-Yo	− 127	− 185	− 53	+ 22
13 Shikoku	− 212	− 289	− 199	− 84
14 Kita-Kyushu	− 177	− 606	− 407	− 231
15 Minami-Kyushu	− 293	− 461	− 343	− 235

Note: Each region shown here is a geographical area (see Fig. 20.1), including several prefectures, with the exception of Hokkaido, as follows:

2 Kita-Tohoku: Aomori, Akita, and Iwate
3 Minami-Tohoku: Miyagi, Fukushima, and Yamagata
4 Kita-Kanto: Ibaragi, Tochigi, and Gunma
5 Minami-Kanto: Tokyo, Kanagawa, Saitama, and Chiba
6 Hokuriku: Niigata, Toyama, Ishikawa, and Fukui
7 Tosan: Nagano and Yamanashi
8 Chukyo: Aichi, Gifu, Mie, and Shizuoka
9 Keihanshin-Shuhen: Shiga, Nara, and Wakayama
10 Keihanshin: Osaka, Kyoto, and Hyogo
11 San-In: Shimana and Tottori
12 San-Yo: Okayama, Hiroshima, and Yamaguchi
13 Shikoku: Kagawa, Tokushima, Ehime, and Kochi
14 Kita-Kyushu: Fukuoka, Nagasaki, Saga, and Oita
15 Minami-Kyushu: Kumamoto, Miyazaki, and Kagoshima

"+" denotes net in-migration and "—" denotes net out-migration.

period, with the exception of 1970-1975, but the net in-migrants of the latter were much less.

The Chukyo region has come up as a third metropolitan area only in the postwar period, but the number of net in-migrants in that region was smaller than the Tokyo and Keihanshin Metropolitan areas.

Table 20.1 indicates that some new changes in migration seem to have begun, and these will be discussed in Section 3.

As a result of a remarkable concentration of population due to shifts of population in the twin giant cities, Tokyo and Osaka, and their suburbs, the populations of these two metropolitan areas have shown extraordinary expansion. In the 25 years between 1950 and 1975, the population of Japan grew from 84,115,000 to 111,933,000. Against a national population increase of 27,818,000, the population of the two metropolitan areas grew by 20,682,000. In other words, the greater part (74.3%) of the population growth of Japan was accounted for by the population increase in these two metropolitan areas. Against a national population growth rate of 33.1%, that

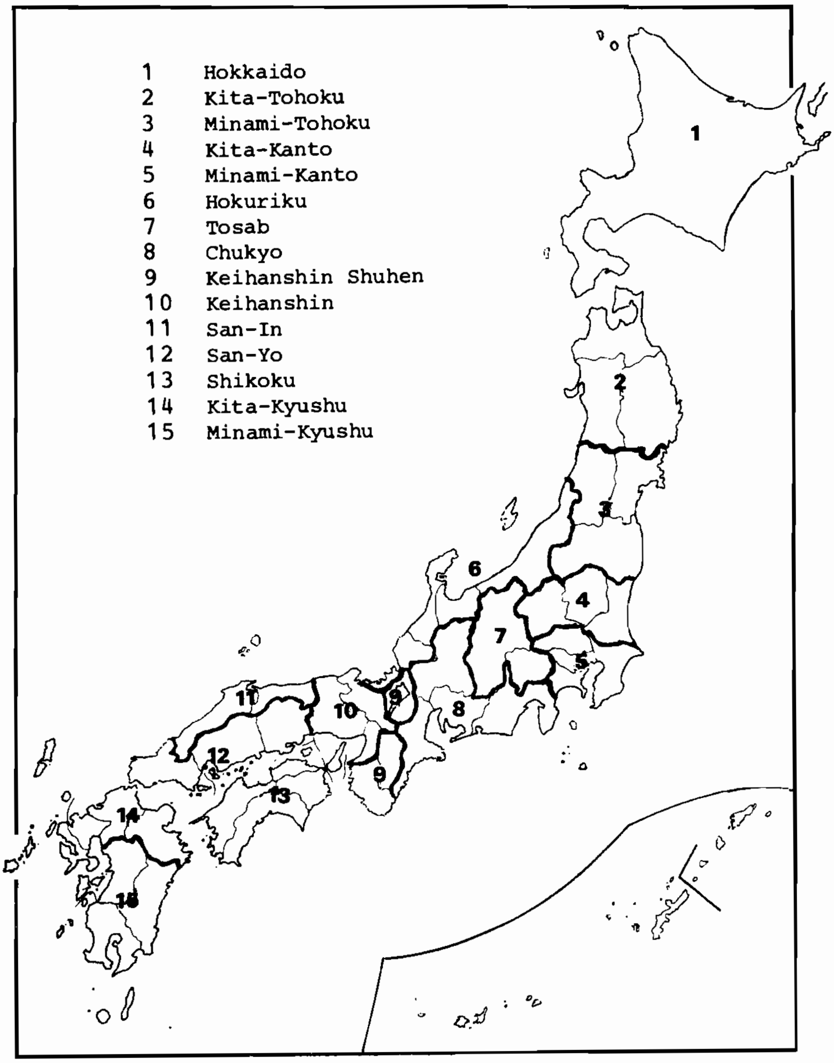

Fig. 20.1. Map of Japan to illustrate Table 20.1.

of the metropolitan areas was 93.8%. Although they occupy only 7.6% of the country, their share of the nation's population was 26.5% in 1950, but increased to 38.2% in 1975. Table 20.3 shows the population growth of three metropolitan areas: Tokyo, Osaka, and Chukyo.

3. New Dimensions of Migration and Distribution of Population

Table 20.1 indicates clearly that in terms of net migration among regions:

(a) Net in-migration in both Minami-Kanto (i.e. Tokyo Metropolitan area) and Keihanshin (i.e. Keihanshin Metropolitan area) regions reached their peak

TABLE 20.2. *Interregional net migration, 1920-1940, in 5-year periods (thousands)*
Source: Net migration is calculated by subtracting the natural increase derived from vital statistics from population increase based on census returns by prefecture.

Region	1920-1925	1925-1930	1930-1935	1935-1940
1 Hokkaido	−110	+ 49	− 24	− 56
2 Tohoku	−145	−190	−238	−404
3 Kita-Kanto	− 93	−109	−137	−142
4 Minami-Kanto	+605	+619	+619	+751
5 Hokuriku and Tosan	−192	−182	−300	−281
6 Tokai	+ 31	− 28	+ 8	− 17
7 Keihanshin	+456	+434	+778	+453
8 Areas surrounding No. 7	− 45	− 41	− 35	− 94
9 Sanin	− 32	− 26	− 55	− 61
10 Sanyo	− 47	− 68	− 18	− 0
11 Shikoku	− 91	− 92	−177	−197
12 Kita-Kyushu	− 89	+ 0	− 35	+104
13 Minami-Kyushu	− 76	− 59	−150	−249

Note: The prefectures included in each region are as follows:
Tohoku: Aomori, Iwate, Akita, Miyagi, Yamagata and Fukushima.
Kita-Kanto: Ibaragi, Tochigi and Gunma.
Mitami-Kanto: Tokyo, Kanagawa, Saitama and Chiba.
Hokuriku and Tosan: Niigata, Toyama, Ishikawa, Fukui, Yomanashi, and Nagano.
Tokai: Aichi, Gifu, Mie, and Shizuoka.
Keihanshin: Osaka, Kyoto, and Hyogo.
Areas surrounding No. 7: Shiga, Nara, and Wakayama.
Sanin: Tottori and Shimane.
Sanyo: Okayama, Hiroshima, and Yamaguchi.
Shikoku: Kagawa, Ehime, Tokushima, and Kochi.
Kita-Kyushu: Kumamoto, Miyazaki, and Kagoshima.
" + " denotes net in-migration and "−" denotes net out-migration.

TABLE 20.3. *Population growth in three metropolitan areas*
Source: National censuses.

Metropolitan area	1975	1970	1965	1960	1955	1950
	Population (thousands)					
Tokyo	27,037	24,113	21,017	17,864	15,427	13,051
Keihanshin	15,696	14,538	13,070	11,405	10,174	9,000
Chukyo	9,417	8,688	8,013	7,330	6,838	6,396
Total	52,150	47,339	42,100	36,579	32,437	28,447
Japan	111,933	100,467	98,275	93,419	89,276	84,115
	As % of national population					
Tokyo	24.2	23.2	21.4	19.1	17.3	15.7
Keihanshin	14.0	14.0	13.3	12.2	11.4	10.8
Chukyo	8.4	8.4	8.2	7.8	7.7	7.7
Total	46.6	45.6	42.8	39.2	36.3	34.2
Japan	100.0	100.0	100.0	100.0	100.0	100.0

Note: Metropolitan Tokyo centers upon Tokyo Metropolis and includes the three neighboring prefectures of Kanagawa, Saitama, and Chiba. Metropolitan Keihanshin includes Osaka, Kyoto, and Hyogo prefectures. Metropolitan Chukyo includes Aichi, Gifu, and Mie prefectures. Populations for 1950 and 1975 include Okinawa prefecture.

in the 5-year period 1960-1964, and then started to decrease rapidly.

(b) Nearly all other local regions characterized by traditional out-migration have begun to show declining trends of net out-migration after peaking in the period 1960-1964 — some of them earlier. Chukyo Metropolitan area follows the same pattern as Tokyo and Keihanshin. Hokkaido is the only exception, still keeping an increasing trend of net out-migration.

(c) Minami-Kanto and San-Yo have reversed from net out-migration to net in-migration in the last period, 1970-1974, a fact which deserves special attention. Keihanshin-Shuhen, comprising the three prefectures of Shiga, Nara, and Wakayama, which are just outside the cities of Osaka, Kyoto, and Kobe, has already shown net in-migration since 1965-1969. mainly because they are conveniently located as suburban areas for the Keihanshin Metropolitan area.

These findings demonstrate that new dimensions of migration have emerged from the mid-1960s. In addition to suburbanization [4], which began earlier, particularly in the Tokyo and Osaka areas, a new return migration pattern has appeared. This is really new in the sense that it has not been experienced before, and consequently migration in Japan has entered a new stage, which should be examined fully in the economic and social context.

The decreasing trend of net out-migration in local regions like Tohoku and Kyushu is due to two factors. One is the decreasing in-migration into metropolitan areas from local regions, and the other is the increasing trend of out-migration from large metropolitan areas like Tokyo and Osaka to local areas. These changes of migration streams can be seen from the *Annual Report on Internal Migration Derived from the Basic Resident Registers,* compiled by the Bureau of Statistics, Prime Minister's office.

Return migration in Japan seems to be more or less specific because most of them are youths or young adults* returning to their home towns or nearby. I have called such return migration a "U-turn". Large numbers of young people who came up to metropolitan areas to obtain better jobs and enjoy a socially and culturally advanced environment had grown up and were educated in their home towns, where parents, relatives, and friends were still living. Why did they decide to return? This is a controversial question. In trying to answer it, the fact should be noted that the majority of the "U-turn" people are young, mainly 20-24 and 25-29 years old [5,6]. This suggests that half of them are probably already married and may have one or two children, and that they have presumably seriously considered their future life in the social and physical environment of great urban centers like Tokyo and Osaka, where the great concentration of industries has made the environment remarkably unsuitable for family life. On the other hand, various regional development policies have been initiated and intensified by the central and local governments during the postwar years, and they have gradually created and increased employment opportunities in rural areas. This has been a very strong factor in bringing back young people who left their home towns to look for

*Okazaki [5] estimated net migration rates by age groups of males by prefecture for the periods 1965-1970 and 1970-1975; see also Nishikawa [6].

jobs in urban centers and who have begun to look for somewhere else to live and work. A better environment, and lower cost of living are additional attractive factors, even though the social infrastructure and amenities are still lagging behind urban centers.

There are other indications that imply a redistributive movement of population in addition to an interesting pattern of return migration. The 1975 census gave much interesting information on national population distribution.

First, the number of prefectures losing population in the 5-year period 1970-1975 decreased considerably to only five, the least developed, compared with twenty prefectures in the period 1965-1970; twenty-five in 1960-1965, and twenty-six in 1955-1960. Moreover, rates of population decrease have declined remarkably. This means that many prefectures which continued to lose population through net out-migration have shifted to gaining population through decreasing out-migration and increasing in-migration.

Second, large cities with more than 500,000 inhabitants have shown a lower rate of population increase, only 4.3% for the 5-year period 1970-1975, while small and medium-sized cities with populations of more than 100,000 to less than 500,000 have shown about a 13% increase for the same 5-year period. These cities are classified into four groups according to the size of population. The rates of population increase for 1970-1975 are as follows:

Size of cities	Population increase (in thousands)	Rate of increase (%)
300,000-499,999	1432	13.6
200,000-299,999	1072	12.6
100,000-199,999	1380	12.7
50,000- 99,999	1558	12.5

Third, it should be noted that the number of minor civil divisions, city, town, and village (*shi, machi,* and *mura* in Japanese), which showed more than a 10% decrease in the 5-year period has shrunk considerably, from 937 for the previous 5-year period (1965-1970) to 443 in the 1970-1975 period. More than 10% decrease of population in a 5-year period is one of the conditions for local governments (*shi, machi,* or *mura*) to qualify for assistance from the Central Government through subsidies, etc.

In addition to return migration, intrametropolitan or intermetropolitan migration and interlocal migration should be mentioned as increasing migration streams. In particular, migration between adjoining local regions should receive special attention. For example, the migratory flow between Kita-Tohoku and Minami-Tohoku, and between San-In and San-Yo, and so on, had formed a new migration pattern [7].

4. Policy and Development

Considerations of policy have always had two aspects, one economic and the other demographic. The demographic aspect concerns fertility, mortality, and migration. Recommendations to reduce mortality have been included in all policies. Population policy considerations in the postwar period are characterized by a shifting of emphasis from reduction of fertility to redistribution of the population. In the first decade after the war, the major concern was fertility control:

The mid-1950s was probably a socio-economic and demographic turning-point. The demographic transition was completed, with birth and death rates stabilizing at a very low level. At that time the rapid postwar economic growth was also in its early stage.

A "double income program" was initiated by the Government in 1960 to achieve rapid industrial growth based on local development programs and heavy industry and chemical industry. Public and private investment was greatly expanded, and economic growth rates continued to exceed those expected by the Government. The greatest emphasis was, however, placed on economic development in order to approach as quickly as possible the advanced level already attained in the more highly developed countries. Consequently, the Government tended to neglect the impact of social development on the population.

The rapid economic growth that began in about 1955 was made possible by concentrating and accumulating population and industries in a few limited urban areas, primarily in the three giant cities, Tokyo, Osaka, and Nagoya, and in the large metropolitan areas surrounding them. The heavily crowded urban areas inevitably began to produce environmental disruption. Rural areas became depopulated and contained a high proportion of older people, owing to the heavy migration of the young to urban centers. More and more, after 1960, government attention was concentrated on various diversified development plans and programs at national, regional and local levels. In August 1963 the Population Problems Advisory Council, at the request of the Minister of Health and Welfare, submitted opinions on regional development from the standpoint of population problems.

The council had two basic objectives. One, the goal of any regional development, was to increase the actual welfare of the population, either of the nation as a whole or of a region. The other was to balance the growth of regional economic and social development. With these goals, and taking into account the serious effects on human welfare of massive migratory movements, the Council recommended an adequate population redistribution policy, to be achieved by adjusting the volumes and speed of migration. For that purpose, implementation of regional policies designed to locate and develop industries requiring the employment of many people in local areas was suggested as the most desirable solution.

Other important points in regional development policy are: (a) the shrinking trend towards increase in productive-age population and the increasing trend towards a middle-aged and older population, accompanied by the change in age composition of the population; (b) the need to modernize agriculture and small-scale enterprises in cities; (c) the creation of urban areas with a high-quality environment; (d) the promotion of health and welfare, etc.

In the postwar period, the nature and emphasis of population problems changed as economic progress and social change proceeded. Basically there were two changes: the shift from quantitative to qualitative problems of population, and the transition from the economic-oriented to the equilibrium-oriented problem between economic and social development. Unprecedented overlaps of demographic and socio-economic transformation produced population problems of a different nature, and policy also shifted from simple fertility control to quality improvement and, more recently, to migration and redistribution factors.

As rapid growth started about 1957 and accelerated every year, rural-to-urban migration increased quickly and heavily. A nation-wide migratory movement brought an enormous young labor force into great cities like Tokyo and Osaka from all rural and agricultural areas, as discussed in Section 2.

The country was then polarized into two distinctive areas, one heavily crowded and another heavily depopulated. Both public and private sectors as well as central and local governments have become keenly aware of the extremely adverse effects on people's welfare of an extreme imbalance of population distribution.

As early as 1962 the Government recognized that excessive concentration of population and industries in great cities should be prevented and that balanced regional development should be promoted. In 1962 a National Overall Development Project was adopted, and a New Industrial Cities Promotion Law was enacted. The principal aim of the law was to establish several new industrial cities that were expected to be growth points in local areas and, consequently, slow down the migratory flow into the great cities. At the same time, measures to stimulate industrialization in underdeveloped areas were adopted, including the passage of a law for this purpose. Its basic principle was that regional development should give priority to the welfare of the citizens rather than to the advancement of industrial production.

Finally, in 1971, a law to stimulate the reallocation of industries was enacted in order to accelerate decentralization of industries to local areas. To implement the duties prescribed by this law, a new organization was established in 1972.

The public's increasing awareness of environmental disruption in great cities — e.g. air and water pollution, traffic congestion, inadequate housing, noise disturbances, etc. — and increasing employment opportunities in local cities and towns seemed to function as incentives to return migration. The results of the 1970 census also indicate that major transformations in population redistribution are under way. During the 5-year period 1965-1970. great cities for the first time showed depopulation or a remarkable slowing-down of increase. Population increase rates in the last intercensus period in the three great metropolitan areas were the lowest in the postwar period. The fastest growth rates for urban entities were registered by medium-sized cities with populations between 200,000 and 300,000 and not by the larger cities. However, it is also true that heavy accumulation of population is still continuing even though the speed has been reduced. Various expert committees of the Economic Advisory Council to the Prime Minister came to the same conclusion, namely that the decentralization policy of population and industries should be adopted in order to attain the greatest possible benefit to the public. Effective implementation of the redistribution policy is a formidable task for the Government. The policy extends over various fields of social, economic, and fiscal arrangements and of urban, rural and environmental problems. The entitlements and desires of people who are selecting places of residence and work are basic factors in formulating redistribution policy. It seems clear that the migration and redistribution of population is now the most urgent population policy facing present-day Japan.

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21. *The Shinkansen and the Future Image of Japan*

T. SANUKI

The Problem

When plans were formulated for the construction of the Tokaido Shinkansen, it was the general belief in Japan and the rest of the world that transport systems would no longer be railway-oriented but centered on motor vehicles. It was no wonder that the project should be severely criticized. To give an extreme example, the undertaking was cited as one of the three largest but most useless projects of the world, the three being the Great Wall of China, the Japanese battleships *Yamato* and *Musashi,* and the Tokaido Shinkansen.

Amongst the most critical were university professors and politicians, who claimed that it was incomprehensible why all three should be in Asia, with two in Japan to make matters worse. Although they have not yet said a word about their mistakes, it is to be noted that these very people are now making great use of the Tokaido Shinkansen as a safe, reliable and speedy means of transport.

This paper attempts to analyze from facts the positive and negative effects produced by the opening of the Shinkansen. Based on this analysis, the function and role of the Shinkansen in relation to the future image of Japan is dealt with as a proponent of an integrated transport system. For this it was necessary to make an estimate of the future volume of passenger traffic, develop an OD chart therefrom, and clarify the share to be borne by each mode of transport. Estimates obtained by the gravity model and the Fratar method are presented, to which the author's "third productivity theory" will be applied. Then the future image of Japan is discussed. Finally, some proposals are made on city planning in relation to the Shinkansen stations.

The Shinkansen and Economic Growth

In 1947, after the termination of the Pacific War, the scale of the Japanese economy was only 3600 million dollars in GNP, but it has grown to the present-day 463,600 million dollars. The years from 1945 to 1955 may be regarded as the rehabilitation period and the 20 years from 1955 to the present as the growth period.

In the 20 years from 1955 to 1975, the Japanese economy showed a tremendous nominal growth of 16.70 times at the annual rate of 15.1%, and real growth of 5.29 times at the annual rate of 8.7%.

This may be broken down into four periods:

Periods		Real growth (annual)	Nominal growth (annual)
1st	(1955-1960)	8.7%	12.8%
2nd	(1960-1965)	9.7%	15.2%
3rd	(1965-1970)	11.7%	17.4%
4th	(1970-1975)	5.2%	15.3%

In line with this economic growth, the per capita national income rose rapidly, and Japanese society changed from poverty to affluence:

Year	Per capita national income	Desired commodities
1955	$227 (1.00)	Black and white television, refrigerator, washing machine
1960	$395 (1.74)	Car
1965	$735 (3.24)	Car, color television, air conditioner
1970	$1560 (6.87)	Car, cottage, cooker (electronic range)
1975	$3394 (14.95)	Quality of life

Average wages have risen to the high level of 23.28 yen per 60 seconds, and the jobs of factory workers have changed from physical labor to mental technical work. Assuming that it takes 6 minutes to smoke one cigarette, it means that the state has been reached where 139.68 yen (or $0.49 at $1 = 285 yen) will go up in smoke when somebody passes the time smoking one cigarette.

With the rise in income level, passenger transport demand grew rapidly, and the increased spendable income led to more frequent use of transport facilities. As shown in Fig. 21.1, the volume of passenger traffic by various means grew 4.98-fold between 1955 and 1974. The growth was 81.2-fold by aircraft, 54.6-fold by automobile, 5-fold by bus, and 2.4-fold by Japanese National Railways (JNR). The growth of JNR was relatively low compared with that of aircraft and automobile, but the share of the railway and motor vehicle has now been reversed, as shown in Fig. 21.2.

In spite of this trend, the passenger traffic by the Shinkansen grew 5.1-fold from 1965 to 1975, showing a different and much higher pattern of growth than the other JNR lines. Particularly outstanding is the fact that this growth far exceeded that of the GNP (2.2 times in real terms) and per capita national income (4.1 times), as shown in Fig. 21.3.

A comparison of the annual growth rate of the Shinkansen traffic and GNP, given in Fig. 21.4, shows that the growth rate of Shinkansen traffic exceeded that of the GNP, except in 1969, 1971, and 1972. Even in 1969, the growth rate was 8.6%, which is still quite high. When considering that the 1971 low was a

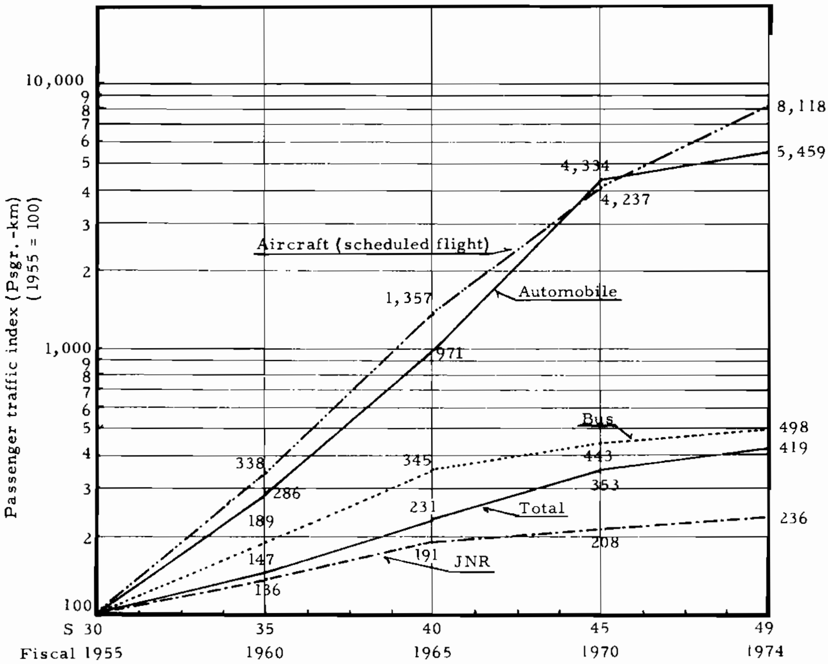


Fig. 21.1. Growth of passenger traffic by different means of transport.

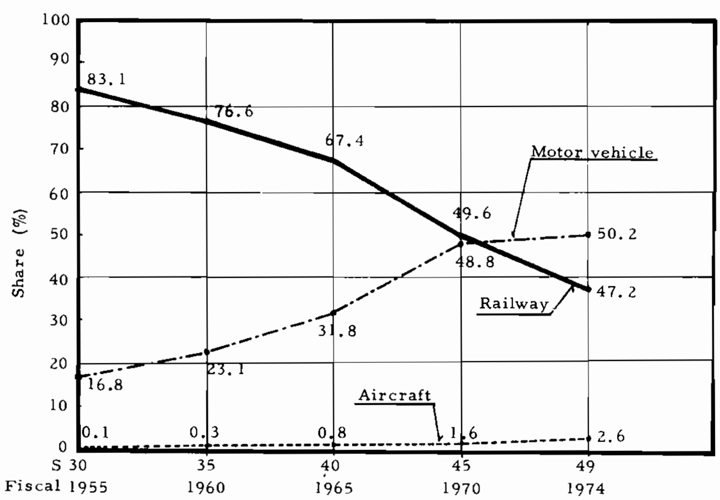


Fig. 21.2. Change in share of domestic traffic by mode of transport.

repercussion of the 1970 high brought about by EXPO '70, it may be said that the elasticity of the growth has been high. What was the reason? In short, the economic growth had raised the level of incomes to where the public could easily use the Shinkansen.

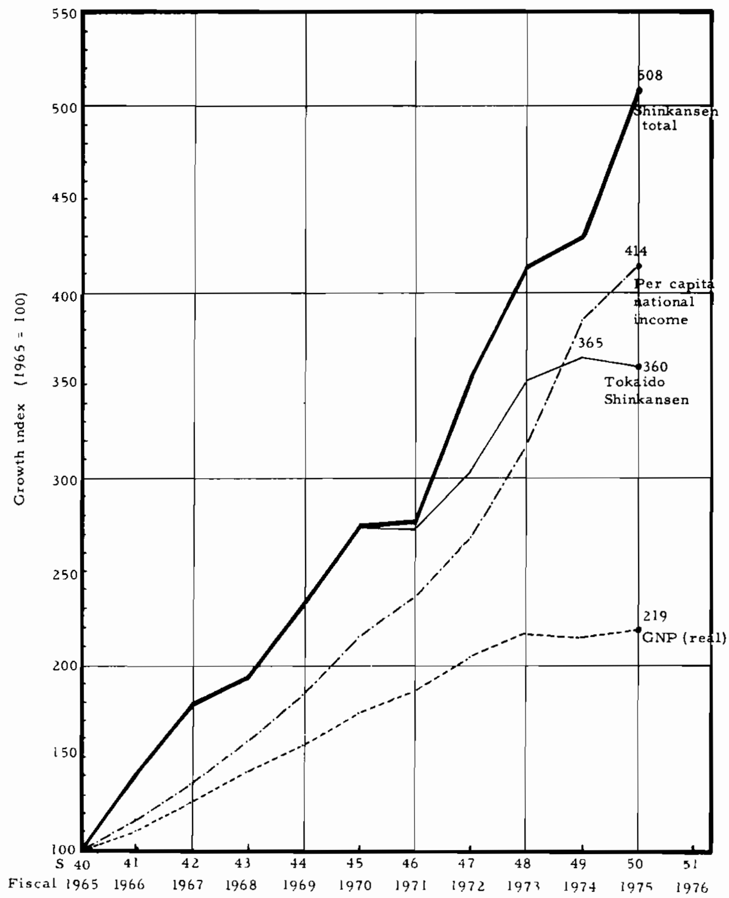


Fig. 21.3. Economic growth and Shinkansen traffic.

Interregional OD Structure of Shinkansen Passenger Traffic

The interregional OD structure of Shinkansen passenger traffic, given in Table 21.1 and Fig. 21.5 for 1975, reveals that:

1. the Shinkansen is fulfilling its function as a means of high-speed transport in the Tokaido megalopolis, linking the three great metropolitan areas of Tokyo, Nagoya and Kyoto-Osaka-Kobe;
2. the Shinkansen is serving as a traffic artery between the Tokaido megalopolis and the four regions of Chugoku, Shikoku, Kyushu, and Hokuriku;
3. a breakdown of the OD structure by station shows that the Shinkansen is being used for journeys in the 150-160-km range; and
4. in most recent years, a rapid increase is seen in the use of the Shinkansen even in the 70-100-km range.

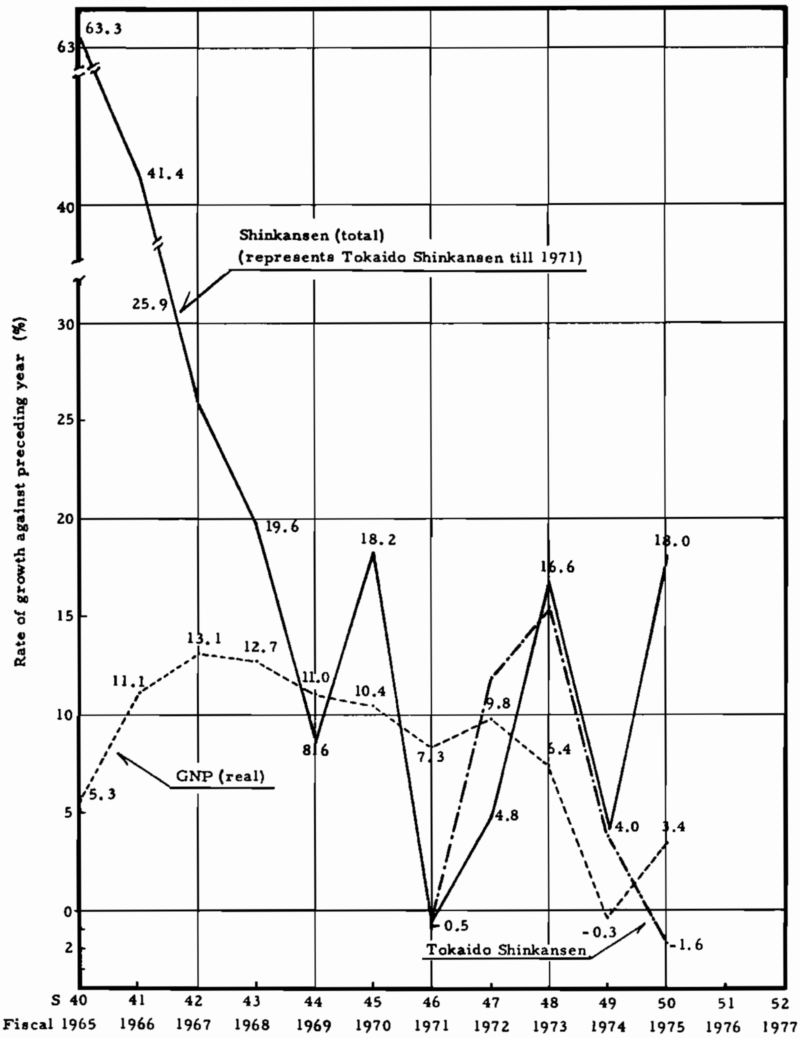


Fig. 21.4. Economic growth and Shinkansen traffic growth (compared with preceding year).

Positive and Negative Effects of the Shinkansen

The transport revolution brought about by the Shinkansen may be likened to a double-edged sword.

IMAGE CHANGING

In the past, Japan was to foreigners "the land of Mount Fuji, cherry blossoms and geisha girls". This image of Japan has greatly changed, and it is now "the land of precision machine industry, the Shinkansen, dense population and Tokyo's most beautiful neon signs". Thus, one impact of the opening of the Tokaido Shinkansen can be seen in this image-changing effect.

TABLE 21.1. *Interregional OD structure of Shinkansen passenger traffic (fiscal 1975) (thousands)*

	Tokyo metro-politan sphere	Izu-Hakone tourism sphere	Shizu-oka-Ha-mamatsu city sphere	Nagoya city sphere	Hokuriku transfer base	Kyoto-Osaka-Kobe city sphere	Sanyo megal-opolis	Kyushu sphere	Total	Inter-sphere coeffi-cient
Tokyo metropolitan sphere	324	5739	3209	6646	1092	11,413	3246	1447	33,116	0.990
Izu-Hakone tourism sphere	7076	485	973	1644	253	2312	301	129	13,173	0.965
Shizuoka-Hamamatsu city sphere	3226	963	915	1721	156	1746	225	84	9036	0.899
Nagoya city sphere	6799	1309	1953	669	686	6096	2186	1221	20,919	0.968
Hokuriku transfer base	1186	233	174	469		741	62	34	2899	1.000
Kyoto-Osaka-Kobe city sphere	11,885	1634	1406	7801	715	3197	9695	2621	38,954	0.918
Sanyo megalopolis	3167	199	199	1533	85	10,504	8278	3183	27,148	0.695
Kyushu sphere	1438	86	102	784	47	3112	3447	2938	11,954	0.754
Total	35,101	10,648	8931	21,267	3034	39,121	27,440	11,657	157,219	0.893
Inter- and intra-sphere structure: Intra-sphere coefficient	0.009	0.046	0.102	0.031	0.000	0.082	0.301	0.252	0.107	—
Inter- and intra-sphere structure: Inter-sphere coefficient	0.991	0.954	0.892	0.969	1.000	0.918	0.699	0.748	0.893	—

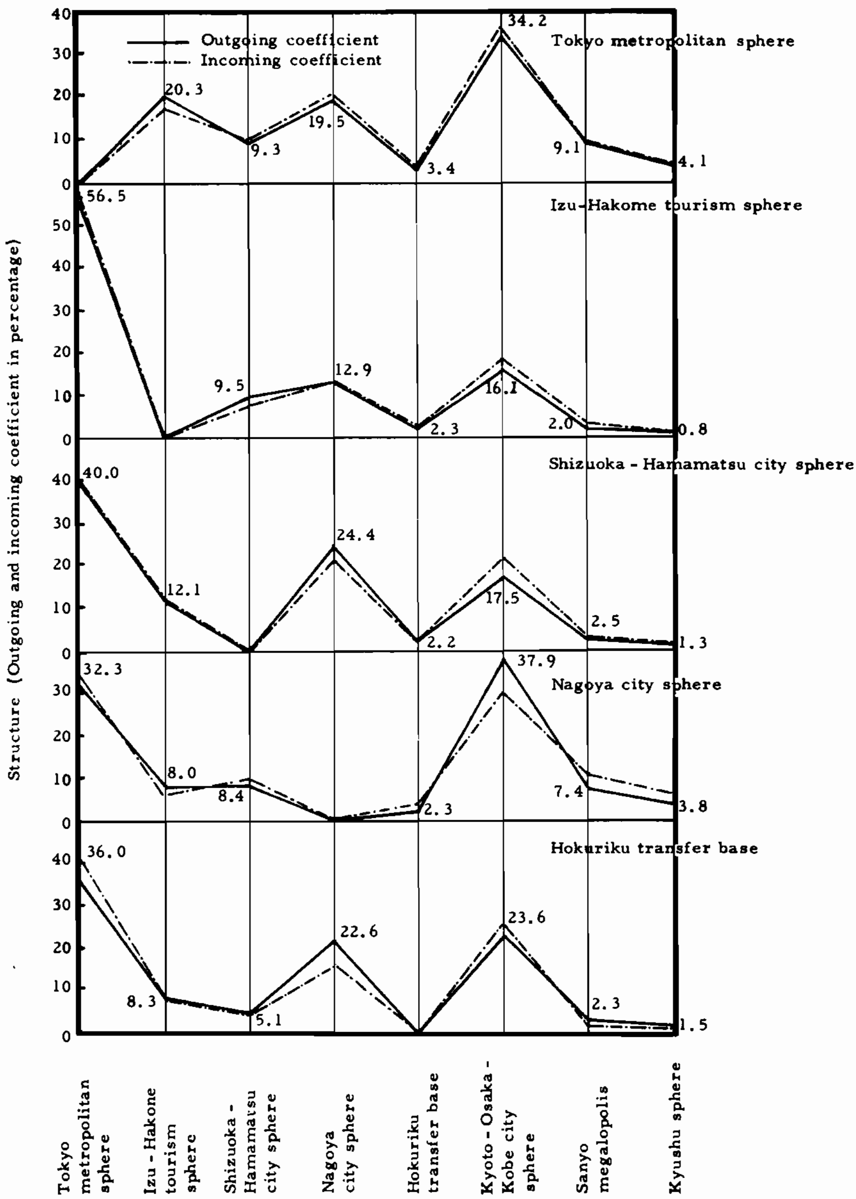


Fig. 21.5. Interregional OD structure of Shinkansen passenger traffic (fiscal 1975).

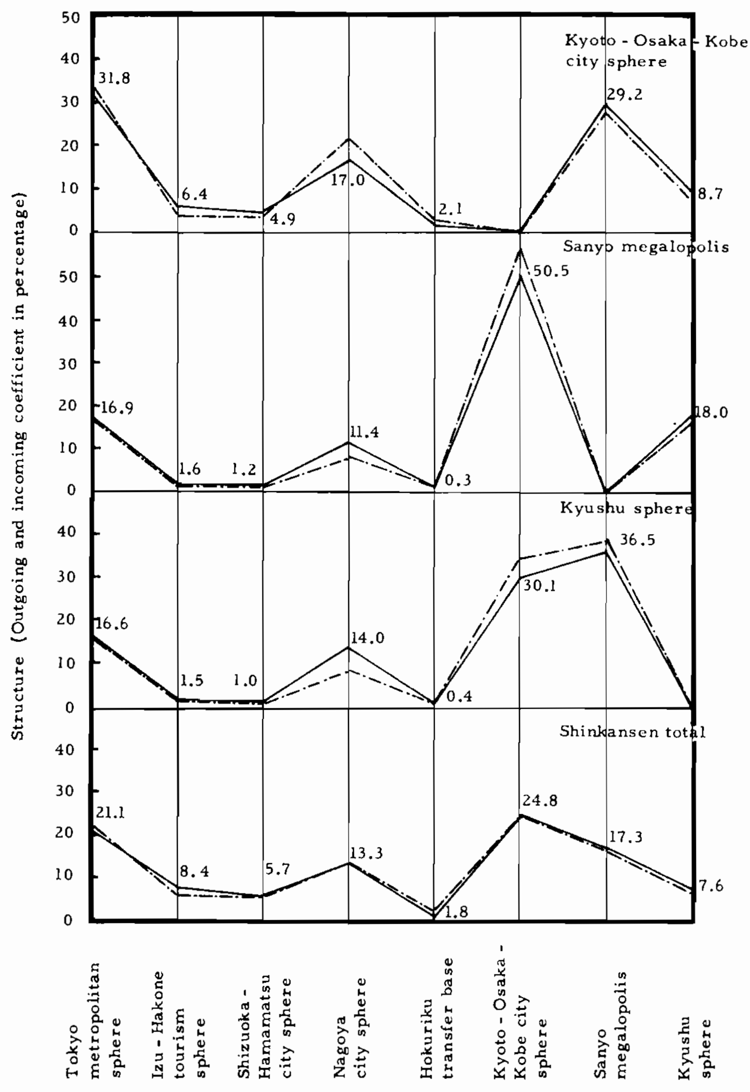


Fig. 21.5. continued.

TIME PRODUCTION

In the period of 11½ years, from its inauguration on 1 October 1964 to 31 March 1976, 977 million people have used the Shinkansen. This has yielded a saving of 2246 million hours, which is the extra time that would have been spent by using conventional trains. In terms of wages, this amounts to 2,527,600 million yen, based on 1964 prices. Assuming that this time saved is assigned to working, the effect would be the creation of one year of working time for 1.22 million people, with 2 days off a week. This work force corresponds to 1.7 times the working population of Kyoto, which demonstrates the great time-production effect of the Shinkansen.

The faster service has greatly widened the scope of a day's trip. A journey between Tokyo and Osaka, and return, used to be considered a 3-day trip, with two nights at the destination, but by the Shinkansen it is an easy day trip. This, in turn, has changed travel patterns.

The traffic volume on the Shinkansen has therefore continued to grow and the line is expected to become saturated around 1979, giving rise to the need of a second Tokaido Shinkansen, as shown in Fig. 21.6.

AIRPORT FUNCTION

The opening of the Tokaido Shinkansen had a great effect on city functions, a typical example of which may be seen in the function of Nagoya Airport. Just before the inauguration of the Shinkansen, this airport had accommodated 300,000 passengers, ranking fifth of the 88 airports in Japan. In 1967, when the Shinkansen Hikari trains began full-scale operation, this

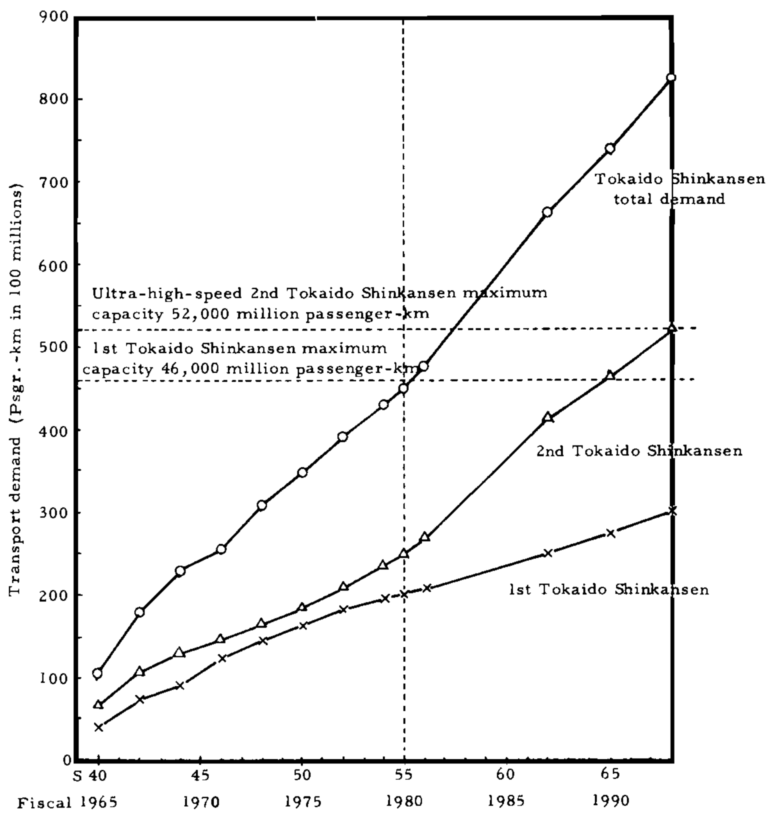


Fig. 21.6. Tokaido Shinkansen (1st and 2nd) demand projection and maximum capacity. *Note:* bottom line represents capacity by Kodama train and middle line by Hikari train, up to 1980.

volume shrank to one-quarter, lowering the rank of the airport to the nineteenth, and it took 7 years to return to the pre-Shinkansen level. The function of this airport in the Tokyo–Nagoya–Osaka trunk air route had disintegrated, narrowing down to interaction with off-route local cities. This is seen in the reduction of the Tokyo–Nagoya flights from eight per day to one; and also, with the load factor at 18% in 1970 and 40.8% in 1975, the flight has become unremunerative.

This change may be understood from the standpoint of time-benefit:

$$\text{Time-benefit} = \text{B-A/C-D}$$

where
A = cost of Shinkansen,
B = cost of flight,
C = time required by Shinkansen,
D = time required by plane.

The time required for travel between CBD of Tokyo and Nagoya is less by the Shinkansen, and, when calculated in money terms, it would not be worthwhile to go by air unless the airline company reimbursed the user at the rate of 20,250 yen per hour.

The advent of the Shinkansen has made it necessary to reexamine the appropriateness of current social overhead investments. Its impact points to a greater need of an integrated transport system, and this deserves attention.

Upon construction of the Sanyo Shinkansen to Hakata, the airports along the newly laid line were greatly affected. Hiroshima and Fukuoka Airports had a reduction of 397,000 and 1,027,000 passengers per year, respectively, after the inauguration of the line, following the same pattern as Nagoya Airport. Air passenger traffic between Tokyo and Fukuoka dropped 16.2% in a year, and that between Osaka and Fukuoka dropped 46.3%. This again indicates the need for an integrated transport system.

THE NUCLEUS-CONTROLLING FUNCTION

It was not only the function of Nagoya Airport that disintegrated after the inauguration of the Shinkansen; the nucleus-controlling function of this city was to face a similar situation. The nucleus-controlling function in Japan disintegrated from the [Tokyo]–[Nagoya]–[Kyoto, Osaka, Kobe] pattern into a bipolar one of [Tokyo]–[Kyoto, Osaka, Kobe], as may be seen from the marginal managerial personnel coefficient shown in Fig. 21.7.

Further, taking the head office function and the financial function (loaning function), a drop was seen not only in Nagoya but also in the Kyoto, Osaka, Kobe area, pointing to the higher degree of concentration of these functions in Tokyo.

This trend was more pronounced in the Stock Market, which has come to be dominated by Tokyo. Of course, the transport revolution by the Shinkansen was not the only cause; added to that were the various forms of information revolution such as data communication, facsimiles, etc. The changes in these functions are given in Table 21.2.

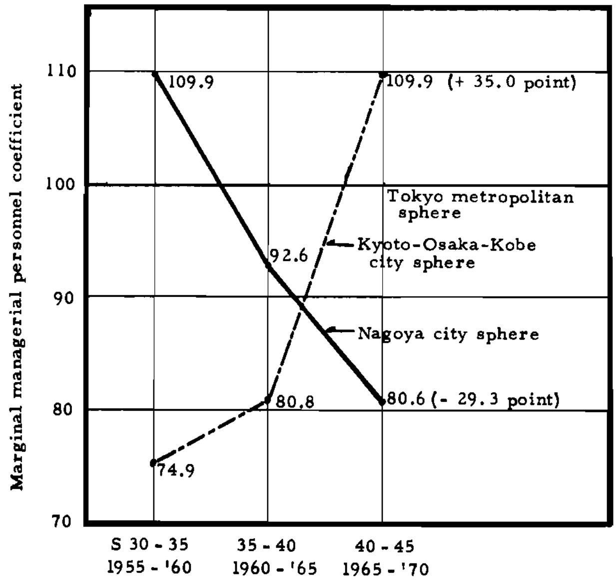


Fig. 21.7. Comparison of growth in nucleus-controlling function. Source: Tosio Sanuki, *Gendai Toshi Ron*, Gakushu Kenkyusha, 1975, p. 311.

TABLE 21.2. *Effect on nucleus-controlling function*
Source: Head Office, Financial and Stock Market Functions

	Difference in growth (Three city spheres)		
City = 100	Head office function	Financial function (loaning)	Stock market function
Tokyo	103.7	105.1	105.1
Nagoya	92.8	92.8	86.8
Osaka	98.3	98.3	95.1

COMMERCIAL AND TOURISM FUNCTION

Wholesale function

As shown in Fig. 21.8, the wholesale function will be reorganized among the base cities, but as the Shinkansen is exclusively a passenger service, it will not have much direct negative effect. Instead, a greater negative effect will most likely be induced by a combination of expanded freight-liner service on the other narrow-gauge lines, new expressways, and data communication systems, which will lead to reorganization of the base cities.

Retail and hotel functions

The inauguration of the Shinkansen had a great effect on the retail function of the cities at which the Shinkansen trains stopped. A typical example is Shizuoka City. Of the retail business of the city, the sale of high-class

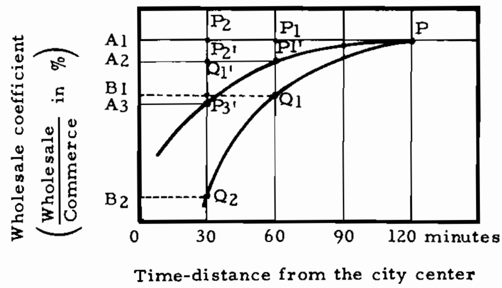


Fig. 21.8. Time-distance and the wholesale function. Source: Tosio Sanuki, *Gendai Toshi Ron,* Gakushu Kenkyusha, 1975, p. 314.

merchandise and fashion goods at specialty shops rapidly fell. But, with the cooperation of the Shizuoka Bank, Shizuoka Economic Research Institute, the local Chamber of Commerce and Industry, and local shopping centers, the city was redeveloped. New management and operational strategies were introduced, which made the city more commercially attractive. This led to subsequent development and growth, proving that negative effects can be reversed to the positive, depending upon the efforts of the local community.

Table 21.3 shows the effect on the retail commercial function and the hotel (tourist industry) function of the cities along the Shinkansen line. Except for cities with deficiencies in city planning, such as Mishima City, considerable positive effect has been seen. This will probably also trigger further development of the cities themselves. The extent of the positive and negative effects on the cities along the Tohoku and Joetsu Shinkansen lines which are still under construction depends, of course, on city planning and other measures yet to be taken.

Rapid growth was seen in the first stage of commercial development in Japan, which followed the pattern: economic growth — income growth —

TABLE 21.3 *Effect of the Shinkansen on commercial and hotel functions*

City		Commercial function		Hotel function	
		Sales increase (%)	Greater prosperity of city (%)	Greater use of hotels (%)	Greater prosperity of city (%)
Along Tokaido Shinkansen	Atami	33.1	16.2	42.5	25.0
	Mishima	25.9	75.8	86.3	24.5
Along Sanyo Shinkansen	Okaya	35.3	78.9	83.3	83.3
	Hiroshima	31.1	80.6	65.3	78.6
	Kita-Kyushu	58.8	74.5	46.2	30.8
	Fukuoka	56.5	95.6	75.0	80.0
Along Tohoku and Joetsu Shinkansen	Morioka	69.5	86.2	85.7	100.0
	Sendai	64.1	84.6	64.3	85.8
	Niigata	58.7	100.0	68.8	93.8
	Takasaki	50.0	91.0	40.0	80.0

refinement, diversification, and uniqueness of commodities. In this phase there was competition between shops. In the second phase, along with the advancement in urbanization, city redevelopment took place, and the competition was between shopping centers. In the third phase, owing to the transport revolution by the Shinkansen, the competition was between cities. Moreover, along with the advancement of urban redevelopment projects prompted by the inauguration of the Shinkansen, the function of cities as commercial bases is being reoriented, and this leads to competition between shopping centers within the cities themselves.

It should now be clear that whether or not the fullest use will be made of the effects of the Shinkansen depends on how appropriate the city planning, land-use system, and the underlying software system have been in bringing city functions into full play.

General Appraisal of the Shinkansen

It would be a mistake to make an appraisal of the Shinkansen per se. This should rather be made from the viewpoint of the positive and negative effects on Japan as a whole and on each city, and whether the strategies for augmenting the positive and reducing the negative have been successful.

MULTIPLE PRODUCTIVITY

For appraisal of the Shinkansen from the standpoint of an integrated transport system, Table 21.4 and Fig. 21.9 compare its efficiency with that of aircraft. It is found that in each of six productivities, the efficiency of the Shinkansen is two to nine times higher than that of aircraft.

TABLE 21.4. *Comparison of efficiency of Tokaido Shinkansen and aircraft*

		Unit	Tokaido Shinkansen	Aircraft
Capital productivity	(A) Annual capital charges on ground installations	Passenger-km/yen	0.62 (1.82)	0.34
	(B) Annual capital charges on vehicle and plane	Passenger-km/yen	1.41 (5.64)	0.25
Land productivity (Transport efficiency per unit of Tokyo–Nagoya–Osaka right-of-way land area)		(A) Passenger-km/m^2	3261 (3.34)	976
		(B) Passenger/m^2	11.11 (3.97)	2.80
Labor productivity (no. of passengers per employee)		Million passenger-km/employee	2.9 (2.64)	1.1
Energy productivity		Passenger-km/kcal	0.96 (8.81)	0.11

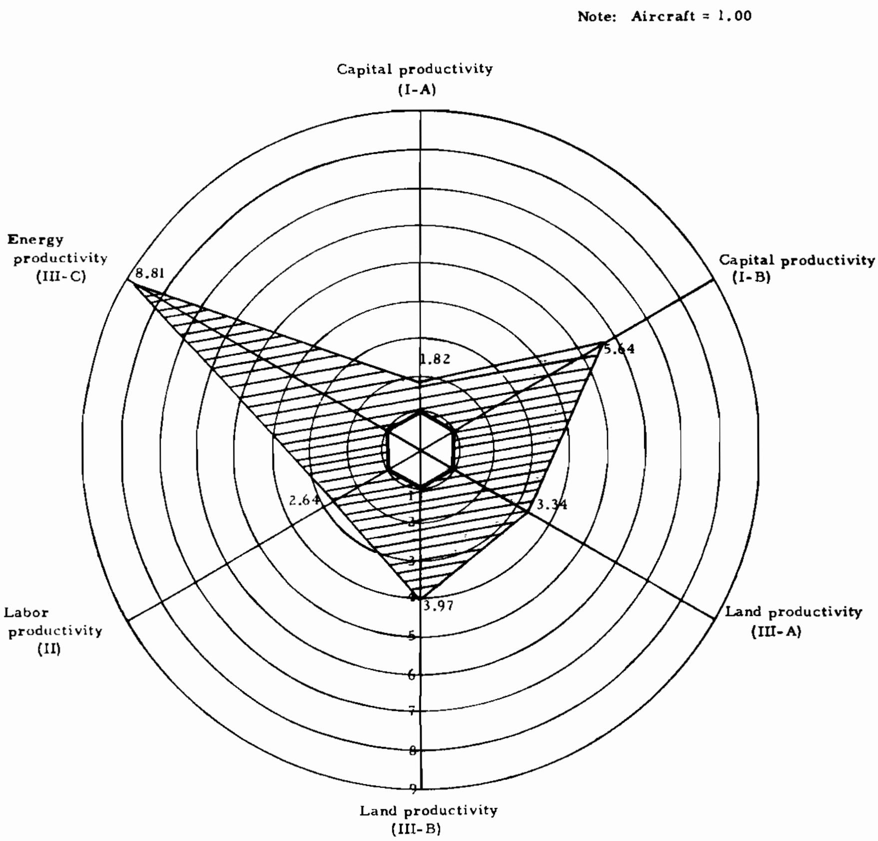


Fig. 21.9. Efficiency of Tokaido Shinkansen compared with aircraft.

SAFETY

Despite the tremendous volume of over 1000 million passengers carried by the Shinkansen since its inception, there has not been a single casualty. Taking JNR as a whole as 1, with its other lines included, the incidence of deaths in the case of private railways is 5, that for aircraft is 166, and for motor vehicles 611, as shown in Table 21.5.

TIME-BENEFIT

The Shinkansen offers its passengers a great advantage over aircraft, as shown in Table 21.6. A problem lies in how long, ergonomically speaking, a passenger can tolerate sitting in the same seat. This is a determinant to the passenger in selecting the means of transport. Taking this factor into account, in Japan the 50-70-km range suits the non-Shinkansen railways and automobiles, 70-600 km suits the Shinkansen, and over 600 km is appropriate for aircraft.

TABLE 21.5. *Safety of different means of transport*

			Traffic volume (A) (100 million passenger-km)	Passenger deaths (B) (Persons)	Casualty rate (B/A)	Index
Railways	JNR	Shinkansen	2551	0	0.000	0
		Other lines	16,468	54	0.003	1
		Total	19,019	54	0.003	1
	Private railways		9473	146	0.015	5
Aircraft			878	437	0.498	166
Motor vehicles			24,715	45,338	1.834	611

TABLE 21.6. *Time-benefit of the Shinkansen compared with aircraft*

			Between Tokyo and Osaka	Between Tokyo and Nagoya
Cost to user	Shinkansen	(A)	8300 yen	5700 yen
	Aircraft	(B)	14,900 yen	11,100 yen
Time required	Shinkansen	(C)	3h 10 min	2h 01 min
	Aircraft	(D)	2h 05 min	2h 05 min
Difference	Difference in cost (B-A)		+ 6600 yen	+ 5400 yen
	Difference in time (C-D)		1h 05 min	-0h 04 min
Time benefit (B-A/C-D)			6094 yen/h	-20,250 yen/h

It will therefore be necessary to create a transport network according to this concept, and to shape the future image of Japan accordingly.

While the spatial distance has remained the same, faster means of transport is shrinking the time-distance between Tokyo and local cities, as shown in Fig. 21.10, and the configuration is coming closer to a circle. On the other hand, the time-distance within the city sphere may possibly lengthen, depending on how the urban transport system is to be formed, as shown in Fig. 21.11.

Conclusion

Figure 21.12 is obtained when the volume of passenger traffic between the Tokyo–Yokohama–Chiba region and other regions is estimated using the gravity model and the Fratar method to form a nationwide Shinkansen network, based on the preceding studies and in the context of an integrated transport system. Further, an estimate of the interregional passenger traffic OD structure and the share to be borne by the Shinkansen and aircraft, based on the above estimated values, gives Fig. 21.13. It is seen that there is a clear demarcation in the spheres of activity of the two.

In these circumstances land development must be carried out accordingly when shaping the future of Japan. Limitations of space permit only three

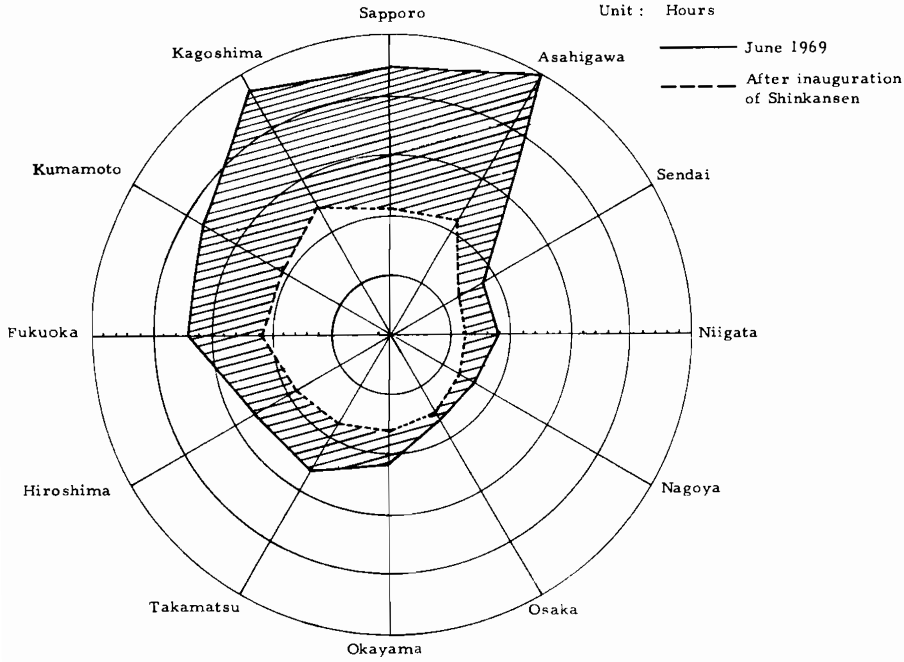


Fig. 21.10. Change in time-distance from Tokyo by JNR.

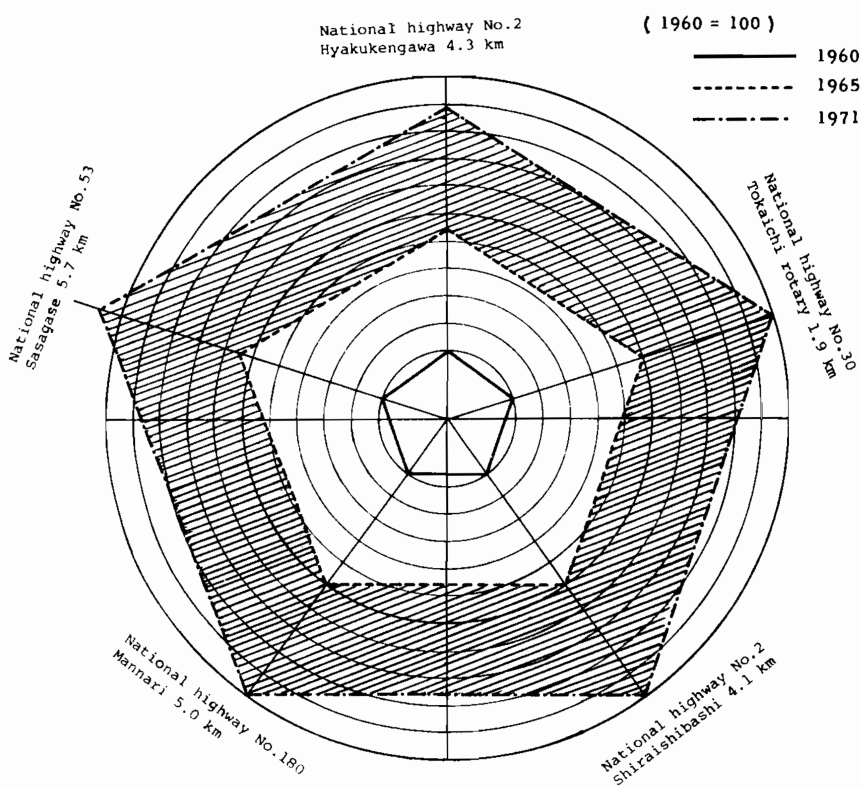


Fig. 21.11. Change in time taken from Okayama Station.

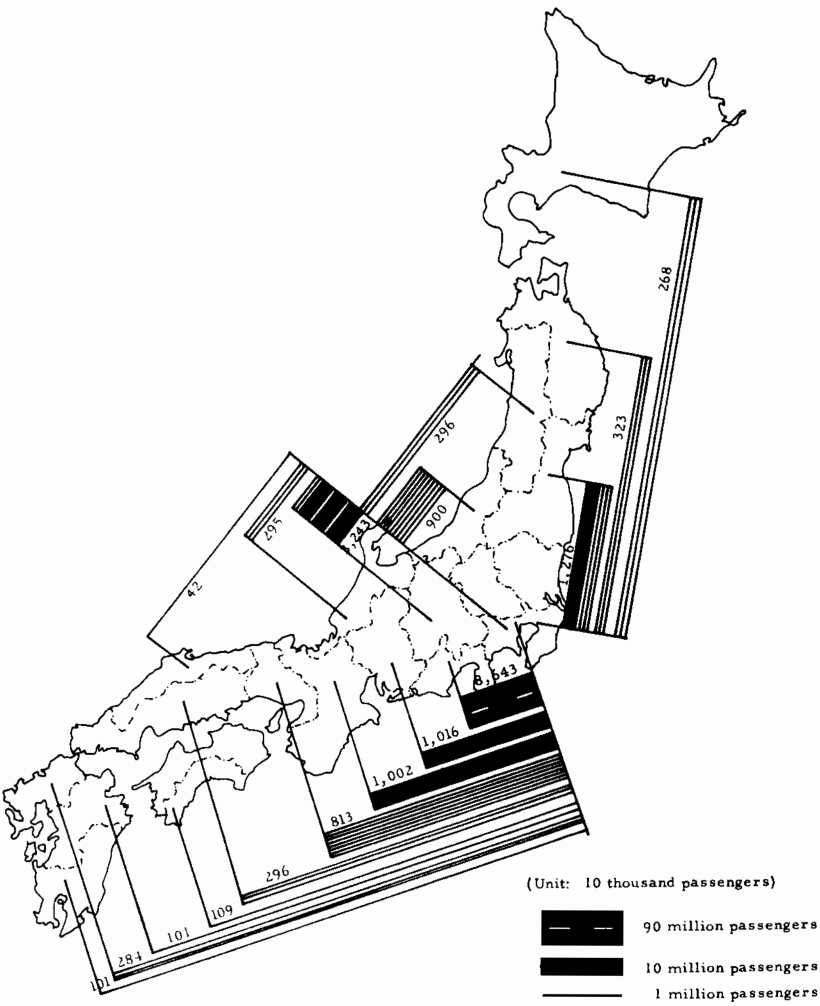


Fig. 21.12. Estimation of passenger traffic volume between the Tokyo–Yokohama–Chiba Region and other regions.

additional figures to expand and illustrate this idea. The first (Fig. 21.14) is a flow chart of the twenty-first-century image of Japan as conceived by the Kenzo Tange Group, of which the author was a member engaged in the task of compilation. The second (Fig. 21.15) shows the software system for realization of the image, and the third (Fig. 21.16) is a flow chart for remodeling the Japanese Archipelago.

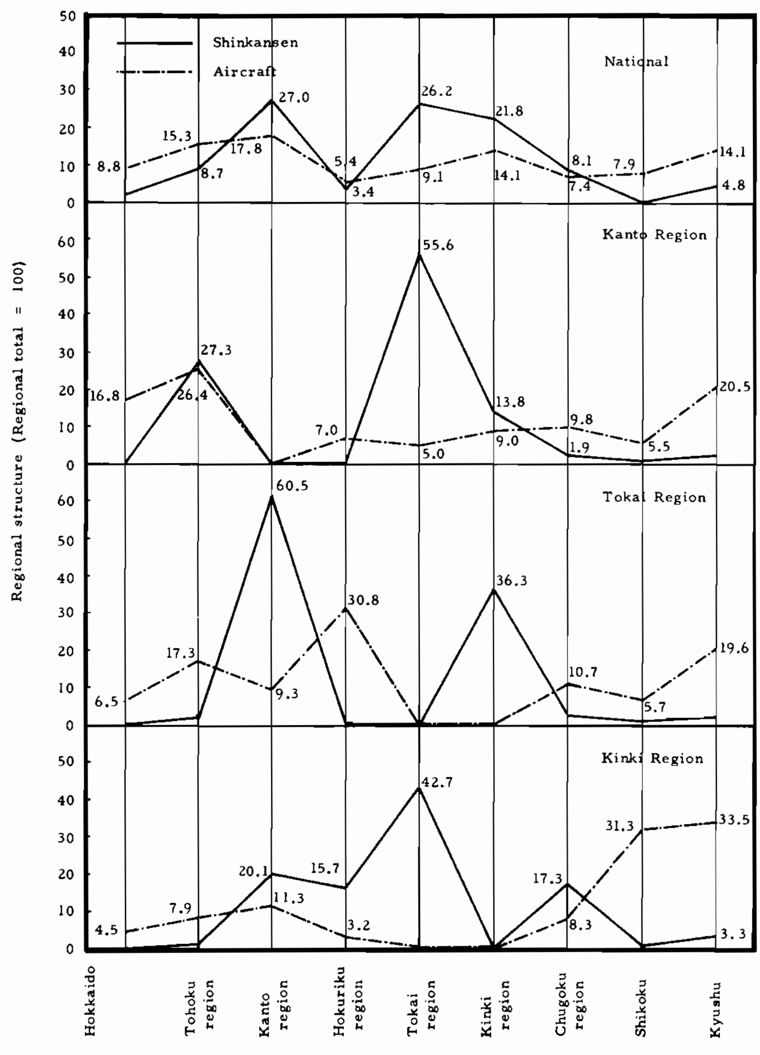


Fig. 21.13. Interregional OD structure of Shinkansen and aircraft passenger traffic (extra-regional passengers-origin basis).

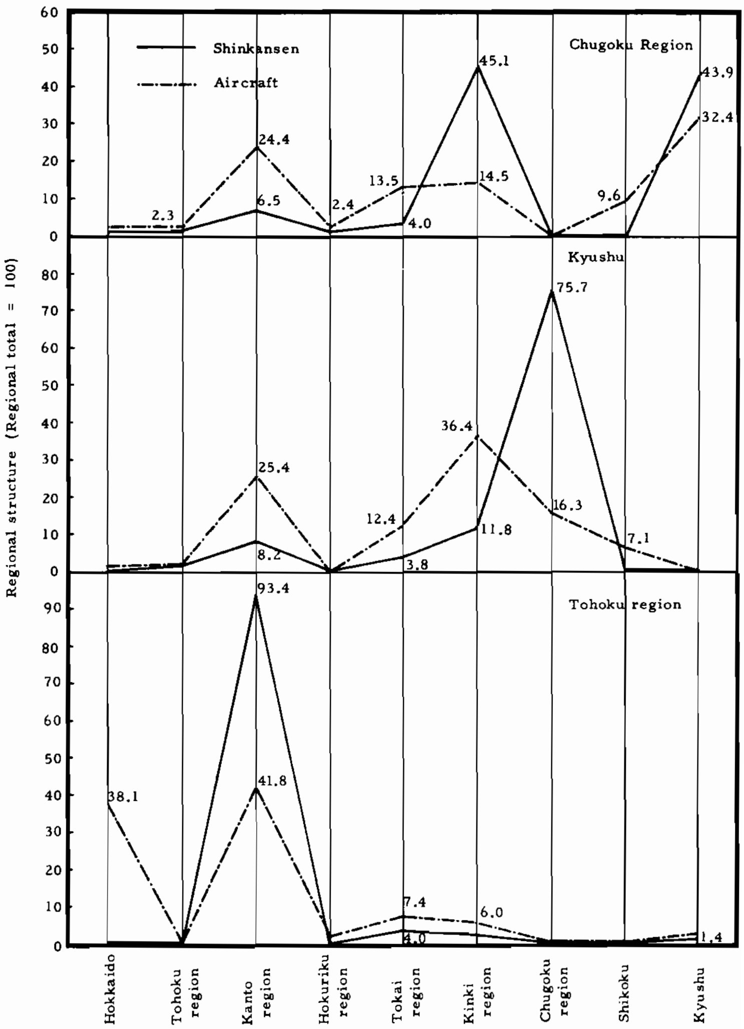


Fig. 21.13. continued.

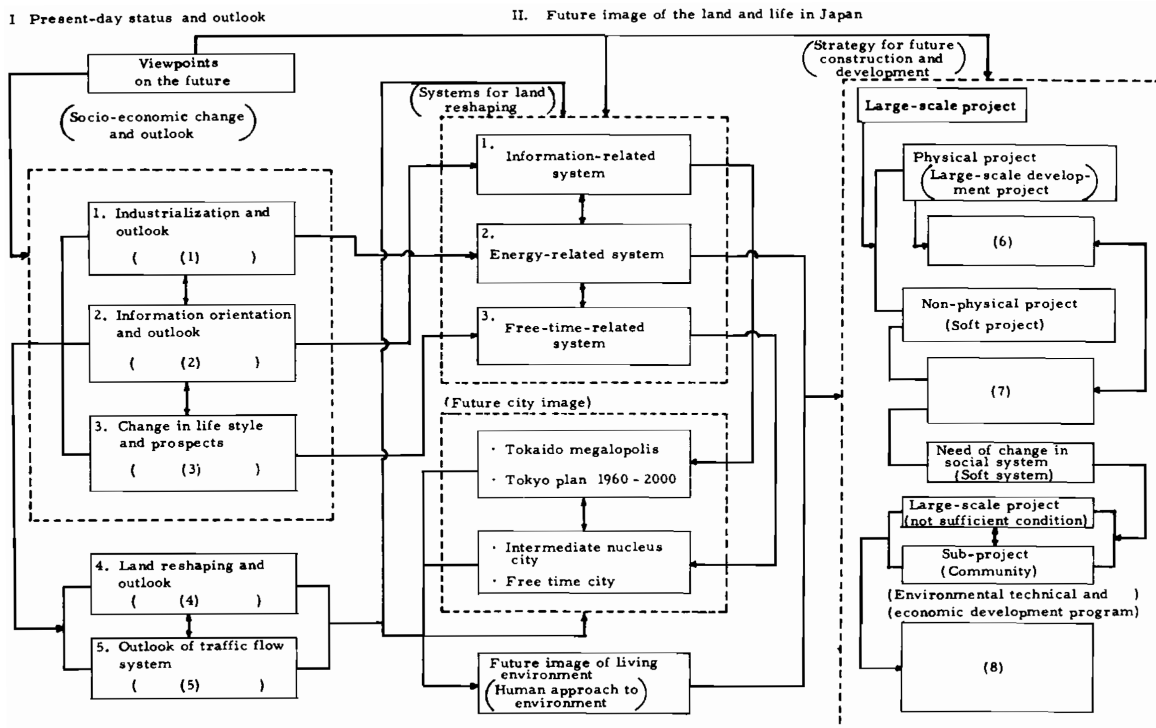


Fig. 21.14. System for twenty-first-century image of Japan (Kenzo Tange Group). (For items indicated by numbers in parentheses, see the next page.)

Numbers in Parentheses in Figure 21.14

(1) Industrialization
- (a) Information and system orientation of industry
- (b) Outlook of industry placement
- (c) Future industry

(2) Urbanization
Information orientation
Internationalization
- (a) Transition to urbanized and information-oriented society
- (b) Outlook of knowledge, information and technological industries (information industry complex)
- (c) Information-oriented society and internationalization system

(3) More free time
- (a) From spare time to free time
- (b) System for feedback with community
- (c) Creative society and free time

(4) (a) Imbalance of high-density concentrations
- (b) Population, economic, city, and regional model (dynamo model)

(5) (a) Formation of transport system and outlook
- (b) Transport and information system

(6) (a) Transport and information network
- (b) Environment development project
- (c) Large-scale industrial development project
- (d) Large-scale recreation project

(7) (a) Medical care system
- (b) Environmental system
- (c) Educational system
- (d) Technological system
- (e) Executive, legislative and judicial system
- (f) Other social systems

(8) (a) Involvement in international large-scale projects
- (b) Transition from physical large-scale projects under the Concept of the New National Comprehensive Development Plan to the non-physical large-scale project era

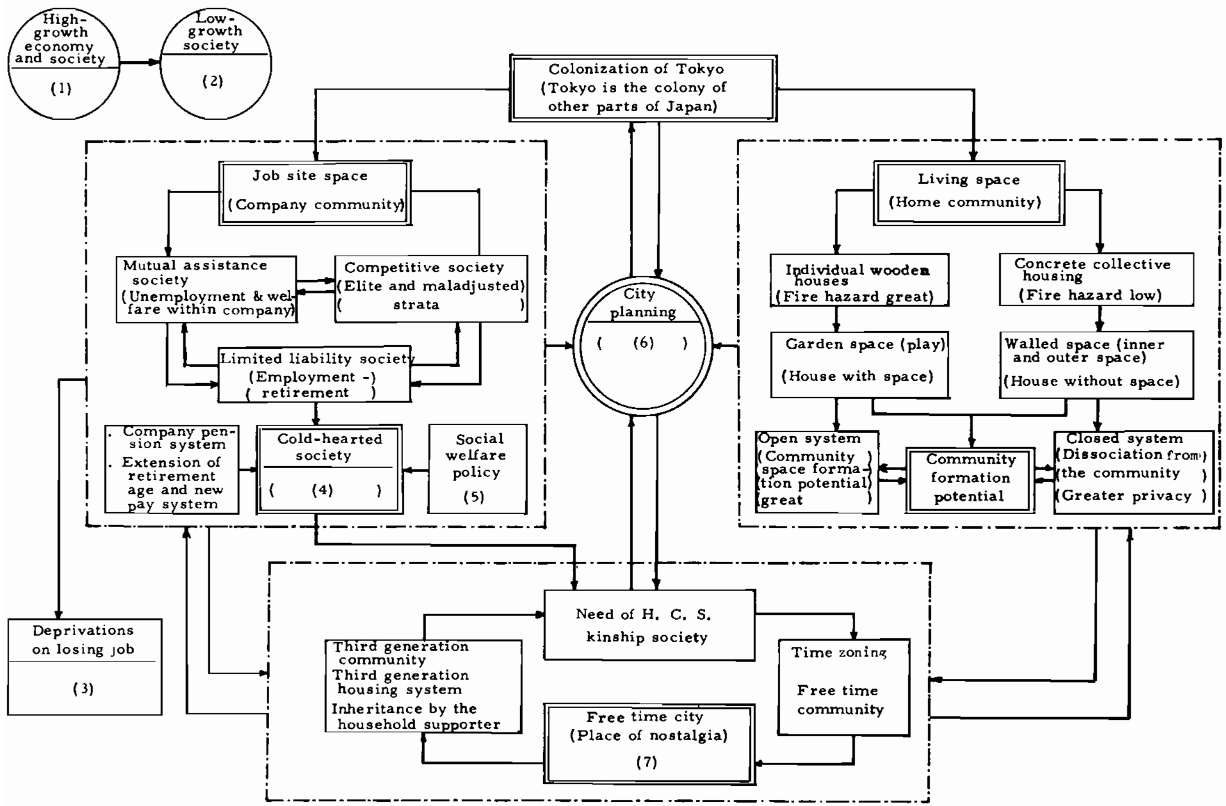


Fig. 21.15. City planning philosophical conceptual model. (For items indicated by numbers in parentheses, see the next page.)

Numbers in Parentheses in Figure 21.15

(1) (a) Ultra-full-employment society
(b) Rapid rise in income
(c) Acceleration of population movement
Concentration of the young in cities

(2) (a) Chronic unemployment society
(b) Stagnation of income
(c) Shrinkage in population movement scale
Concentration of unemployed in cities

(3) (a) Salary and wages
(b) Company residence and office
(c) Health and unemployment insurance
(d) Secretary and expense account
(e) Company car

(4) (a) Stringency by low-growth
(b) Mental and livelihood relief
(c) Sense of self-reliance and support

(5) (a) Old age pension
(b) Medical care for the aged
(c) Unemployment insurance
(d) Health insurance

(6) Creation of human environment
(a) Hard—physical
(b) Soft—metaphysical

(7) Home town
(a) 1st—birthplace
(b) 2nd—place of education and employment
(c) 3rd—free time after retirement

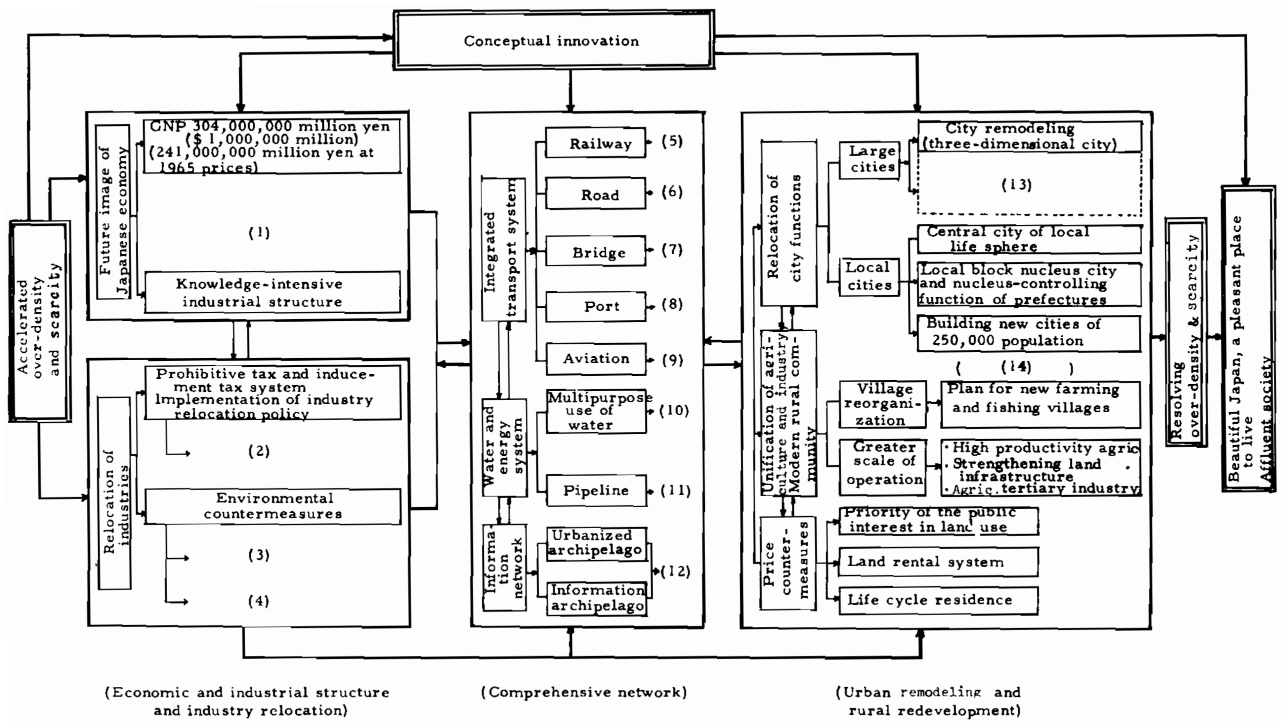


Fig. 21.16. Remodeling the Japanese Archipelago conceptual flow chart. (For items indicated by numbers in parentheses, see the next page.)

Numbers in Parentheses in Figure 21.16

(1) Industrial output 273,000,000 million yen
Industrial land 280,000 ha
Industrial water 93.7 million m^3/a
Freight traffic 1,320,000 million t/km
Annual income per working capita 3 million yen

(2) Large-scale industrial base (5 places)
Middle-scale littoral industrial bases (14-15 places)
Inland industrial complex construction

(3) Restriction on total emission (environmental capacity)
Development of preventive technology
Green belts

(4) Industrial bases
Industrial parks with less pollution

(5) Shinkansen (9,000 km or over)
Strengthening other lines
Reassessment of local lines

(6) Expressway (10,000 km or over)
Loop expressway
Green promenade

(7) 3 Honshu-Shikoku bridges
Development of Shikoku and Kinki region
Connection with Sukumo and Tokushima

(8) Large industrial port
Distribution port
Local trade port

(9) Jumbo. STOL
Aviation network
Airport industrial complex

(10) Dams at 1,000 places
Development of water production plants

(11) Water pipeline
Oil pipeline

(12) Data transmission network
Feedback system

(13) International nucleus function
Urban development public corporation
Suburban development

(14) Industry capital
Dispersion of academic cities

22. *Comprehensive National Development Plans in Japan: Their Logic and Reality*

K. MIYASAWA

1. Logical Structure of Regional Development Problems in Japan

1.1. POLICY, STATE, TARGET

Japan is divided into 47 administrative regions called prefectures, and each prefecture is divided into several administrative regions called cities. The administrative organization has a hierarchical structure consisting of three strata; under the central government there are several prefectural authorities under each of which are several city authorities (Fig. 22.1).

Let us denote by G_n a plan of the central government for the work and construction related to land, water, and space, and let us denote by I_n its plan for public investment, fiscal measures, etc., related to G_n. We call the set $S_n \equiv (G_n, I_n)$ a development *policy* of the central government or of the nation. Let Σ_n be the set of all possible policies of the nation. Similarly we define (development) policies S_p, S_c and the sets of policies Σ_p and Σ_c of a prefecture p and a city c, respectively.

When the central government is going to implement a policy S_n, if a policy S_p of a prefecture p is not one which is the realization of S_n with respect to the prefecture p, i.e. if S_p contradicts S_n in a logical sense, then it is not possible to implement both S_n and S_p simultaneously. For example, when S_n implies construction of a railway network through all the prefectures in the country, if S_p implies that a prefecture p will not construct a railway in the prefecture, then it is not possible to implement S_n and S_p simultaneously.

Let the set of all policies S_p of a prefecture p which do not contradict S_n, i.e. those which can be implemented with S_n simultaneously, be denoted by $\sigma_p(S_n)$. Generally, a policy S_n of the nation will be stated in a rather general, abstract form and a policy S_p of a prefecture p will be stated in a more concrete form. Therefore it may happen that S_p refers to items which are not referred to in S_n. Even in such cases, so far as S_p does not contradict the general statements of S_n, we understand that S_p can be implemented with S_n, i.e. $S_p \in \sigma_p(S_n)$. Accordingly, the set $\sigma_p(S_n)$ may consist of many policies of a prefecture p. Similarly we define the set $\sigma_c(S_p)$, $c \in p$, where $c \in p$ means that a city c is in a

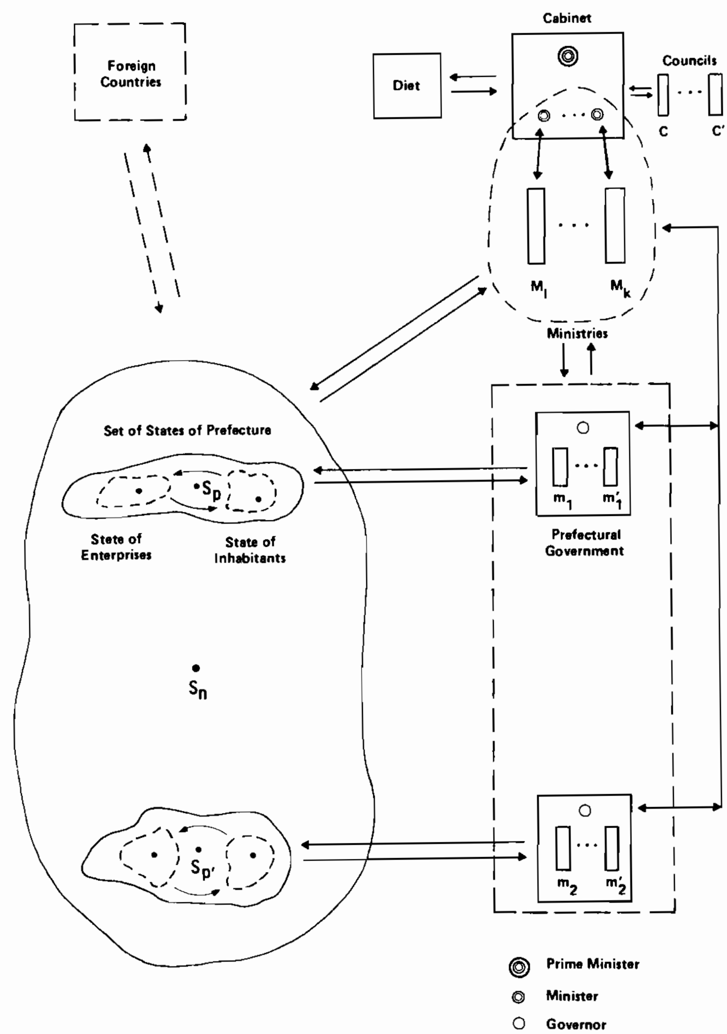


Fig. 22.1. Set of states of nation.

prefecture p. Conversely, for instance, when a city c is going to implement a policy S_c a prefecture $p(\in c)$ is not one such that $S_c \in \sigma_c(S_p)$, then it is not possible to implement both S_c and S_p simultaneously.

Definition 1 (Consistency among policies)

If $S_p \in {}_p(S_n)$, we say that S_p is *consistent* with S_n. If each of the policies of the set $\{S_p, \forall p\}$ is consistent with S_n and all the policies of the set can be implemented simultaneously, then we say the set of the policies $\{S_p, \forall p\}$ is *consistent* with S_n. Similarly we define the consistency relation between S_p and S_c, $\forall c \in p$, $\forall p$. Finally, if the set $(S_p, \forall p)$ is consistent with S_n and the set

(S_n, $\forall c \in p$) is consistent with S_p, $\forall p$, then we say the policies S_n; S_p, $\forall p$; S_c, $\forall c$ are *consistent*.

Proposition 1. The central government, all the prefectures and all the cities can implement their policies S_n; S_p, $\forall p$; S_c, $\forall c$ simultaneously if and only if they are consistent.

An example of the case where each S_p is consistent with S_n, but where the set of such policies $S_p, \forall p$ cannot be implemented simultaneously, will be given as follows. Let S_n be a policy of the central government which implies constructing an art gallery in one prefecture by granting it a subsidy of 1 million dollars. Then for each prefecture p, a policy S_p which implies constructing an art gallery by getting the subsidy from the Government is consistent with S_n. But it is not possible to implement such policies S_p, $\forall p$ for all prefectures because the government can grant a subsidy of 1 million dollars to only one prefecture.

Now let us define a *state* s_ν, $\nu = n, p, c$, of the administrative region ν as a detailed objective statement concerning everything in the region ν, where $\nu = n, p, c$ means the nation, a prefecture, and a city, respectively. Of course, a state s_ν is meant as being at a specific time point t, and ought to be written $s_\nu(t)$, but for simplicity, we shall often omit the t.

From our definition, a state s_ν may consist of an infinite number of components, but a person facing a state s_ν will recognize only a finite number of components of s_ν. So, we denote a state recognized by a person as $R(s_\nu) = s_\nu$ and call s_ν a recognized state. Then the following should be noted:

1. There are many states s_ν which give the same recognized state s_ν, i.e. for a given recognized state $\tilde{s}_\nu$ there are many s_ν such that $R(s_\nu) = \tilde{s}_\nu$.
2. It is possible that the recognized state $\tilde{s}_\nu$ of the state $\tilde{s}_\nu$ may differ depending on who is recognizing it, i.e. depending on what components of s_ν are being recognized. Therefore it is quite natural that the different evaluations of the state s_ν may occur among different people for this reason.

When s_ν is a state of the nation, let the statement concerning a prefecture p in s_n be denoted by $[s_n]_p$ and call it the projection of s_n on a prefecture p. Similarly we shall define the projection of s_p on a city $c \in p$ and call it $[s_p]_c$. If the state of the nation, a prefecture p, and a city $c \in p$ at the time-point t are $s_n(t)$, $s_p(t)$, and $s_c(t)$, respectively, then it should follow that $s_p(t) = [s_n(t)]_p$ and $s_c(t) = [s_p(t)]_c$.

When the state of the nation at the time-point t is $s_n(t)$, it could be assumed that the state $s_n(t + \Delta t)$ of the nation at the next time-point $(t + \Delta t)$ is determined by the consistent policies S_n; $S_p, \forall p$; $S_c, \forall c$ taken by the nation, the prefectures and the cities, and by many other factors which we shall denote in a lump by $U(t)$. For convenience we shall express the relation as follows:

$$s_n(t+\Delta t) = \Phi(S_n; S_p, \forall p; S_c, \forall c \mid s_n(t), U(t)), \qquad (*)$$

and, as stated above, the states $s_p(t+\Delta t)$, $s_c(t+\Delta t)$ of a prefecture p and a city c at the time-point $(t+\Delta t)$ are given by:

$$s_p(t+\Delta t) = [\Phi(S_n; S_p, \forall p; S_c, \forall c \mid s_n(t), U(t))]_p, \qquad (**)$$

$$s_c(t+\Delta t) = [[\Phi(S_n; S_p, \forall p; S_c, \forall c \mid s_n(t), U(t))]_p]_c, \qquad (***)$$

When a regional development becomes an issue, it will be disputed whether it will bring about a desirable future state. Now, let the set of all the recognized state $\tilde{s}_v$ with which the administrative authorities v will be satisfied if it could be brought about in the future by a certain regional development be denoted by $\tilde{\Delta}_\nu$ and call it a *(development) (recognized) target.* Let the set Δ_ν be defined by

$$\Delta_\nu \equiv \{ s_v ; R(s_v) \in \tilde{\Delta}_\nu \}$$

and call it a *(development) target* of $v, v = n,p,c$. From the definition it is clear that Δ_ν is determined only by the values of the components of s_v which specify a recognized state $\tilde{s}_v$ and is free from the values of other components of s_v. *In* that sense $\tilde{\Delta}_\nu$ may be said to be a cylinder set. There will be the problem of who will specify a target $\tilde{\Delta}_\nu$, but we assume that when we say, for instance, that $\tilde{\Delta}_p$ is the target of a prefecture p, it is the target of the people of the prefecture p as well as that of the prefectural authorities. For the assumption to hold, it may be necessary to go through some democratic discussions between the authorities and the people of the prefecture, but we shall not enter into this problem here.* We assume the same assumption also applies to $\tilde{\Delta}_n$ or $\tilde{\Delta}_c$.

At a time when public awareness of regional development problems was not great, it is clear that even if the target $\tilde{\Delta}_n$ of the nation is being set up, the targets $\tilde{\Delta}_p$ and $\tilde{\Delta}_c$ of the prefectures and the cities are not set up explicitly. Such cases will be considered in Cases (I.1) and (I.2). Recently, however, the awareness and concern of the public concerning regional development has been increasing and the nation, the prefectures and the cities are setting up their respective targets $\tilde{\Delta}_n$, $\tilde{\Delta}_p$, and $\tilde{\Delta}_c$ of regional development. In such a situation, the kind of problems connected with regional development will be studied later in Cases (II.1), (II.2), and (II.3).

We define a policy S_n of the nation as *desirable* if it is judged that a desirable state $\tilde{s}_n \in \tilde{\Delta}_n$, i.e. a certain state s_n such that $s_n \in \Delta_n$ will be brought about in the future when the policy S_n is implemented simultaneously with the policies $S'_p, \forall p; S'_c, \forall c$ such that $S_n; S'_p, \forall p; S'_c, \forall c$ are consistent. Let us denote the set of all desirable policies of the nation by $O(\Sigma_n)$. Similarly let us define a policy S_p of a prefecture p as *desirable* if it judged that a desirable state $\tilde{s}_p \in \tilde{\Delta}_p$, (i.e. a certain state s_p such that $s_p \in \Delta_p$) will be brought about when the policy S_p is implemented simultaneously with the policies $S'_n; S'_p, \forall_p \neq p; S'_c, \forall c$ such that $S_n; S_p, S'_p, S'_p, S'_c, \forall c$ are consistent. Let the set of all desirable policies of a prefecture p be denoted by $O(\Sigma_p)$. Similarly we define a desirable policy of a city as the set $O(\Sigma_c)$. (The reason we so define a desirable policy comes from the relations (*), (**), and (***).)

Even though we have assumed, for example, that the prefectural authorities and the people of the prefecture agree concerning the target $\tilde{\Delta}_p$, the following problems may arise. Let S_p be a desirable policy from the viewpoint of the prefectural authorities because they judge that the policy S_p will bring about,

*This is the same problem as one to be considered later as Case (II.3). The paper does not take into account the residents of a city explicitly, but it should be noted that the logic studied in the paper does not depend on the number of levels of the hierarchy.

with other consistent policies, a state s_p such that $s_p \in \tilde{\Delta}_p$. But the people of the prefecture may judge that the policy S_p will bring about, with other consistent policies, a state s_p such that $\tilde{s}_p \notin \tilde{\Delta}_p$ and the people object to the policy S_p. In fact, as is seen in (*), (**), and (***), the future state s_p depends not only on the policy S_p but also on many other unpredictable factors such as $U(t)$. So it is quite possible for such disagreements to occur. We assume, however, that by a certain democratic procedure the authorities and the people of the prefecture have reached the same opinion concerning whether the policy S_p, with other consistent policies, will bring about a state s_p such that $\tilde{s}_p \in \tilde{\Delta}_p$ or such that $s_p \notin \tilde{\Delta}_p$. Therefore $O(\Sigma_p)$ is the set of desirable policies S_p for both the authorities and the people of a prefecture p. We assume the same condition concerning $O(\Sigma_n)$ and $O(\Sigma_c)$.

1.2. WHEN ONLY THE TARGET $\tilde{\Delta}_n$ IS BEING SET UP

In the case where the central government has been setting up its recognized target $\tilde{\Delta}_n$ but the prefectures and the cities do not have advance knowledge of their recognized targets $\tilde{\Delta}_p$, $\forall p$ and $\tilde{\Delta}_c$, $\forall c$, the decision procedure of the policies of the prefectures and the cities has followed one of the following two cases in Japan.

Case (I.1)

When the entire population is united in attaining the target $\tilde{\Delta}_n$ of the nation, the policies of the prefectures and the cities will simply be determined by the following process. Once the central government expresses its policy S_n to attain the target $\tilde{\Delta}_n$, the prefectures and the cities will gladly take the policies S_p and S_c such that S_n; S_p, $\forall p$; S_c, $\forall c$ are consistent. So this is no problem.

It will be shown in Section 2 that in Japan the following case has often occurred.

Case (I.2)

First, the central government sets up a target $\tilde{\Delta}_n$ of the nation and states that it will adopt a policy $S_n \equiv (G_n, I_n)$ which is judged to bring about (with the consistent policies of the prefectures and the cities) a desirable recognized state $\tilde{s}_n \in \tilde{\Delta}_n$, i.e. a state $s_n \in \Delta_n$, where I_n implies the following. If a prefecture p is going to cooperate with the central government by accepting a policy S_p such that $S_p \in \sigma_p(S_n)$, then the government will offer an *inductive policy measure* D_n to the prefecture p. Here an inductive policy measure D_n usually means that the government will give a prefecture: (1) a favorable fiscal policy such as a public investment and/or a subsidy; (2) a favorable taxation system; (3) a favorable financial policy such as a low interest rate, long-term loan, etc. Therefore, a prefecture p which is offered an inductive policy measure D_n will be able to extend its original set of policies Σ_p and let the extended set of policies be denoted by $\Sigma_p(D_n)$. At the same time, a prefecture p being offered an inductive policy measure D_n is required to accept a policy S_p such that $S_p \in \Sigma_p(D_n) \cap \sigma_p(S_n)$. On the other hand, if a prefecture p accepts a policy $S_p \in \Sigma_p(D_n) \cap \sigma_p(S_n)$, then, usually, it is almost certain that the policy S_p (with S_n and other consistent policies) will bring about a much more desirable state than the present state of the prefecture. So it is natural that a prefecture p will set up a new target $\tilde{\Delta}_p$ which consists of the above state and other states that are more desirable, at least, than the present state, and will endeavor to obtain the inductive policy measure from the government, explaining to the people that it will enable the prefecture to attain the target $\tilde{\Delta}_p$. Therefore, in this case, there will be keen competition between the prefectures to obtain the more favorable inductive policy measure from the government. In Japan, a "petition battle" developed among the prefectures, which had the effect of strengthening the authority and power of the central government.

In this way, the prefectures will finally be induced to accept the policies S_p, and similarly the cities will be induced to accept the policies S_c such that S_n; $S_p, \forall p$; $S_c, \forall c$ are consistent. In this case the nation, the prefectures, and the cities can all be satisfied by accepting such policies.

Now, let me make the following remark. It will take a considerable time to complete the implementation of the policy S_n which is considered desirable by the government. During that time, owing to the unexpected change of $U(t)$, the recognized state $\tilde{s}_n(t)$ may take an undesirable course of change:

1. The establishment of a certain mechanism with the following function will therefore be requested. Once the state $\tilde{s}_n(t)$ begins to show a movement that does not lead to the target $\tilde{\Delta}_n$, the information is rapidly transmitted to the government, which will modify the policy S_n according to this information so that the movement of $\tilde{s}_n(t)$ will tend to $\tilde{\Delta}_n$.
2. In regional development, however, it will be almost impossible to change the policy S_n so often in a short period of time. For instance, it will be very difficult in practice to suspend railway construction work which is in progress or to change the course of a railway once it has been built. Therefore it is obvious that in deciding a development policy we must give careful consideration to the future and prudently perform the environmental assessment, etc.
3. After implementing a policy S_n, even if the target $\tilde{\Delta}_n$ has not been attained, it often happens that it has not been made clear who should be responsible for the failure. It may be because the future state $s_n(t)$ is determined not only by the policy S_n but also by many other factors such as $U(t)$, which is beyond the control of those concerned with the development program. Even so, it is hoped to establish an organization which will make clear where the responsibility lies in the processes of decision and policy implementation.

1.3. WHEN THE TARGETS $\tilde{\Delta}_n$, $\tilde{\Delta}_p$, $\tilde{\Delta}_c$ ARE ALL BEING SET UP

Recently, as a result of the upsurge of public interest in regional development, not only the central government but also the prefectures and the cities have been setting up their recognized targets $\tilde{\Delta}_n, \tilde{\Delta}_p, \tilde{\Delta}_c$, respectively, and as a result serious trouble has occurred over regional development problems. We would like to find the source of such troubles. For that we define

Definition 2 (Consistency among the targets)
We say that the recognized targets $\tilde{\Delta}_n$; $\tilde{\Delta}_p$, $\forall p$; $\tilde{\Delta}_c$, $\forall c$ of the government, the prefectures, and the cities are *consistent* if there exist their policies S_n; S_p, $\forall p$; S_c, $\forall c$ such that

(1) $S_n \in O(\Sigma_n)$; $S_p \in O(\Sigma_p)$, $\forall p$; $S_c \in O(\Sigma_c)$, $\forall c$,
(2) and they are consistent.

Then we have the following:

Proposition 2. Under the hierarchical structure of administration such that at the top there is the central government, under which there are several prefectures, and under each prefecture several cities, there can exist their policies S_n; S_p, $\forall p$; S_c, $\forall c$ such that they can be implemented simultaneously, and the central government, the prefectures, and the cities can all be satisfied by accepting those policies, respectively, if and only if the recognized targets $\tilde{\Delta}_n$; $\tilde{\Delta}_p$, $\forall p$; $\tilde{\Delta}_c$, $\forall c$ that they are setting up in advance are consistent.

Proof. If conditions (1) and (2) hold, then because of condition (2), all the policies S_n, S_p, and S_c can be implemented simultaneously. Therefore, by (*), (**), and (***) in Section 1.1, they will bring about the states s_n, s_p, and s_c such that $s_p = [s_n]_p$, $s_c = [s_p]_c$, $c \in p$. Further, from condition (1) and the definition of the set $O(\Sigma_v)$, $v = n,p,c$, the government, the prefectures, and the cities are judging, respectively, with regard to these states s_n, s_p, and s_c that $R(s_n) = \tilde{s}_n \in \tilde{\Delta}_n$, $R(s_p) = \tilde{S}_p \in \tilde{\Delta}_p$ and $R(s_c) = s_c \in \tilde{\Delta}_c$. Accordingly, the government, the prefectures, and the cities are all satisfied with the policies S_n, S_p, and S_c, respectively. The truth of the converse is clear.

As an example, let the target $\tilde{\Delta}_p$ of a prefecture p imply the construction of a sewage-disposal plant somewhere in the prefecture. This is a target which all the inhabitants of the prefecture agree with. On the other hand, let the target $\tilde{\Delta}_c$ of a city $c \in p$ imply that the sewage-disposal plant should not be constructed in the city c, $\forall c \in p$. Then it is clear that $\tilde{\Delta}_p$, $\tilde{\Delta}_c$, $\forall c \in p$ are not consistent. This is the situation where all the inhabitants of the prefecture want to have a sewage-disposal plant in the prefecture, but any one of them is against the construction of the plant in his city. Where should the plant be built?

As can be seen from this example, it seems that the difficulties we face today in the regional development problems basically come from the fact that the targets $\tilde{\Delta}_n$; $\tilde{\Delta}_p$, $\forall p$; $\tilde{\Delta}_c$, $\forall c$ which are being set up by the hierarchical administrative authorities are not consistent. For, in such a case, by Proposition 2 it will be impossible to discover the policies which all the administrative authorities are satisfied with. Then what should be done? Let me refer to a couple of cases.

Case (II.1)

First, the central government sets up the recognized target $\tilde{\Delta}_n$ and announces a policy S_n, saying that it will bring about a desirable recognized state $\tilde{s}_n \in \tilde{\Delta}_n$ if the prefectures and the cities cooperate with the central government in the following way. Usually the policy S_n will imply a certain inductive policy measure D_n as one of its conditions. The government then forces the prefectures to accept a policy S_p such that $S_p \in \Sigma_p(D_n) \cap \sigma_p(S_n)$, $\forall p$ and the set $\{S_p, \forall p\}$ is consistent with S_n. Then the prefecture p accepting such a policy S_p forces the cities c, $\forall c \in p$ to take a policy S_c such that $S_c \in \Sigma_c \cap \sigma_c(S_p)$, $\forall c$ and the set $\{S_c, \forall c \in p\}$ is consistent with S_p, $\forall p$. In this case, if $[s_n]_p = s_p \in \Delta_p$ for the target Δ_p which is being set up in advance by the prefecture p, $\forall p$, then there is no problem. But if $s_p = [s_n]_p \notin \Delta_p$, i.e. the recognized state $\tilde{s}_p$ which is expected to be brought about by the compelled policy S_p is not desirable for the prefecture p, then the trouble occurs. In such a case the governor of the prefecture p will be in a dilemma, being forced by the government to accept the policy S_p and at the same time being forced not to accept it by the people of the prefecture. This trouble comes from the fact that $\tilde{\Delta}_n$; $\tilde{\Delta}_p$, $\forall p$ are not consistent. Later, we shall briefly discuss how to handle the trouble. The same situation will occur when a prefecture p forces the cities c ($\in p$) to accept its policy in the above sense.

Case (II.2)

There seem to me to be some people in Japan who advocate that regional development in the true sense of the term should be for the benefit of the inhabitants and that the development targets should be set up, conversely to Case (II.1), from the bottom to the top in the following way. (I hope the second half of the contention is due to my misunderstanding.)

At first, each city c sets up its development target $\tilde{\Delta}_c$ based on the demand of the citizens and then the cities require the prefecture p ($\ni c$) to set up a target $\tilde{\Delta}_p$ such that $\tilde{\Delta}_p$ and $\tilde{\Delta}_c$, $\forall c \in p$ are consistent. Then each prefecture p, accepting the above claim, requires the government to set up a target $\tilde{\Delta}_n$ such that the targets $\tilde{\Delta}_n$; $\tilde{\Delta}_p$, $\forall p$; $\tilde{\Delta}_c$, $\forall c$ are consistent. But it is clear that in this procedure there are logical contradictions.

1. Even if a city c needs to attain a state $s_c \in \Delta_c$ by taking a policy S_c, as is shown in (*), (**), and (***) in Section 1.1, the city's future state s_c is determined not only by the city's policy S_c but also by the policies of the prefectures and the nation. Therefore when the targets are settled by the above procedure, there is no guarantee that the city c will be able to attain its desirable state $\tilde{s}_c \in \tilde{\Delta}_c$. For example, let us assume that all the cities set up the targets $\tilde{\Delta}_c$, $\forall c$, such that each target $\tilde{\Delta}_c$ requires the improvement of the inhabitants' welfare and a quiet environment by expelling all the factories from the city. If both the prefectures and the central government accept these cities' targets, it is clear that the national

economy would collapse and there would be no hope of improving the inhabitants' welfare, i.e. of attaining the target $\tilde{\Delta}_c$.

2. If all the prefectures set up their targets only from their own point of view, then it may happen that it is not possible to attain these targets simultaneously because they are competing with each other. For instance, in the example related to Definition 1, each prefecture p may set its target $\tilde{\Delta}_p$ such that the prefecture p has an art gallery built with the government's aid. But these targets $\tilde{\Delta}_p$, $\forall p$ cannot be attained simultaneously, as is shown there.

Thus we cannot accept the above-mentioned contention. What should be done when the targets being set up in advance by the government, the prefectures, and the cities are not consistent? Let us briefly consider such a problem as the next case.

Case (II.3)

When the targets $\tilde{\Delta}_n$; $\tilde{\Delta}_p$, $\forall p$; $\tilde{\Delta}_c$, $\forall c$ which are being set up in advance by the government, the prefectures, and the cities are not consistent, it may be said that they should be modified to the consistent targets. Only if they become consistent through modification, as shown in Proposition 2, could all parties concerned with the regional development problem be satisfied. But such consistent targets could not be reached by compulsion from the top as in Case (II.1) nor by the drive from the bottom as in Case (II.2). It could be hoped that such consistent targets could be attained through the repetition of certain democratic consultations between the government, the prefectures, the cities, and the citizens. But it may take too long to reach the consistent targets, or there may be no guarantee of reaching them through consultations. Therefore, before reaching them, the states $\tilde{s}_n$, $\tilde{s}_p$, and $\tilde{s}_c$ may deteriorate. Something will have to be done. It seems to me that there is no way for the solution but to legislate a certain democratic rule for consultations between the government, the prefectures, the cities, and the citizens, which is likely to lead them to the consistent targets.

Many people in Japan have recently contended that it is necessary to legislate the rule of participation by the inhabitants in regional development problems. I agree with this contention so far, at least, as the above statement, but we have not yet succeeded in making such a law. Is not this one of the basic causes of the difficulties we are facing with regional development problems?

2. Land Development in Postwar Japan

INTRODUCTION

In this section we discuss in retrospect how the land development in postwar Japan has taken place so far, dividing the whole process into several time periods each of which is characterized by its own development policies. It should be borne in mind that the country concerned has a population of about 120 million, living in an area of 377,435 km², with extremely poor domestic resources. We have followed the logic considered in the preceding section, using the same notation. An overview of development is given in the Appendix. Figure 22.2 shows new industrial cities and the special areas designated for industrial development.

2.1. 1945-1959: THE POSTWAR REHABILITATION PHASE, THE PERIOD OF COMPREHENSIVE SPECIAL AREA DEVELOPMENT PLANS (RESOURCE DEVELOPMENT SYSTEM)

During the period immediately following the end of the Second World War (1945), Japan adopted the development target $\tilde{\Delta}_n$ (1945-) and the policy S_n (1945-) as outlined below. The development procedure in this period corresponds to Case (I.1).

Δ_n(1945-): To bring the postwar confusion under control, to increase production of foodstuffs, and to restore the nation's standard of living to the prewar level.

S_n (1945-): To develop energy resources, to ensure an adequate system of irrigation, and to prepare infrastructures for industrial development.

The country strove to attain the target, and the results were remarkable. However, it soon became obvious that in order to implement the policy effectively, i.e. to realize a comprehensive and balanced progress unhindered by bureaucratic sectionalism, a special legislation for the comprehensive development must be enacted. Thus the *Comprehensive National Land Development Act* was created in 1950, with the aim of ensuring comprehensive utilization, development, and conservation of the nation's land, and to provide adequate infrastructures for industrial development and for improved social welfare. The establishment of this law was an epoch-making event in the history of national land development in Japan. It defined comprehensive national land development as a comprehensive national development plan, a comprehensive prefectural development plan, a comprehensive regional development plan, and a comprehensive special area development plan. One of the most critical problems associated with these plans was that many government agencies were involved, and that each of them tends to insist on its own policies and prerogatives. To resolve this problem, the new land provided for the establishment of the *Comprehensive National Development Council* as an organ for coordinating the opinions of the various government agencies concerning national land development. In retrospect, while the Council was endowed with very important authority and responsibility under the text of the law, one could say that it was very often influenced by diverse political powers.

Of these four categories of land development plans, the *comprehensive special area development plan* was the first to be introduced. In this plan, the national target $\tilde{\Delta}_n$ (SA) and the policy S_n (SA) were basically as follows:

$\tilde{\Delta}_n$ (SA): To achieve a self-supporting economy by means of development of resources and industry, preservation of land, prevention of disasters, etc.

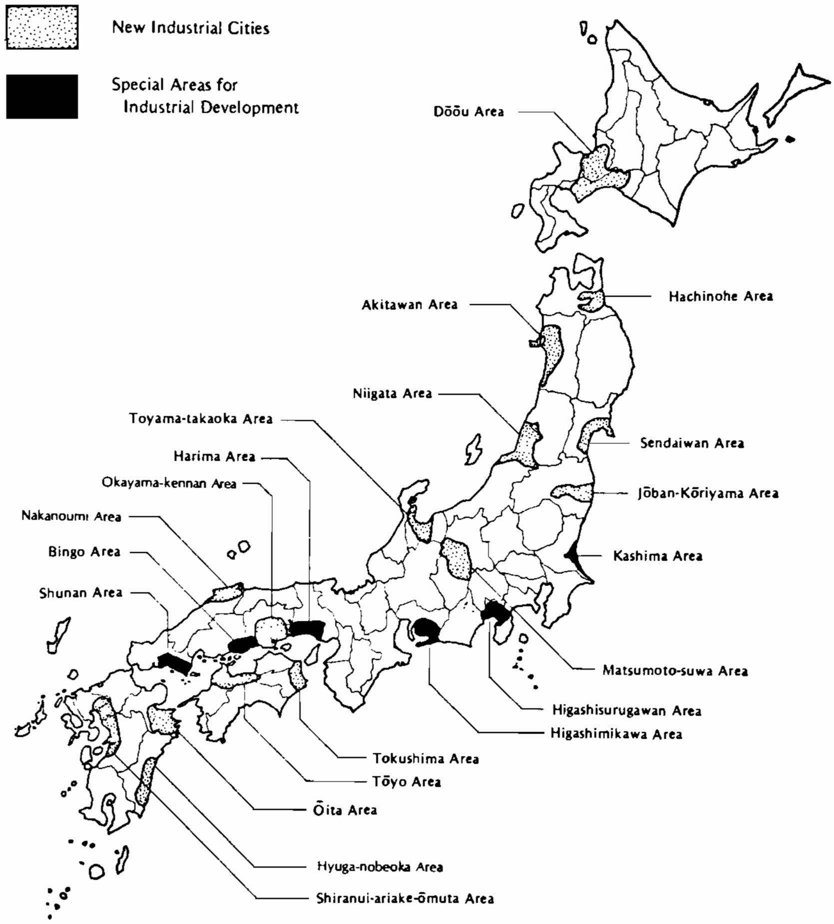


Fig. 22.2. The new industrial cities and the special areas for industrial development.

S_n (SA): To designate a certain number of special areas and introduce a series of inductive policy measures D_n, such as public investment, to those designated areas for a period of about 10 years as a means of achieving the target $\widetilde{\Delta}_n$ (SA).

Under this plan, it was natural that the development procedure followed the process of Case (I.2). In fact, every prefecture competed for designation as special areas. Since 42 prefectures out of 47 became candidates, the number had to be reduced in order to use the limited capital resources efficiently. This proved an extremely difficult task because the comprehensive national development plan was not yet in existence and the government had difficulty in determining the criteria on which such designations should be made. Finally, without any logical reason and simply as a political compromise, 21 areas representing roughly a quarter of the total land were designated special areas. In fact, such a scale could no longer be qualified as "special". As a political compromise, it only amounted to an all-round policy. Most of the 21 special areas were underdeveloped regions along rivers, and the target of development $\tilde{\Delta}_p$ (SA) and the policy S_p (SA) of the special areas were more or less as follows:

$\tilde{\Delta}_p$ (SA): Comprehensive development of rivers as a means of developing hydroelectric power; increase of agricultural output; antiflood construction and afforestation. The development should contribute to the progress of agriculture in the surrounding areas and to improvement of the standard of living through electrification.

S_p (SA): To build multipurpose dams in most of the designated areas for flood control, generating electric power, and for irrigation. It was understood that the development system of the Tennessee Valley Authority would be a good guide to the realization of the policy.

The state $\tilde{s}_p$ (SA) which arose as the result of implementation of the policy was recognized as follows:

$\tilde{s}_p$ (SA): Although the dams built were allegedly multipurpose, they were eventually used almost exclusively for hydroelectric power generation because of the massive involvement of capital from the electric power utility companies. For this reason, it is questionable whether the dams contributed directly to the economic welfare of the regional inhabitants in any remarkable manner. However, the policy definitely increased power-supply capacity, thereby contributing to the development of industry.

In the meantime, the international situation and the resulting economic environment of Japan (U(1950-)) had undergone significant changes.

U (1950-): The outbreak of war in Korea in 1950 brought the "special procurement boom to Japan", and the San Francisco Peace Treaty in 1951 enabled Japan to resume international trade with other countries. Private sectors reflecting these events started to show a strong willingness for capital investment. As a result, the emphasis moved to expansion and modernization of infrastructures for production and to the construction of industrial zones with petrochemical and other large-scale plants. Reflecting these situations, the *New Long-range Economic Plan* of the Japanese Government in 1957 placed the main emphasis of public undertakings on construction of highways and other key industrial infrastructures, and priority of public investment was given to those advanced industrialized areas. Consequently, the designated "special areas" began to suffer from inadequate funding backup.

2.2 1960-1968: NATIONAL INCOME DOUBLING PLAN, COMPREHENSIVE NATIONAL DEVELOPMENT PLAN (THE NODAL SYSTEM DEVELOPMENT PROGRAM)

In 1960 the Ikeda Cabinet announced the *National Income Doubling Plan,* with the following target and policy:

$\tilde{\Delta}_n$ (ID): To double the national income in real terms in 10 years from 1961 to 1970.

S_n (ID): To create new industrial zones by taking advantage of geographical conditions in the "Pacific Coast Belt" connecting the four large industrial areas, Kei-Hin, Chukyo, Han-Shin, Kita-Kyushu, in order to promote large-scale expansion and combination of production units. For this an inductive policy measure D_n to invest more than 16 billion yen for preparation of such industrial infrastructures as roads, ports, construction sites and water supply in the new zones would be introduced. In fact, during the 5 years from 1961 to 1965, nearly 70% of the total public investment was put into the Pacific Coast Belt. Again, this resulted in the process of Case (I.2), namely,

S_p (ID): Prefectures located on the Pacific Coast Belt vigorously competed to qualify for the inductive policy measure D_n. They tried hard to attract industry and carried out regional development centered on "combinato", i.e. the complexes of large-scale production units.

$\tilde{s}_p$ (ID): Enterprises were by no means less eager to take advantage of the new policy and intensified capital investments in the interested areas. Consequently, huge "combinatos" (complexes of steel, petroleum, petrochemical, and energy-generating plants) mushroomed all along the Pacific Coast Belt.

However, from the viewpoint of the nation as a whole, the following state $\tilde{s}_n$ (ID) came to be recognized during that 5-year period:

s_n (ID): Because priority of public investment was given to industry located in the Pacific Coast Belt endowed with favorable geographical conditions, and as the industry's enterpreneurship was greatly enhanced by the new environment, the economic growth of Japan considerably exceeded the targets set by the National Income Doubling Plan. However, because population was increasingly concentrated in industrialized urban areas and because there was an imbalance between private capital stock and social capital stock, many people began to be conscious of the evil of excessive concentration. However, such "evil" was understood not as an evil of overcongestion in the modern sociological sense but rather as bottlenecks to further production growth. On the other hand, dissatisfaction was growing among people living outside the Pacific Coast Belt who could not benefit by the public and other investments. There was growing concern over the regional differentials in the income level.

The need for a comprehensive national development plan was thus ever more imminent, and 12 years after the establishment of the Comprehensive National Land Development Act, the *Comprehensive National Development Plan* was adopted in 1962. The target of the plan was:

$\tilde{\Delta}_n$ (CND): Promotion of well-balanced regional development through effective utilization of Japan's national resources and adequate distribution of capital, labor, technology, and other resources among regions, at the same time preventing uncontrolled growth of urban population and decreasing economic and other gaps between the regional areas.

To achieve these objectives, the first thing to be done was to promote decentralization of industry, while avoiding dispersion of industry all over the country without due regard to capital efficiency. The policy actually undertaken was the following:

S_n (CND): This policy is called the *"nodal system development program";* in other words, areas excluding Tokyo, Osaka, Nagoya and their suburbs are classified according to their own characteristics and each area thus classified is endowed with a node for large-scale development which is matched to its own characteristics. Furthermore, nodes for medium- to small-scale developments are arranged in consideration of their relationship to the central node as well as to the agricultural and fishing villages surrounding them. These nodes are linked in an organic way by means of a good transport and communication network. This achieves a stimulating interrelationship between the nodes, and at the same time the surrounding rural areas benefit from such relationships. Development is promoted by a sort of chain reaction among the constituents. (Taking transportation for example, the first step was to build the Shinkansen railway between Tokyo and Osaka as the main artery, and the plan stated that further extension of the Shinkansen to the west beyond Osaka would be considered depending on the needs of transportation in the areas concerned.)

This policy S_n (CND), which is the essence of the nodal system development plan, materialized as the following two policies:

$S_n^{(1)}$ (NI): Construction of new industrial cities, and
$S_n^{(2)}$ (SI): Development of the special areas for industrial development.

These policies can be described as follows:

$S_n^{(1)}$ (NI): To build several new industrial cities with comprehensive urban functions for industrial development mainly in those areas which are suffering from relative absence of benefit of the accumulation of external economy (i.e. Tohoku, Chugoku, Shikoku, and Kyushu). Initially, efforts would be made to develop heavy chemical or petrochemical industries closely connected to sea-ports. The central government will provide the inductive policy measure $D_n^{(1)}$, which implies that those local public bodies from one of those new industrial cities would be given financial assistance by the government, and those enterprises willing to operate in such new cities would be given favorable treatment in development finance, etc.

It is, however, more advantageous for the efficiency of capital to develop areas surrounding already established industrialized zones which have favorable opportunities for industrialization rather than develop new industrial cities which must start from the provision of the infrastructures for production. For this reason, the following policy would also have to be implemented:

$S_n^{(2)}$ (SI): Those areas which satisfy certain of the above conditions, i.e. those located on the Pacific Coast Belt, would be designated a *Special Area for Industrial Development,* and several coastal industrial bases would be built in them. The government would assume an inductive policy measure $D_n^{(2)}$, similar to that applied to the new industrial cities.

Corresponding to such policies of the central government, the prefectures and cities followed Case (I.2) in deciding their development policies. Prefectures competed vigorously in petitioning the government to be designated a special area. After very complicated political negotiations, fifteen new industrial cities and six special areas for industrial development were finally selected.

The basic idea of the nodal system development program can be summarized as follows. If the government is successful in attracting heavy chemical and petrochemical industry to a given area by making public investment for constructing industrial infrastructures in the nodal area, this would stimulate the development of related industries in the same area, while agriculture in surrounding rural areas would also be much improved. Consequently, the level of income would rise in the area as a whole, contributing to increased revenue for the local governments. This would in turn permit an expansion of public investment which is desirable for the improvement of living standards, and finally contribute to the improvement of the welfare of the inhabitants. If we examine the actual results of these policies, the following observation can be made regarding the recognizable states $\tilde{S}_p^{(1)}$ (NI) and $\tilde{S}_p^{(2)}$ (SI) of the new industrial cities as well as the special areas for industrial development as the embodiment of the government policies $S_n^{(1)}$ (NI) and $S_n^{(2)}$ (SI):

$\tilde{S}_p^{(1)}$ (NI): Private industry advanced actively into those areas where accumulation had already reached the stage of providing an effective basis of production, and the scale of economy expanded further. However, in those less fortunate areas which had required several years to acquire designation as a special area, or where there was difficulty in securing sufficient sites, the willingness and desire for development often cooled off. In some areas, although public investments were obtained, attempts to attract industry remained unsuccessful. Several areas thus failed to reach the projected level of industrial development. According to the national census, the average annual growth rate of population in the new industrial cities was a mere 5.4% for the period 1965-1970, while the annual growth rate of the total Japanese population for the same period was 5.5%. It cannot, therefore, be claimed that the new industrial cities have contributed to any significant extent in lowering the concentration of population in the large cities, nor would they seem to have made any substantial contribution to improving the standard of living of local inhabitants.

$\tilde{s}_p^{(2)}$ (SI): In these areas, there has been some increase in the proportions of population and industrial output to those of the country as a whole. It must be pointed out, however, that the public investment was concentrated on providing the necessary infrastructures for production and that practically no progress was achieved in providing the infrastructures for the daily life of inhabitants. As a result, these areas began to suffer from the environmental pollution that has become a major social issue, now that public awareness of such matters has begun to change significantly.

In these circumstances, $\tilde{s}_n$, the recognized state of the nation as a whole, could be identified as follows:

$\tilde{s}_n$ (1962-1968): The national economy achieved a high growth rate, far above the original expectation. However, in spite of the adoption of the nodal system development program, the trend towards population concentration in the large cities was increasingly serious, to such an extent that overconjestion became a major social problem along with environmental pollution. At the same time, the population continued to drain out of rural regions, which found it increasingly difficult to maintain such basic facilities for living as schools, hospitals, and fire stations. The excessive decrease of population in these areas was considered a serious social problem in the sense that these areas could not maintain their functions as communities. The problem of regional differentials began to be recognized, not only as the problem of disparity in income level but also in the standard of living — the level of living environment in a broad sense. The Comprehensive National Development Council therefore recommended to the Prime Minister in 1966 that the Comprehensive National Development Plan should be redrafted, to include a thorough review of the systems of public finance, taxation and private finance. As a result, the New Comprehensive National Development Plan was adopted in 1969.

2.3. 1969-1971: THE NEW COMPREHENSIVE NATIONAL DEVELOPMENT PLAN (LARGE-SCALE DEVELOPMENT PROJECT SYSTEM)

The *New Comprehensive National Development Plan* of 1969 extends until 1985, covering 20 years. Its targets may be summarized as follows:

Δ_n (NCND): To create an affluent environment for human beings by harmonizing the following four requirements with the aspirations of an advanced welfare society:

1. To maintain harmony between humanity and nature and to preserve and protect national environments permanently; to satisfy the people's desire for contact with nature, which is expected to intensify as urbanization proceeds, and to conserve nature perpetually.
2. To modify the basic conditions of development and to provide a proper balance in potentialities for national development by the efficient utilization of all land areas to avoid uneven utilization of particular regions (in fact, at that time, 48% of the total population lived in areas representing only 1.2% of the total land).
3. To reorganize land utilization systems and improve efficiency by promoting independent regional development programs and modification to fit local conditions.
4. To promote and conserve safe, pleasant, and cultural environmental conditions throughout the urban and rural sectors and to protect people from discomfort and peril as a result of increasing economic and social activities and the higher density of economic and social activity.

To achieve these objectives, it was further contended that it is necessary to have a strategic, large-scale development project which can realize a new land-management generating system that will correspond to technological innovation, the so-called information society, and the full-fledged progress of urbanization. Such a large-scale development project was summarized in the following policy:

S_n (NCND):

1. A network of communication, air traffic, high-speed railways and road systems must be constructed to prepare for *a new network* affecting all the islands of Japan.
2. *Large-scale industrial development projects* will be implemented in relation to the new network so as to suit particular regional characteristics. For instance, industrial production development has reached its limit in large urbanized areas because insufficient suitable space is available; hence, large-scale production bases must in future be built in Hokkaido, Tohoku, Kyushu, and other remote areas.
3. A large-scale environment conservation program will be promoted.
4. *Broad activity zones* are to be established (with a radius of 30-50 km for major urbanized areas and 20 km for local cities) in order to secure

a national standard of living environment. The environmental facilities, means of transport, and communication within the zone are to be improved effectively to assure a safe and pleasant life to the inhabitants of the zones. If necessary, adjustments are to be made on jurisdictional zoning of administration.

The government is requested to take appropriate public financial measures to implement the policy. Further, in order to make efficient use of private funds for development, positive participation of private capital is requested by means of the establishment of public-private joint working bodies (the "third sector") and of private developers in the development projects. (This may mean participation by large private capital in the development but not necessarily by the inhabitants themselves.)

The New Comprehensive National Development Plan aimed at a sort of division of work in the whole country, and required a combination of the specialized areas by means of a network, so that the entire country could be organized as an efficient organic entity. The plan was a very ambitious and well-conceived scheme for development, but it failed to pay due regard to the feelings of the people. As a result, at a time of greatly increased public awareness of the effects of industrial development on the environment, the plan was doomed to failure.

2.4. 1972: SEARCHING FOR A NEW SYSTEM OF DEVELOPMENT

When the New Comprehensive National Development Plan had barely started, overcongestion in some areas and underpopulation in others, combined with environmental pollution, was becoming increasingly serious. The Comprehensive National Development Council recommended in 1971, only 3 years after the adoption of the plan, that it should be thoroughly reviewed, and it was recognized that the state of the nation after 1970 was as follows:

$\tilde{S}_n$ (1970-): Even after the adoption of the New Comprehensive National Development Plan, the trend towards population concentration in major cities continued and the living environment in those cities showed further deterioration. Activities in a megalopolis are balanced precariously, and even a minor accident might result in a large-scale catastrophe whose influence would very quickly extend all over the country. Expansion of the large cities had almost reached the limit. Not only the population but also the economic functions of the nation were excessively concentrated at the major cities, so the time had come to disperse the functions of both physical production and central management.

It is generally agreed that the very fast growth of the Japanese economy in the 1960s was realized through the unilateral enjoyment of the benefit of agglomeration by enterprises which in turn forced the inhabitants to accept the disadvantages of agglomeration. However, by the 1970s, the inhabitants were no longer prepared to accept the sacrifice.

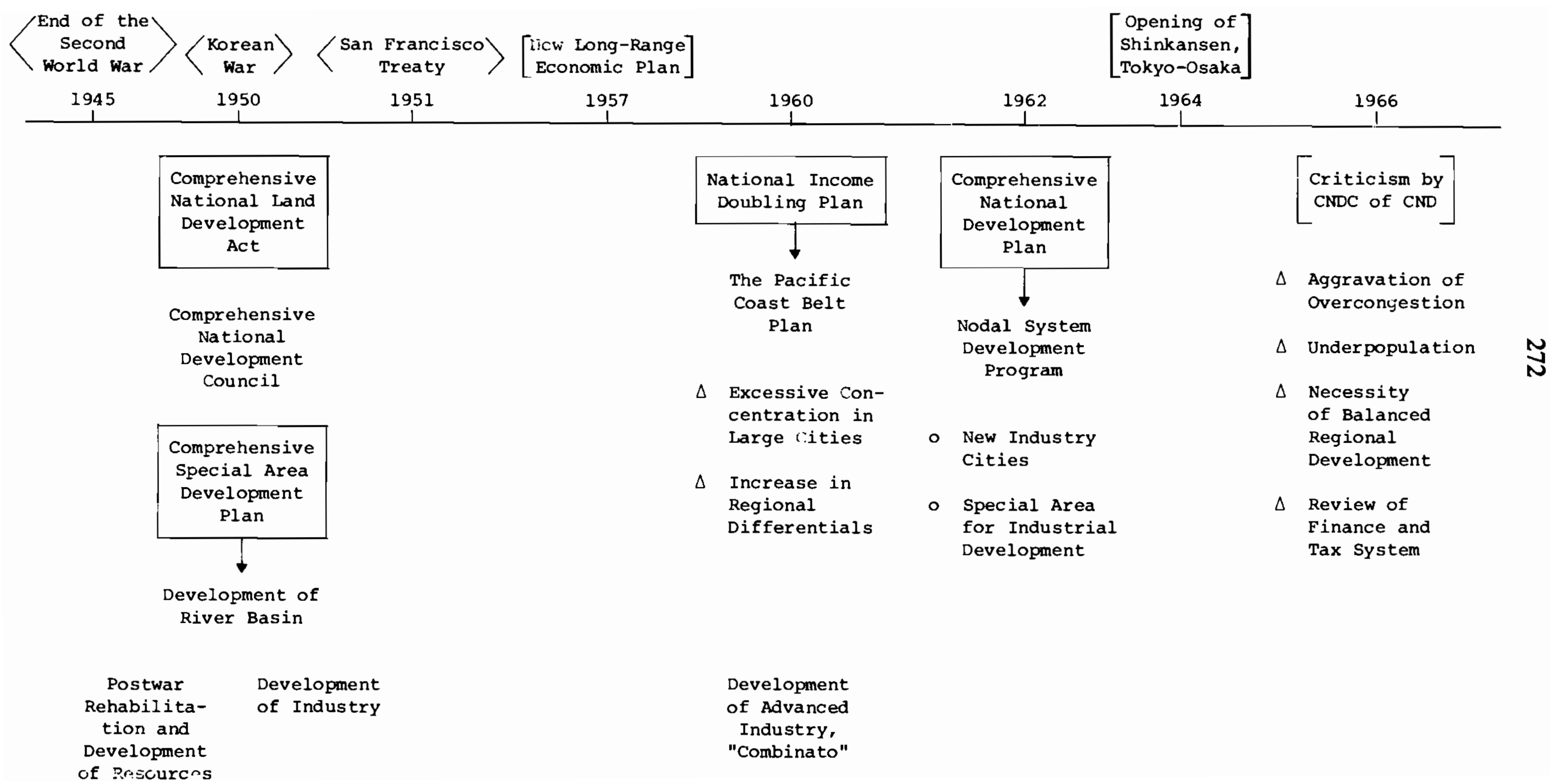
Another serious issue concerned the availability of land space for development. Owing to the high liquidity of finance after 1971, massive speculation in real estate began all over Japan in anticipation of the implementation of the New Comprehensive National Development Plan. The value of real estate skyrocketed and the destruction of nature took place due to indiscriminate development. The rise in price of land caused individual capital gains to reach 55 to 69 billion yen and those of corporations to reach 24 to 30 billion yen during the 6 years from 1964 to 1970.

In the meantime, the Tanaka Cabinet, which began in 1972, proposed the *Remodelling of the Japanese Archipelago.* This was essentially the same type of large-scale development program as the New Comprehensive National Development Plan in that both of them tried to improve the nation's welfare by means of accelerated growth of economy. While the Remodelling Plan was being actively debated, the Tanaka Cabinet collapsed in 1974. The oil crisis of 1973 had changed international economic conditions and greatly influenced the Japanese economy, temporarily creating a chaotic situation. The spectacular growth of the Japanese economy is now over and we are seeking a stable economic growth within the unfavorable international environment.

Public concern over regional development had grown in the meantime. The needs of the Japanese people have become more complex: they are no longer interested in a higher level of income for its own sake; they want a better living environment as human beings, better conservation of environmental conditions and participation by the inhabitants in regional development. However, as we have seen in Section 1, there was an obvious contradiction in the process of setting up the targets $\bar{\Delta}_c$, $\bar{\Delta}_p$, and $\bar{\Delta}_n$, starting from the inhabitants and proceeding upwards in the hierarchy as in Case (II.2). This leads to the conclusion that we are now at the stage where there is a real need to find some solution to the problem referred to in Case (II.3).

In 1974 the *National Land Use Planning Act* was established to curb the accelerated rise in land and to control improper utilization of land, mentioned earlier in conjunction with $\tilde{s}_n$ (1970-). This Act is vitally important to regional development because it imposes additional restrictions on private rights over real estate. For instance, public agencies can now intervene in land transactions and apply various restrictive measures in connection with prices and use of lands. It can be considered as epoch-making legislation.

At this point, a few words on environmental issues are in order. While it may often be difficult to identify and locate the source of pollution, there is little question, once it has been identified, that the polluter should be held responsible for stopping it at his own expense, i.e. the "polluter pays" principle should be applied. We cannot, however, assume that the market mechanism or other existing economic systems will automatically ensure this, and the only practical approach would be, by means of legislation, to oblige the polluter to stop it. At this point, the question arises where to set the quality standard of environmental conditions in order to condemn pollution as such. Many aspects of environmental conditions have not yet been made clear


End of the Second World War
Korean War
San Francisco Treaty
New Long-Range Economic Plan
Opening of Shinkansen, Tokyo-Osaka
1945
1950
1951
1957
1960
1962
1964
1966
Comprehensive National Land Development Act
Comprehensive National Development Council
Comprehensive Special Area Development Plan
Development of River Basin
National Income Doubling Plan
The Pacific Coast Belt Plan
Δ Excessive Concentration in Large Cities
Δ Increase in Regional Differentials
Comprehensive National Development Plan
Nodal System Development Program
o New Industry Cities
o Special Area for Industrial Development
Criticism by CNDC of CND
Δ Aggravation of Overcongestion
Δ Underpopulation
Δ Necessity of Balanced Regional Development
Δ Review of Finance and Tax System
Postwar Rehabilitation and Development of Resources
Development of Industry
Development of Advanced Industry, "Combinato"

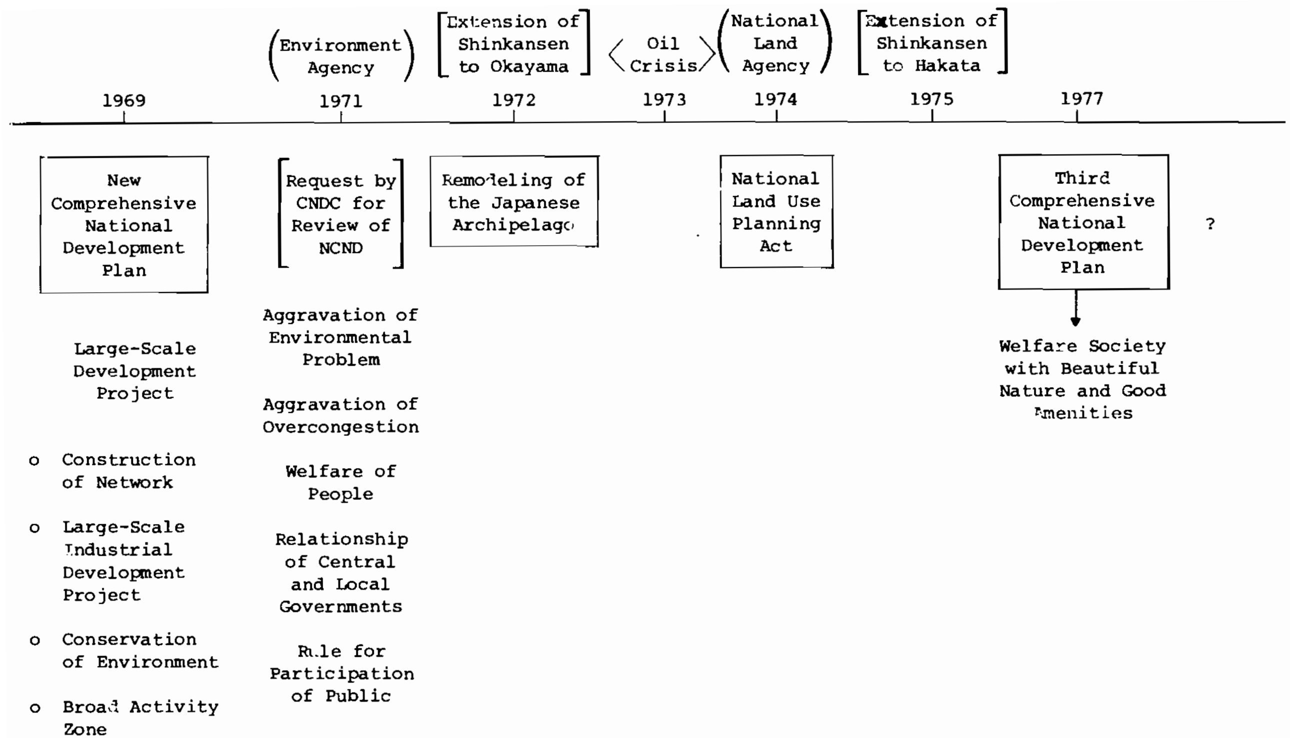


Fig. 22.3. National development in Japan from 1945 to 1977.

scientifically. Therefore, the different positions of interested parties such as inhabitants, enterprises, and public agencies could justify different claims concerning the quality standards of environmental conditions, and these conflicting situations must be resolved. This difficult problem is essentially the same as the one discussed in Case (II.3).

It is not fair merely to claim, as many people in Japan now do, that regional development should be promoted on the initiative of the inhabitants, without making sincere efforts to solve the problem of establishing basic rules for reaching the consistent targets $\bar{\Delta}_n$, $\bar{\Delta}_p$, and $\bar{\Delta}_c$, referred to in Section 1.3.

The *National Land Agency,* inaugurated in 1974 to coordinate the public administration of national land, is responsible for drawing up the *Third Comprehensive National Development for 1976-1985,* which considers the prospect up to the year 2000. At the time of the writing of this paper the Third Plan has not yet been published, and one of the many reasons for the delay in publication is obviously the difficulty of solving the problem as stated in Case (II.3). We are waiting for the publication of the Third Comprehensive National Development Plan which, it is announced, will establish standards of quality of life and welfare to match the increase in population, and will explore the possibilities of economic growth and industrial development under the constraints of resources, environment, usable land space, and water supplies. It is said that the implementation of this plan will bring us a welfare society with the beauty of nature preserved and with good amenities.

National development in Japan from 1945-1977 is shown in Figure 22.3.

23. *Goal and Conflict Analysis of Public Policy Plans*

D. V. WINTERFELDT

Formal models to analyse policy plans and decisions are rare, partly because of the lack of formal training of policy analysts and partly because of a suspicion among analysts that formal models will not provide any additional insights into planning and decision-making that go beyond the policy analyst's experiences and insights. Yet, formal models can provide structure, make transparent the process by which the policy problem is analysed, identify gaps and inconsistencies (in the model's terms), and allow a precise communication of ideas and findings. I think Miyasawa's model of national, prefectural, and city policy plans clearly demonstrates these possible benefits of formalizations.

Here at IIASA we have made a somewhat similar attempt in structuring and analyzing decision-making by using goal-tree and decision-tree approaches borrowed from the field of decision analysis. These formal tools were used to study the regional strategy setting in the development of the Tennessee Valley Authority and the Bratsk-Ilimsk Territorial Production Complex process, as well as for analyzing more specific decision processes on power production planning [1,2,3].

Our analytic approach has much in common with that of Miyasawa, and the purpose of this brief presentation is to sketch these common points, discuss some major differences, and indicate the solution of some of the policy-setting problems that Miyasawa mentions.

Goal trees specify the hierarchical structure of policy objectives in terms of general supergoals, intermediate objectives and subgoals, and lower-level attributes. Decision trees put into logical order the basic policy alternatives and subsequent external events; they follow up actions, etc. Goal trees correspond roughly to the concept of state variables s and target Δ in Miyasawa's model. The span of logical decision alternatives (without their linkage to external events) corresponds to Miyasawa's concept of development policies S. External events in the decision-analytic approach correspond to Miyasawa's "unpredictable factures U". Thus, there are some substantial structural similarities between the models.

However, there are also some important differences in the logic of the two approaches. The main one is the difference between objectives and targets which will be discussed in the following example of the New Comprehensive Development Plan of Japan.

In Miyasawa's model, targets are desirable points in the state space that are being set up by all three levels of planning and decision making: the national, prefectural, and city levels. In goal trees, on the other hand, only desirable state variables or dimensions are specified, no points. Thus, rather than setting up a certain target of reducing air pollution by, say, 20%, the goal tree approach would list the objective of "minimizing air pollution". Another difference is the way in which goals are disaggregated as distinct from the three-level dissaggregation of targets in Miyasawa's model. In the goal tree approach the disaggregation of objectives sometimes leads to a disaggregation of regions and subregions, but sometimes the disaggregation stays solely within one decision level, say the national. Fig. 23.1, for example, a simple goal tree is structured for the New National Comprehensive Development plan of Japan. The goal "to provide a proper balance in the national development" that was part of this plan can be disaggregated to operational attributes purely within national level objectives. Thus subobjectives like "avoid crowding" or "improve mobility and communication" refer to nationally defined measures of success of a plan. Here no specific objectives would be set up for the regional or subregional level.

On the other hand, if one considers the goal "to promote the efficiency of regional land development", the most natural disaggregation principle is that of regions and subregions, i.e. the disaggregation would put into a hierarchical order the various subobjectives specifying the notion of "efficiency" for each region.

An intermediate case is illustrated by the goal of "promotion and conservation of environmental conditions". Here, a goal tree could, as a first step, define on a national level what is meant by this goal, namely, a reduction of air pollution, etc. Then, on the next step of disaggregation one could use the regional disaggregation logic and define for each region and subregion what these objectives mean in regional and subregional terms; for example, reduction of water pollution in a specific river, lake, or sea shore.

Since in these goal trees no specific targets as points in the state space are identified, the issue of *consistency of targets*, a main concept in Miyasawa's model, does not arise. Rather, the idea of *conflicting objectives* is central to

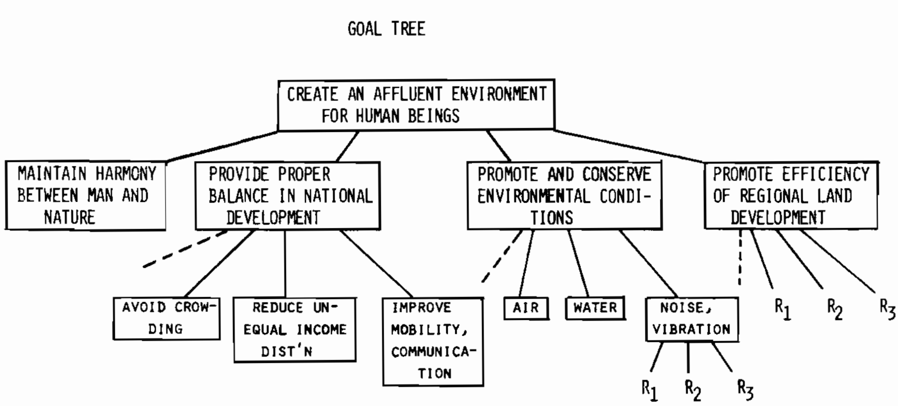


Fig. 23.1. Illustrative application of the DT approach to the new comprehensive national DP: goal tree.

the goal-tree analysis. Ideal decisions would maximize each objective, but since such decisions are not available in the real world, crucial trade-offs have to be made between the conflicting objectives. In a goal-tree analysis these trade-offs can often be expressed by weights attached to the various sub-objectives. Thus, the goal-tree analysis approach to the issue of coordinating the interests at the three levels of decision-making is largely an issue of setting appropriate weights rather than identifying inconsistent targets.

In the case of purely national disaggregation of a goal, e.g. "provide proper balance in national development", these weights will have to be set up on each level. On the national level, weights must be set up which reflect the national policy priorities among subregions, etc. Finally, on the lowest level, weights must be set up which reflect the trade-offs among various efficiency criteria. (This case corresponds to Miyasawa's Case II.) In each case the conflicts arise in the process of setting up the weights among objectives, and the conflict resolution process is a process which would allow each level to set up its weights in due consideration of the interests of the lower decision-making levels.

I think this approach of constructing a goal hierarchy and analyzing the conflicts by weighting schemes has some advantages over Miyasawa's approach of constructing targets and analysing consistency. First, it disentangles two notions that the idea of target consistency compounds: preference and feasibility. Goal-tree analysis is only concerned with different types of preferences, and it formalized these differing preferences through different objectives and different weights. Target analysis, on the other hand, is concerned with both preference and feasibility. Targets express preferences by defining desirable states. In this sense one could perform a conflict (not a consistency) analysis on targets similar to the goal-tree analysis by studying the implicit preferences expressed in targets. On the other hand, targets also restrict the feasible set of policy solutions. Thus the question becomes one of the feasibility of a joint resolution of targets of different levels. Mixing feasibility of a joint resolution of targets of different levels. Mixing feasibility and desirability (preference), as Miyasawa's model does in the concept of consistency, can sometimes cloud the issue where conflicts actually lie — in the distribution of positive and negative effects on different levels of the policy setting or in the physical economic unfeasibility of a joint realization of different policies.

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2. Know, H., ed., *The Bratsk-Ilimsk Territorial Production Complex,* Proceedings of the Second IIASA Conference on Case Studies of Large-scale Planning Projects, CP-77-3, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1977.
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24. *Discussion*

Relationship of JNR Policy to Japanese National Development Policy

The Shinkansen has had great influence in centralizing the population along the Pacific coast of Japan. The papers by Sanuki and Kuroda, however, both mention that the current Japanese development policy is one of decentralization. It was therefore asked how this current policy of development influences JNR decision-making concerning the construction and extension of new Shinkansen lines?

It was suggested that the difference between mobility and migration may have been misunderstood. The papers were concerned with migration in particular, and in this sense the Shinkansen does not conflict with stated national policy. The Shinkansen has certainly had a remarkable effect on the mobility of people in the heavily populated regions of Japan, but it is very difficult to attribute migration to the Shinkansen *per se.* The general opinion was that future construction of Shinkansen lines would not conflict with the present Japanese national development policy.

The additional Shinkansen lines that are currently being constructed in Japan and those which are under consideration in order to link the entire country could be considered as just one part of the comprehensive Japanese national development plan. This plan proposes targets designed to decentralize the Japanese system, to stop the growth of population in large cities, and to halt the tendency to underpopulation in rural areas. In this sense, JNR's plans for the extension of Shinkansen lines do not conflict with national development plans.

Migration and Public Investment

It was suggested that it would be very difficult to show that the Shinkansen had any influence on migration. There are many reasons for trends towards centralization of population, and one of them may be the availability of an efficient transportation system. One factor that should be considered, however, is that a transportation mix would be desirable which would suit any particular user's choice. With the right mix and the user being able to make a variety of choices, centralization may diminish.

One personal view was that the Tokaido Shinkansen did affect the acceleration of population growth within the Tokaido corridor. It was also recommended that the historical perspective of the Tokaido Shinkansen be taken into account. At the time of the Shinkansen's construction, Japan's economic level was lower than it is today. The average person could not afford an automobile or an air ticket. Mobility, however, is an important factor in stimulating economic growth. From this point of view, construction of the Tokaido Shinkansen was necessary.

The issue of how public investments of the Shinkansen type affect income distribution was raised. In a real sense, the Tokaido Shinkansen investment may be considered a regressive investment in that it took general tax money and redistributed it essentially to the service of people with higher than average incomes — the regular passengers on the Shinkansen. This was rebutted by the statement that it would be very difficult to determine the total contribution of the Shinkansen within a social system. It was pointed out that the Shinkansen operations contribute a large sum of money to JNR in general and helped to support certain unprofitable local lines operated by the JNR. Such an *ad hoc* distribution policy may not be desirable, but its existence cannot be denied.

The indirect influence of the Shinkansen was mentioned. Even if it were assumed that some regions in Japan suffered owing to capital diversion for such projects as the Shinkansen, national development in Japan has been extremely rapid during the last 25 years, partly due to the extremely heavy concentration of industry, such as factories and shipyards, in the Tokaido corridor. It follows that much of the development of Japan was not made in rural areas, but in the Tokaido corridor itself. This increase in industrial and economic output and in the population base would not have been possible if an equal distribution of taxes and public investment had occurred. This retrospective view shows that it is not easy to determine what type of strategy should be followed. It appears that sometimes when public and private investment (which in Japan was even greater during this period) is concentrated in a comparatively small region, the resulting changes in the price and wage structure may be distributed to regions outside where the growth occurs. Equalization of investment is not always good for the poor; it may sometimes be bad for them.

Saving Time

One paper determined the benefits from Shinkansen operations, and used "time saved" as a criterion. This brought several comments, one of which was that the induced time factor of travelling with the Shinkansen should be taken into account. The total travel time spent by passengers on the Shinkansen is far greater than the total travel time of people on conventional trains.

It was generally agreed that although the use of the time saved as a determination of one of the benefits of the Shinkansen represents a good starting-point for analysis, careful consideration should be paid to determination of the value of time units.

Planning and Organization of the Shinkansen

25. *Decision-Making and Planning of the Shinkansen*

H. KNOP

In keeping with our mode of studying large-scale development programs in IIASA's Management and Technology Research Area, I shall concentrate on an analysis of decision-making as part of the planning of the Shinkansen program, using the logical structure developed for the previous studies (see Fig. 25.1). This logical structure assists the analysis of goal setting by taking into account the needs and values, the external and internal goals of the program. This includes planning activities of needs/demand forecasting identification of the degree of possible and necessary social acceptance of these needs for a clearly defined period, and derivation of goals and objectives which follow. In addition an analysis is made to determine how quantifiable and non-quantifiable goals are weighted against each other and how priorities are set. The analysis takes into account the fact that a target function in decision-making is always a function of different goals (G_n) and their weights (α_n):

$$Z = f(\alpha_1 G_1, \alpha_2 G_2, \ldots, \alpha_n G_n) \rightarrow \max$$

The process of finding feasible solutions is also studied. This includes finding and selecting variants/strategies related to the volume and structure of the output of the program studied, feasible, effective and resource-conserving technologies, and the siting of facilities and activities. The process of programming is analyzed, on the basis of goals and feasible strategies/variants, with emphasis on the methods and models used for handling interdependencies and uncertainties and the scheduling of activities.

The foregoing is intended to present a rough idea of our approach to planning and decision-making problems in all of the cases studied in the Management and Technology Research Area. Using this approach, let us now turn to the Shinkansen to underline major aspects of planning and decision-making which can be found in the papers; from these we can derive certain questions that need clarification.

First, I would like to emphasize one point. The Shinkansen represents much more than just a rail transport system operating at high speed; it represents a new quality, a new step in transport systems. There are many places in the world where high-speed operations are performed but, to the best of my knowledge, not on a scale as extensive as the Shinkansen and not utilizing the new approaches to safety and operation which the Shinkansen employs to a very high degree.

Price has been treated as playing a certain role in the determination of alternatives relating to the entire transport system. This corresponds to the forecasting procedures dealing with expected national income and future traffic volume and with the internal goals of JNR. Other internal goals are listed in Fig. 25.1.

The external goals for the transport system are those relating to regional development, urban development, the environment, and others also listed in Fig. 25.1. I shall ask some questions about them. The first deals with the forecasting of national income and traffic volume. Mr. Nishida's paper contained information on the significant deviation of actual development from the forecast. It would be interesting to know more about the reasons behind this deviation between forecasting and actual development.

Another set of interesting and topical questions concern the value system and its actual use in the decision-making process. In many cases, large-scale programs are developed with a set of standards and normatives related to social needs. The Shinkansen presentations also indicate that this was an underlying assumption during the examination phase of the Shinkansen project. There was a forecast of social needs for transport, and there was a determination of possible solutions to meet these needs. But between the forecast of needs and the development of alternatives lies the question of what is feasible at certain stages of development of a society. In many cases, attempts are made to fix this evaluation of needs in terms of standards and normatives. Was there such an attempt in the case of Shinkansen? If so, what role did these standards and normatives play and, in more general terms, which role do quantified values play in the setting of priorities and are these values related to the goal-setting process?

A great deal of information on the problem of finding feasible solutions (Fig. 25.2) is contained in the Japanese papers. However, the papers did not fully explain how the relationships between different modes of transport — air, rail, sea and road — were determined and linked to each other. It would be interesting to know how different modes were examined, what calculations were used, and what was the main criterion in arriving at the final decision.

The next set of questions concern technologies which were analyzed. The papers contain a very extended description of different technological concepts expressed in different average and maximum speeds with different types of trains, different electrical systems, and different track guages. I do not think this needs more explanation, but it was indeed surprising to find that the most technologically advanced solution was the cheapest, according to the criteria established. This does not appear to be fully understandable in the light of the additional R & D effort which was necessary and the creation of a new institute for railroad research which needed additional space, personnel, training, etc. The construction principles employed for the Shinkansen were also of a completely new type. How was it possible to calculate the most advanced solution as the cheapest? A very simple question, but probably without a simple answer.

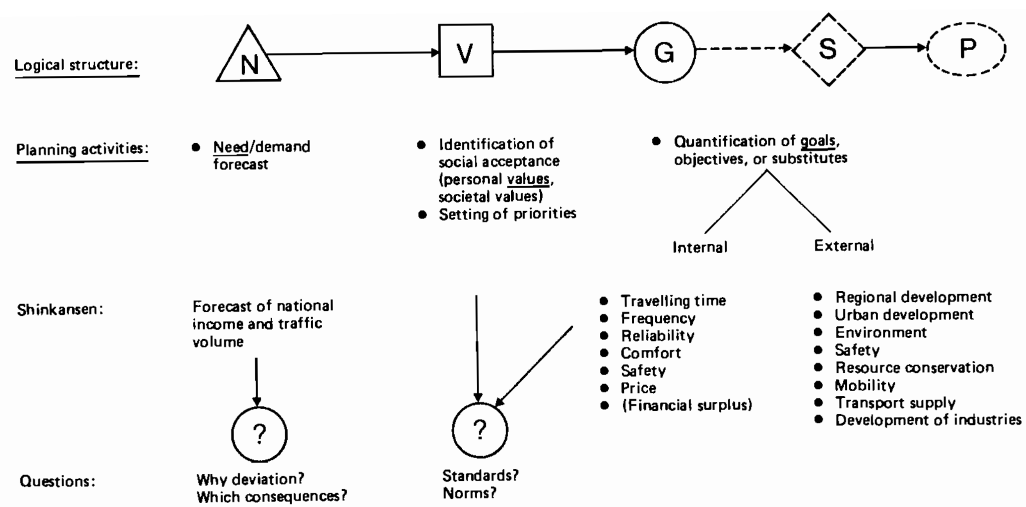


Fig. 25.1. Goal setting.

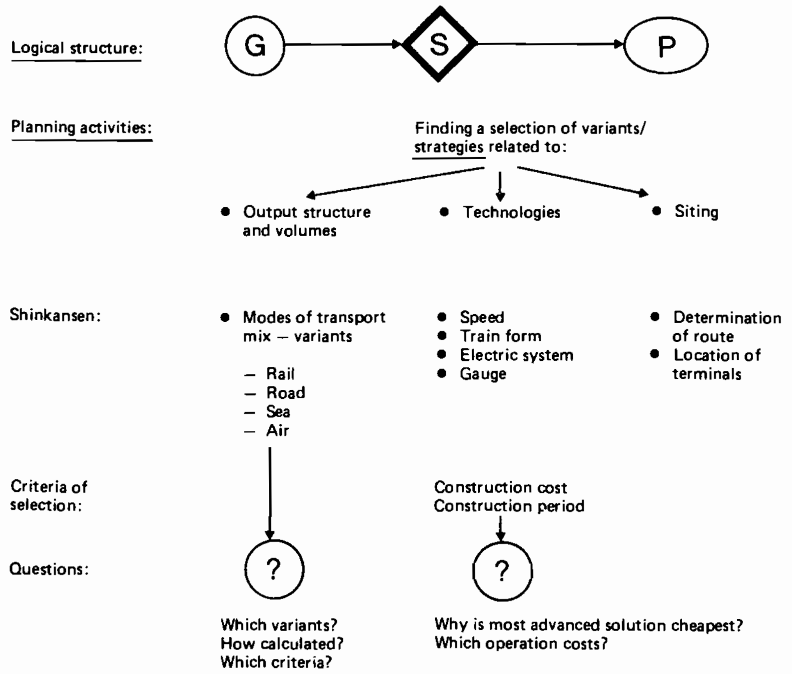


Fig. 25.2. Finding feasible solutions.

The third aspect of the Shinkansen I should like to raise for discussion is that of programming or scheduling (Fig. 25.3). One part of programming is the method of handling interdependencies within the system itself, construction, energy supply, training, etc.; and interdependencies between the system, the nation, and the rest of the national economy.

What kinds of interdependencies had to be taken into account and which instruments and models had to be used in order to calculate and deal with them?

The last item I should like to raise for discussion is the scheduling and time dependencies of the original Shinkansen program. The most important feature of the Shinkansen project, which makes it different from the other programs we have studied, is that there was a strict time limitation; a distinct time constraint within which the scheduling had to proceed smoothly in order to reach the target. This was actually accomplished in the Shinkansen with only a small deviation from the target date initially set for operation. What methods were used by the Shinkansen to accomplish this scheduling and how were the costs in relation to time determined in order to arrive at an optimal solution?

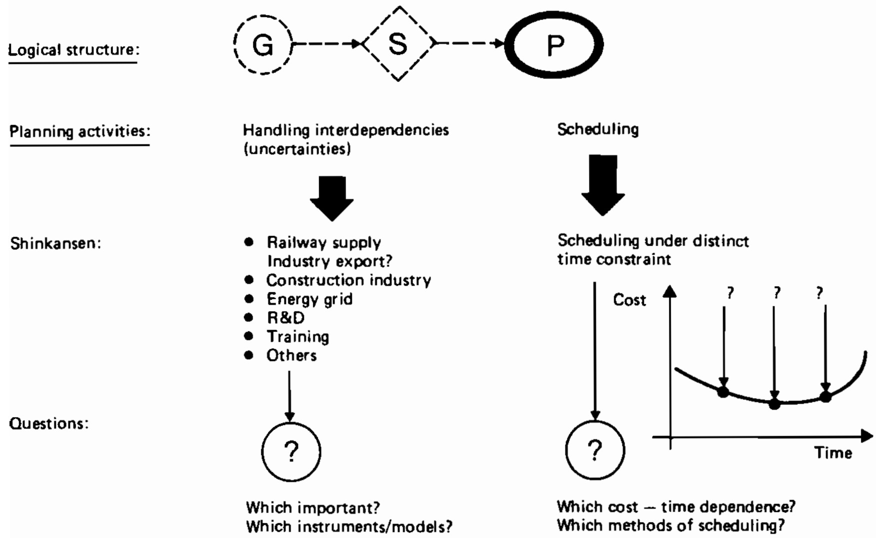


Fig. 25.3. Programming.

26. *The Shinkansen Project: Formation and Construction Setup*

M. NISHIDA

Discussion on Construction of the Shinkansen

The decision to carry out the Shinkansen Plan was taken in the form of a Cabinet approval following discussions with the Tokaido Line Build-up Investigation Commission of JNR, in 1956, the Japanese National Railways Trunk Line Investigation Commission of the Ministry of Transport, in 1957, and the Council of Ministers Concerned in Transportation, organized by the Economic Planning Agency, in 1958.

TOKAIDO LINE BUILD-UP INVESTIGATION COMMISSION

In 1956 JNR appointed the Tokaido Line Build-up Investigation Commission headed by the vice-president of engineering, consisting of the departmental directors concerned, and discussed the following points for about a year: future traffic demand; quality of the future transportation service; type of transportation to adopt in order to increase capacity; type of motive power, rolling stock, repair system, etc.; and other related items.

After various plans had been discussed, JNR requested the Minister of Transport in July 1957 to consider the following points from the national point of view:

The Tokaido Main Line was the most important trunk line in the country and had already reached the limit for a double-track line. To meet the increasing traffic volume generated by the growing national economy, the existing line would need to be quadrupled. Assuming the target year for quadrupling the whole line to be 1963, and taking the construction period into account, it would be necessary to start work in the next fiscal year.

It would be feasible either to lay another narrow-gauge double track alongside the existing narrow-gauge double track or to lay a separate standard-gauge double track line.

JNR had appointed the Investigation Commission and had studied feasible measures, but, since the final decision concerned the country as a whole and not JNR alone, the Government was requested to consider the problem. In the meantime, JNR would continue its studies based on the feasible plans (Table 26.1).

TABLE 26.1. *Feasible plans for the Shinkansen*

	Narrow-gauge track plan	Standard-gauge track plan
Train form:		
Passenger:	Electric railcar train	Electric railcar train
Freight:	Locomotive hauled train	Electric railcar train
Speed (km/h):		
Maximum:	130-150	200-250
Scheduled:	100-120	160-200
Travelling time (Tokyo-Osaka)	4 h 40 min - 5 h 30 min	2 h 30 min - 3 h 30 min
Construction cost	153,100 million yen	138,900 million yen

JNR TRUNK LINE INVESTIGATION COMMISSION

On receipt of JNR's request, the Minister of Transport established in August 1957 the JNR Trunk Line Investigation Commission within the Ministry, consisting of thirty-four members: permanent Vice-Ministers of the Ministries concerned, university professors, leaders of industry and Chambers of Commerce along the railway line, presidents of city banks, journalists, and the President and Vice-President of JNR. The Commission studied the following:

Necessity for a new line

Transport demand on the Tokaido Line.
Various modes of transport:
 superhighway between Tokyo and Kobe,
 coastal shipping,
 airlines.
Date when the Tokaido Line service would reach saturation.

Form of the new line

Narrow or standard gauge.
Method of transport, system of track usage and traffic volume on the new and old lines.
Terminals and route.
Motive power and locomotives.
Track specifications.
Travel time.
Construction period and funds needed.

Funds, construction work, and operation of the new line

Funds needed for construction.
Fares and charges.
Balance between revenue and expenditure.
Method of procuring funds.
Method of expediting construction work.
Method of operation.

NECESSITY FOR A NEW LINE

Transport demand on the Tokaido Line

In estimating the transport demand on the Tokaido Line, the following were considered: population, gross national product, cost-of-living index, industrial activity index, etc. The most conservative estimate disclosed that passenger traffic in 1957 would be almost doubled by 1975, that freight traffic would increase more than three-fold during the same period and that traffic would continue to increase thereafter.

Various modes of transport

In estimating the demand on the Tokaido Line, it was also necessary to estimate the traffic that might be diverted from the Tokaido Line to other modes of transport as a result of various general transport plans. The following conclusion was reached:

Superhighway between Tokyo and Kobe. The superhighway between Tokyo and Kobe was much involved with the Tokaido Line. So, in estimating the traffic to be diverted to it from the Tokaido Line, the two plans for the construction of the Chuo and the Tokaido superhighways had been studied carefully in detail. It was estimated that about 10-19% of the passengers and 4-5% of freight would be diverted to the Tokaido Superhighway when its Nagoya-Kobe section opened in 1962 and the Section between Nagoya and Tokyo opened, as planned in 1965.

Coastal shipping. Although traffic by coastal shipping along the Tokaido area was increasing every year freight had been diverted from coastal shipping to land transport during and after the war, and coastal shipping traffic had considerably diminished. It was therefore assumed that freight traffic diverted from the railway to coastal shipping would not reach a significant level unless drastic changes took place in tariff rates or in the economic situation.

Airlines. The growth of air traffic had been spectacular of late years but although further growth was expected, it was very much less than rail traffic. It was assumed that traffic diverted from the railway to airlines might be qualitatively affected, but quantitively it would be negligible.

Date when the Tokaido Line service would reach saturation

The saturation year of the Tokaido Line was calculated by subtracting the traffic to be diverted to other modes of transport from the transport demand on the Tokaido Line. It was concluded that the transport capacity of the Tokaido Line would most likely reach saturation-point in 1961 or 1962, even when the maximum traffic diverted was considered in relation to the minimum transport demand.

Conclusion

It was concluded that a new Tokaido Line had to be constructed as soon as possible.

FORM OF THE NEW LINE

For the form of the new line, three plans were conceived: an additional narrow-gauge line alongside the existing one; another separate narrow-gauge line; and a separate standard-gauge line (see Table 26.2).

The additional narrow-gauge line meant building a narrow-gauge double track in addition to the existing Tokaido double-track line to form a quadruple line, using the existing stations as they stood. The separate narrow-gauge line meant a line of narrow-gauge double track connected with the existing Tokaido Line only at the main stations of the existing line.

For the separate standard-gauge line, since no interline train operation would be possible owing to the difference in size of rolling stock, the plan called for transfer of passengers, when required from one line to the other at the major stations. For the freight service, a through train between the major stations only was possible.

TABLE 26.2. *Comparison of three plans*
Source: JNR, *Tokaido Shinkansen Construction Chronicle.*

	Additional narrow-gauge line	Narrow-gauge separate line	Standard-gauge separate line
Total length	556 km	500 km	500 km
Maximum speed	120 km/h	(1) 120 km/h (2) 150 km/h	250 km/h
Travelling time (Passenger express train)	6 h 30 min	(1) 6 h 30 min (2) 4 h 30 min	3 h
Track used for	Express and local trains	Through express passenger and freight trains)	Through express passenger and freight trains)
Combined transport capacity of existing and new lines	300-310 times a day	(1) 300-310 times a day (2) 250-280 times a day	330 times a day (converted into narrow-gauge, 375 times a day)
Difficulty of purchasing land	Great	Small	Small
Level-crossings	Many	None	None
Use of rolling stock in common	Possible	Possible	Impossible
Passengers to areas farther than Osaka	No transfer	No transfer	Transfer
Electrification system	DC 1500 V	DC 1500 V	AC 20,000 V
Construction period	7 years	5 years	5 years
Construction cost	Not less than 250,000 yen	192,000 million yen	162,000 million yen

Comparison of track capacity

The first matters to be discussed were how to make maximum use of the total capacity of the new line and the existing line and how to speed up the trains in order to meet the social demand. It was decided to use the existing line for local passenger trains and freight trains, which ran at nearly the same speed, and to use the new line for the through express passenger and freight trains. The track capacity of each line in this case was then studied:

(a) The existing line, with 180 trains operating one way, passenger trains at a top speed of 95 km/h and freight trains at 65 km/h.
(b) An additional narrow-gauge line, with 120-130 trains one way, passenger trains at a top speed of 120 km/h, and freight trains at 75 km/h.
(c) A separate narrow-gauge line, with 70-100 trains one way, passenger trains at a top speed of 150 km/h, and freight trains at 75 km/h, or 120-130 trains one way, passenger trains at a top speed of 120 km/h, and freight trains at 75 km/h.
(d) A separate standard-gauge line, 150 trains one way, passenger trains at a top speed of 250 km/h, and freight trains at 150 km/h (converted into narrow-gauge, 195 trains one way).

Comparison of additional narrow-gauge line plan and separate narrow-gauge line plan

An additional narrow-gauge line would not be more profitable than a separate narrow-gauge line for the following reasons:

the track would be longer;
no high-speed trains could operate owing to the small curve radius;
elimination of all the level crossings (up to 1060) would present many difficulties;
the cost of removing the numerous plants, stores, houses, etc., located along the line would be enormous and would take a long time;
no epoch-making modernization, such as reduction of the travel time, could be expected of the additional narrow-gauge line.

The plan to construct an additional line was therefore abandoned.

Comparison of narrow-gauge separate line plan and standard-gauge separate line plan

A comparative study of the separate narrow-gauge line and the standard-gauge separate line was then made:

Handling of freight on the existing and the new line. The narrow-gauge separate line had an advantage in freight handling by the fact that interline train operation would be possible. However, if express passenger trains for through operations were to run on the narrow-gauge separate line, few freight trains could be scheduled on it because of the difference in speed. With a standard-gauge separate line, on the other hand, no rolling stock could be used in common with the existing line, but faster service would be possible. It was assumed that by building new freight stations in the Tokyo, Osaka, and Nagoya regions, the standard-gauge separate line would have about 80% of the potential traffic.

Handling of passengers on existing and new separate lines. It was concluded that the majority of long- and medium-distance passengers would be diverted to the new standard-gauge separate line, owing to its great advantage over the other in reduced traveling time, if efforts were made to provide proper transfer facilities and adequate seat-booking arrangements.

After the relationship had been studied between the train frequency needed for each line and its track capacity, it was decided that to combine the existing line and a standard-gauge separate line would be more advantageous than to combine the existing line and a narrow-gauge separate line.

COUNCIL OF MINISTERS CONCERNED ABOUT TRANSPORTATION

During the deliberations of the JNR Trunk Line Investigation Commission set up in the Ministry of Transport, it became necessary to investigate the need for the Shinkansen in connection with the plans for the construction of superhighways. A Council of Ministers Concerned in Transportation was therefore appointed in February 1958 in the Economic Planning Agency. A plan for the construction of a superhighway between Tokyo and Kobe via Nagoya and Osaka had taken concrete form and a part of the road was already under construction. The schedule aimed at completion of the expressway between Nagoya and Kobe in 1962 and that between Tokyo and Nagoya in 1965, and much was expected of the superhighway by men of learning.

Lively discussions ensued concerning the transport capacity of an expressway in comparison with a railway line. With little knowledge of the superhighway, people in Japan made all sorts of predictions. The generally accepted idea was a figure of about 40,000 automobiles a day on a four-lane superhighway at the average speed of 70 km/h. Eventually, it was concluded that the transport capacity of a superhighway is far below that of a double-track railway line and, in addition, that the highway requires more than twice as much land as the railway.

It was also disclosed that the traffic to be diverted from the railway to the superhighway would presumably be about 10% of passenger traffic and about 5% of freight, and that since the railway and the highway each has its own function, it would not do to strengthen either one of them alone to meet the increasing transport demand.

Thus the Tokaido Shinkansen construction plan was approved at a Cabinet meeting in December 1958 and the construction cost was appropriated in the budget for 1959.

Incidentally, the present number of motor vehicles on the Tokyo-Nagoya Expressway is about 44,000 a day. The train frequency on the Tokaido Shinkansen is about 240 a day. In its initial period the Shinkansen train consisted of twelve cars, but is now made up of sixteen cars.

Construction Setup

Every facility and all the rolling stock of the Tokaido Shinkansen was produced, with all the know-how of civil and electrical engineering, track and rolling stock techniques, that had been accumulated over the 90 years since the railway was introduced in Japan, backed by up-to-date technology in every field.

The Railway Technical Research Institute of JNR played an extremely important role in the development of the Shinkansen railway technology. The Shinkansen owes very much to this Institute, which had devoted itself modestly to basic studies over many years. Its careful planning, produced brilliant achievements, as a result of which the Shinkansen Construction Standard Investigation Committee, headed by the vice-president of engineering, was set up in the JNR Head Office, and, after careful deliberation, the construction standards for train operation at the maximum speed of 210 km/h on a standard-gauge line were agreed on.

The Shinkansen construction plan was worked out under an inclusive administration system separate from the rest of JNR. To hasten the construction work, the Shinkansen Administration, staffed by competent experts, was established in the Head Office of JNR.

For the execution of work, four local organs, known as the Shinkansen Construction Divisions, were set up in Tokyo, Shizuoka, Nagoya, and Osaka, staffed by civil, electric, mechanical, and construction engineers, as well as land-purchasing experts. At the peak, some 4000 experts were mobilized to work for these four divisions. They carried out surveying, geological investigations, designing, right-of-way purchases, supervision of work, and negotiations with local authorities, such as road and river administration and power plants.

Rolling stock was designed by the Rolling Stock Design Office, an auxiliary organ of the Head Office, and orders were placed with manufacturing companies. Work was executed mainly by contractors.

All sorts of consultants, civil engineering companies, steel-frame and girder-makers, track construction companies, electric machinery installation companies, rolling-stock makers, and many others from different fields participated in creating the Shinkansen.

TECHNICAL DEVELOPMENT SYSTEM

The Railway Technical Research Institute had been carrying out studies on high-speed train operation. Since 1954 it had repeatedly experimented on the shape of high-speed rolling stock and a wind-pressure brake, using models in the wind tunnel, and on a method of measuring the resistance of rolling stock in the water tank. Various kinds of rolling stock were tested on the AC electrified section of the line. The results of studies and experiments were collected in May 1957 and the possibility of a superexpress train running between Tokyo and Osaka in 3 hours was announced. Construction of the Tokaido Shinkansen was heralded in this way.

The Railway Technical Research Institute then built its research system around the Shinkansen Plan, which began to take concrete form. To strengthen its research organization, it established the Shinkansen Investigation Laboratory in April 1960 and assigned to it specialists and experts in all fields to hasten the systematization of Shinkansen technology. The subjects of Shinkansen research are shown in Table 26.3.

The Shinkansen Plan was accepted after careful study and testing over many years in the fields of civil, electrical, and track engineering and rolling stock. It was necessary, however, to conduct technical confirmation tests of everything by laying actual track and running full-size commercial cars. A section about 32 km long was constructed at a place where it could be completed quickly. In April 1962 a model line control depot was set up and test running began a month later. On 31 October 1962 a speed of 200 km/h was recorded and this was followed on 30 March 1963 by a maximum speed of 256 km/h. Testing on the model line section continued until March 1964.

DRAWING UP CONSTRUCTION STANDARDS FOR THE SHINKANSEN

To investigate and study the construction standards for the Shinkansen by which trains would operate most efficiently at high speed in greatest safety, the Shinkansen Construction Standard Investigation Committee was organized in the Head Office of JNR in April 1958. The Committee was headed by the vice-president of engineering, and consisted of the departmental directors concerned and outside men of learning and experience. Twenty meetings were held, the last one in August 1961.

The items studied and decided on by the Committee were as follows:

gauge,
car clearance,
track clearance,

TABLE 26.3. *Railway Technical Research Institute: subjects of Shinkansen research*

Field	*No. of subjects*
Track structure for high-speed operation	25
High-speed rolling stock	29
Operation of high-speed rolling stock	17
Control systems for high-speed operation	18
Trolley wire structure for high-speed operation	25
AC electrification	18
Signalling system for high-speed operation	19
Automatic train operation system	22
Total	173

curve radius,
cant,
transition curve length,
tangent length between curves,
circular curve length,
grade,
longitudinal curve radius,
distance between track centers,
rail,
formation level breadth,
load-bearing capacity of bridges,
stations (effective length of main line, height of platform, distance between platform and track centers),
electric system,
height of trolley wire,
facilities to safeguard train operation.

ORGANIZATION FOR CONSTRUCTION

The construction of a new railway is roughly grouped into construction of roadbed (tunnels, bridges, viaducts, earthwork), stations, tracks, and electric facilities. Figure 26.1 shows the organization for the construction of these facilities and the part taken by each organ. It can be seen that the Head Office organs exercised overall control of the construction work, formed the basic policy, gave advice, controlled the budget, etc., and purchased the principal materials, machines, and equipment.

Local organs acted as the vital centers in hastening investigations and construction work under instructions from the Head Office organs. They negotiated with local governments, made land purchases, etc., and engaged in surveying, designing, drawing up contracts for work execution, inspection, etc.

The local organs set up field organs to supervise construction work in the field, such as work on the roadbeds, stations, buildings, the track, electric power, communications and signals. As the work was mainly executed under contract, it was done by outsiders, various consultants, construction companies, track construction contractors, steel-frame and girder-makers, electric facilities construction companies, and many others. The field organs gave advice and supervised the execution of the work as stipulated by the contracts.

ROLLING STOCK PRODUCTION

The roles of the various organs in the production of rolling stock are shown in Fig. 26.2. The important items, such as technical development, production planning of new rolling stock, decisions on capacity and structure, designing

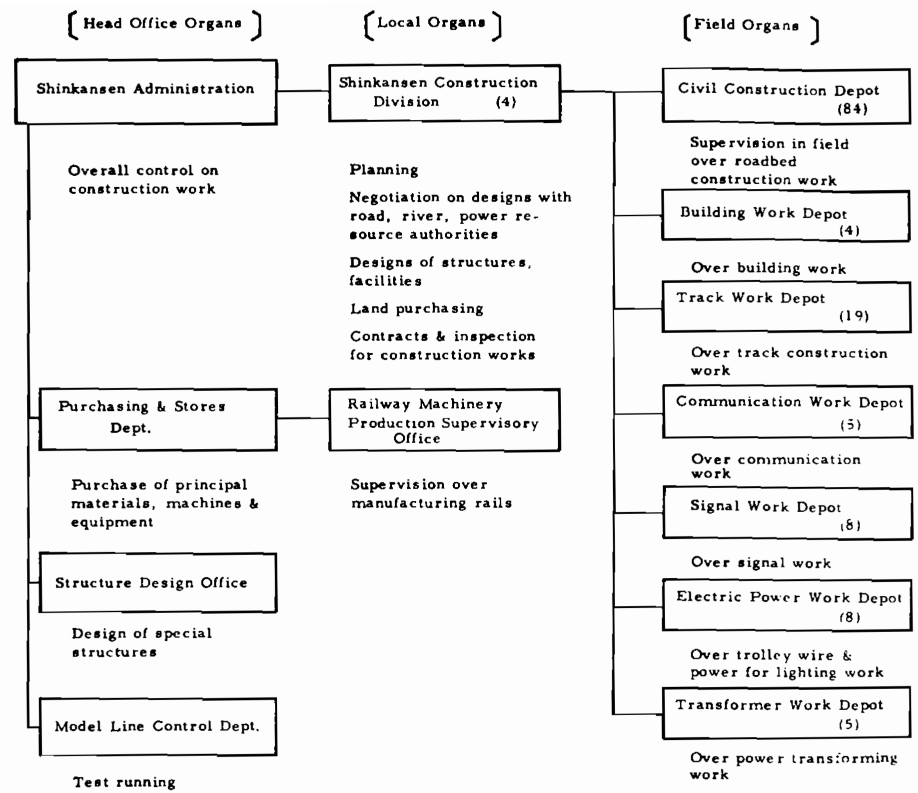


Fig. 26.1. Construction setup (figures in parentheses indicate the number of organs).

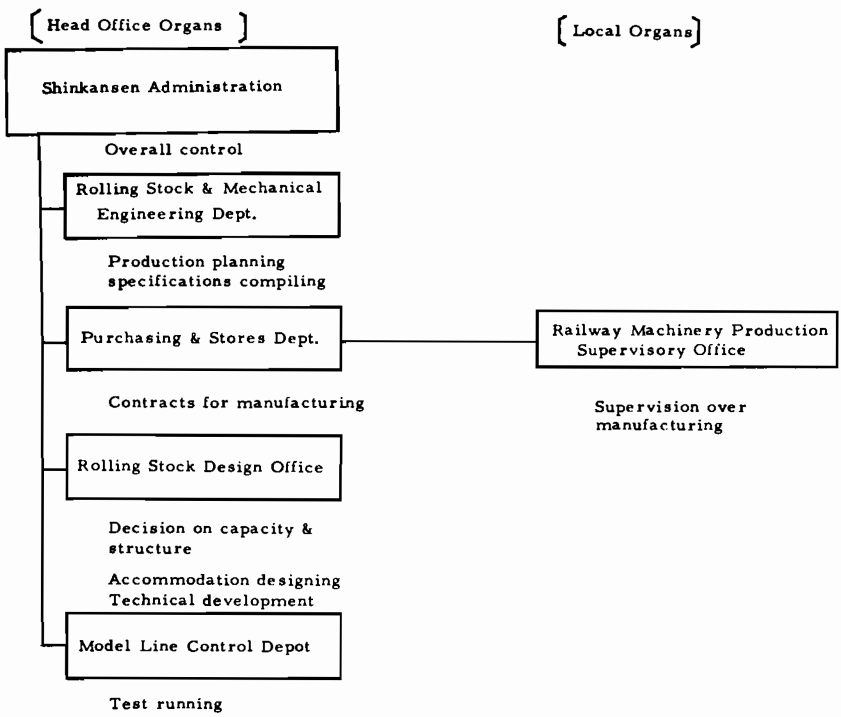


Fig. 26.2. Setup of rolling stock production.

of accommodation, specification compiling, etc., were dealt with by the Head Office organs and the auxiliary organ to the Head Office.

Placing orders and drawing up contracts with manufacturers for rolling stock were the responsibility of the Head Office organs concerned with purchasing and stores. Supervision of the production of rolling stock and main components was exercised by the auxiliary organ to the Head Office. Rolling stock and principal components were manufactured by rolling stock manufacturing companies on orders from JNR.

27. *The Organization of JNR with Special Reference to the Shinkansen*

S. HOSHINO

Legal Status of JNR

The Japanese National Railway was appointed a public corporation in 1949 to operate the Japanese railways. Legally, it is neither a part of the Government nor a private enterprise, but is an independent legal entity with its capital invested entirely by the Government. As a public corporation, JNR is expected to promote public transportation with all the efficiency of modern industry and is responsible for its operation to the people through the Diet and the Cabinet.

Short History of JNR

The history of the railway in Japan covers a century, during which its legal status has undergone many changes, influenced by the needs of the times. With the unification of the feudal state in 1868, Japan joined the family of modern nations and effected many political, economic, and social changes. The resulting economic development was spectacular and transport demand rose rapidly, prompting the Administration to construct trunk rail lines. In 1872 the first railway between Shimbashi (Tokyo) and Yokohama was opened for passenger traffic. Construction of the Government railway continued and the Tokaido Line was completed in 1889.

Meanwhile, the national economic growth encouraged private capital to invest in railway construction. In 1892 private railways appeared all over the country, with a total route length of 2124 km, against the Government railway's 885 km.

Inadequate standardization and the resulting shortcomings of through service in the private lines soon became apparent, and as a result of the depression of 1900, some private railways lost money. Nationalization was considered necessary for economic and military reasons. The Government passed the Nationalization Law in 1906, under which private lines were bought and operated by the Government, with the exception of some local lines.

Railways in Japan developed further during the boom years of World War One. With the increase in route kilometers and haulage, the Railway Board which had been functioning as a small section of the Cabinet, was raised to an independent Railway Ministry in 1920. In 1949 the Government passed a law to reorganize the national railways into a public corporation in order to improve management and operation. This arrangement was strongly influenced by the occupation forces, and studies for the changeover were thus insufficient. Consequently, JNR is formally an independent public corporation but retains many characteristics of ministerial management in its organization.

World Railway Organizations

Railway enterprises are usually state-owned and more or less controlled by the government in countries with both free and centralized economies. This public ownership and participation has been brought about by many complex political and economic factors.

Free competition between railway companies often results in waste of natural and human resources and causes economic confusion. Moreover, railways operate most effectively on a large scale. In such an industry it is necessary to limit competition and practice state-coordinated development. This calls for reshuffling of the economic structure of private enterprises into nationalized or public-controlled organizations.

Railways have a large external economic effect on the local areas along the line. Private companies which are profit-oriented often care little for external social benefits. A public enterprise, operating in the public interest, can make its total economic effect on the basis of wide and long-range considerations.

With the development of other modes of transport, railway companies deteriorated financially in recent years. The railway however, is one of the most efficient means of transport in terms of labor productivity, energy saving, surface utilization and pollution. Governments and local communities began to subsidize railway operation with public funds, and this forced the companies to submit to public control.

In the USA, for instance, although there are rare exceptions of privately owned railways, the situation is gradually changing. Urban transportation services in densely populated areas of the USA are administered by newly established corporate public bodies, and in 1971 a new corporation, Amtrak, was established to provide intercity rail passenger service by public funding.

Organization Structure

Although world rail management is commonly under public control, its organization is of various kinds. A railway may be operated as a government department, as a public corporation, or as a joint-stock company, and there are also some intermediate patterns.

As a government department, control of the enterprise is as tight as the usual administrative institutions. On the other hand, the most distinctive feature of a public corporation is its independence of the government in operation and finance. In a jointstock company, the government exerts its influence as a stockholder. Each form was created out of the historical experience and economic conditions of the country concerned. Thus it would be unjust and incorrect if the merits and faults of an organization were to be judged out of its context.

In Japan the railway had long been under direct government management. The public corporation was introduced for the railways in 1949 in order to stabilize the serious industrial disputes which were developing in the public sector at that time. Trade unions of such government enterprises as railways, telegraph, telephone, and postal services were among the most militant. With the establishment of public corporation, the employees of the national railways and tobacco monopoly were separated from the other government servants and were controlled by new labor mediation and arbitration procedures.

Many serious people at the time visualized an ideal public corporation that would democratize government enterprises and increase their efficiency. To this end, it was believed that a Japanese Government Railway ought to concentrate its efforts on efficient management rather than its accountability to the Diet. The legislation, however, did not take this view into consideration and JNR was not given the same degree of managerial independence as public corporations in other countries enjoy.

Problems of the Public Corporation

It is generally agreed that the most delicate problem of the public corporation is the strained relationship between corporate management and government supervision. The state owns the corporation and is finally responsible to the people. Therefore, some kind of supervision by the state is required. On the other hand, the public corporation can only attain high operational efficiency if it makes its own technical and economic judgements. In addition, the political neutrality of the corporation can only be maintained by managerial independence.

The theory has been expressed that the Minister responsible for the management should be given no power to issue general directions or to concern himself with programs of operation. Others consider that the board of the public corporation is accountable to the Diet through submission of an annual report and is immune from inquiry by the Diet into its day-to-day administration. It seems that these classical principles of public corporations should be modified in the light of the experience of recent years. The general power of ministers over public corporations has increased in several countries, and the relations between railway industries and the Government have changed considerably.

The ministerial power over financial matters has increased owing to the deterioration of the competitive position of railways. In the case of JNR, the development of motor transport has adversely affected its financial condition in the past 10 years. Its balance sheet showed a loss in 1966, and since then, the deficit has increased rapidly, JNR was forced to ask for financial assistance from its government, and this has weakened the independence of the management.

Ministerial control is exercised informally through discussions, negotiations, and other kinds of pressure. The present cooperation between JNR and its government seems to be adequate for the needs of the railway industry in a highly organized modern society.

Relationship of JNR and the State

The Japanese National Railway is operated by the following organs:

— *The Board* is the highest organ for making decisions on important matters and is composed of the President (Chairman), Vice-President (Vice-Chairman) and seventeen other members (part-time members and full-time Managing Members). Matters requiring action by the Board are: establishment of departments within the Head Office and subordinate offices and other important matters relating to organization; important rules and regulations concerning the organization functions; budget, operational plan, fund plan; settlement of accounts; long-term and short-term borrowing and issue of railway bonds; and redemption plans for borrowing and bonds.

— *The executive organ* of JNR consists of the President, the Vice-President and several Managing Members of the Board. The President is appointed by the Cabinet and holds the highest responsibility for carrying out the functions of JNR in accordance with the decisions of the Board. The Vice-President and Managing Members of the Board are appointed by the President upon approval of the Minister of Transport and they assist the President in performing JNR's functions. The Managing Members of the Board are in charge of particular branches of the work and they concurrently assume staff and decision-making functions.

The President, under this system, has great authority in both decision-making and execution, and is responsible for the operation as autocratically as the Ministers of their respective Ministries.

Higher executives of public corporations can be appointed in various ways. For example, the President can be appointed by the Cabinet with Diet approval, or he can be nominated solely by the competent minister. This depends on the social and economic importance of the public corporation and on the degree of executive independence of the President. The appointment of higher executives of public corporations could be made strictly by Diet nomination, and in compensation, they could be given greater authority. This point deserves discussion. The power of the State to choose the executives of the public corporation is usually seen as a minimum measure of public control in case there is no other regulatory means. The core of corporate independence lies in the extent of government control over the corporation, in addition to this minimum power.

Every year, JNR has to prepare a draft budget of the anticipated revenue and expenditure and submit it to the Minister of Transport, who consults with the Minister of Finance, makes necessary revisions and submits it to the Diet after Cabinet approval. The budget becomes effective only when the Diet has voted in favor of it.

These procedures are almost the same as for the budget of a government department, and it is a little different from other small public corporations, whose budgets become valid upon the approval of the competent minister.

In carrying out the budget, JNR is allowed flexibility to adjust it to the increase in transport demand and economic change. When changes in budgetary appropriations are considered necessary, money can be diverted from one budgetary item to another, except for certain restricted items. Even for these restricted items, e.g. salaries and wages, diversions to or from such items can be made with the approval of the Minister of Transport.

The results of the budget executed during the fiscal year are submitted to the Cabinet through the Minister of Transport. The Cabinet sends them to the Diet for approval after they have been audited by the Government's Auditing Board.

The basic fares and rates can only be revised with Diet approval, and revisions in less important categories of tariff can be made with the approval of the Minister of Transport.

When JNR intends to raise the tariff, it prepares a revision draft and submits it to the Minister of Transport. In dealing with this request, the Minister has to inquire of the Transportation Advisory Committee and make its decision in deference to the intention of the Committee. This Committee, formed of seven members who are appointed by the Prime Minister upon approval of the Diet, makes a recommendation after a public hearing. The Minister submits the amendment draft for tariff increase to the Diet after Cabinet approval. The bill proposed in the Diet is discussed and adopted by the Standing Committee of one of the Houses, and is put to a ballot in the Plenary Session of the House. The same steps are taken in the other House, and the bill becomes law on approval of both Houses.

The most important factor governing the level of rates and fares is the principle of covering the total cost of the services rendered, and a number of substantial increases have been made to meet the rising costs of material and labor in recent years. Generally, rail fares have a commercial character and are strongly affected by the national economy. The legal process in the Diet, described above, is considered inappropriate for economic price-making for the following reasons:

- The process is extremely complicated, and revision is often made too late.
- Rail transportation has lost its monopoly and hence there is no need for strict regulation by the state.
- The request for tariff increase is often treated from the political standpoint.

Studies are therefore now being made to improve the tariff-fixing process.

Investment in important work such as construction of new lines and additional track, electrification and large-scale improvement, is made upon approval of the Minister of Transport.

When the Shinkansen construction plan was prepared by JNR, the Cabinet decided to establish the JNR Trunk Line Investigation Committee in the Ministry of Transport. At that time, the important role of a high-speed railway in intercity transportation was not commonly understood. This special government-level committee was expected to give careful consideration to whether the construction of the new line would meet future transportation needs.

After the great success of the Tokaido Shinkansen, each local government began to ask for new Shinkansen lines to link their areas with the Tokaido megalopolis, and a new legislation to control the Shinkansen network for the balanced development of the country was established. By this law, the Minister of Transport plans the route of the new line and consults the Railway Construction Committee, which is composed of dietmen, government officials, the JNR President, and experts. Following the conclusions of this committee, the Minister makes a provisional decision on the route, and instructs JNR to conduct a technical survey of it. The Minister makes the final decision after the survey and gives the order for the construction.

Main Organization

There is a hierarchy of four tiers of organization to control the total activities of JNR: the Head Office, the Regional Office, the Operating Division, and the field unit.

The Head Office is in charge of planning, research and administration of important basic matters. The regional offices are responsible for regional management, headed by some of the Managing Members of the Board. The operating division under the regional offices are the controlling units of the transportation service. They have general authority in a limited area and include many management service staffs and specialists.

The field units are stations, marshalling yards, engine depots, maintenance depots, repair shops, etc., in charge of their own limited functions.

There are some problems in forming the management system of railways. The number of tiers have a bearing on the organizational efficiency. In JNR it has often been asserted that the regional office and the operating division should be unified to simplify the intermediate organs. Generally, the smaller the jurisdictional area of the operating division, the more important it is to have a regional office, because the Head Office will not be able to administer many divisions directly. This depends on the balance of each hierarchical organ, and, fundamentally, on the total scale of the enterprise.

In other industries, the operational authorities are usually delegated downward to the local office. Decentralization of rail management is, however, somewhat difficult owing to its nature as a continuous network. A distinctive feature of railway organization is the concentrated power of the head office and the large number of working forces.

There are two ways of fixing the limits of the operational territory of a local division. Normally, its managerial power is limited to a geographical area. The old Tokaido Line running parallel to the Shinkansen is controlled by three regional offices, together with connecting feeder lines. For the Shinkansen, a special intermediate office, equivalent to a regional office and called Shinkansen Administration, was established with the object of controlling this line only, first from Tokyo to Osaka and later to Hakata in Kyushu. It is the first line control system operated in JNR and was established for the following reasons:

JNR received a loan from the World Bank to fund the Shinkansen, and it was necessary to confine the executive responsibilities of the line to one single office.

The operation system, the system of maintenance, and working conditions were fundamentally different from the old line system, reflecting the new technology, and had to be administered together by one organization.

With the extension of the Shinkansen down to Kyushu, the jurisdiction of the Shinkansen Administration lengthened linearly to a distance of 1000 km. One office would obviously not be able to cover this unusually large area. The Shinkansen Administration has also had some problems concerning administration territories. While the Shinkansen Administration controls the operation of the Shinkansen Line, the regional offices administer other trunk lines and feeder lines in the same region. As a result, there seem to be two regional agencies representing JNR, and this has caused some confusion in the relationship with the local governments.

Thus, improvements of the present control system of the Shinkansen are being considered. It is planned to abolish the Shinkansen Administration, in which case the Shinkansen will be administered in sections by the regional office, which also control the old line.

Conclusions

Is this legal form of public corporation the most effective for the administration of the Shinkansen, or for JNR in general? It is very difficult to give a clear answer at present. The following comments, however, may be made:

— The Shinkansen is constructed and operated at the highest technical level, which exceeds by far the former world standards. Long-term research and the accumulated experience of management made this project a reality. If JNR had been a privately owned company, this huge program involving great uncertainty would not have been achieved. The Shinkansen is the product of the nation and of the publicly owned corporation.

— It is incredible that, after the great success of the Shinkansen, the balance sheet of JNR has shown a deficit in recent years. This is said to be caused mainly by the delay in timely revision of rail fares caused by complicated legal procedures. If the past tariff increases had been made at the proper time, as JNR proposed, most of the current loss would not have been accumulated. The present economic state of JNR may be due, in a sense, to insufficient managerial independence.

It is hard to appraise the effects of the organization on the achievements of the Shinkansen. In general, the successes were the result of a long series of decisions and executions. Some of the good decisions may have come from the appropriateness of the organization, some from the personal ability of executive managers.

The organization structure, as well as other problems, will continue to be reviewed for the benefit of the people of Japan.

28. *Organization of the Shinkansen*

R. TUCH

Before proceeding with the discussion, I should like to present a short review of the basic organizational analyses conducted by the Management and Technology Area, and explain how these will be applied to the Shinkansen.

Many of you are aware of our first two case studies on large-scale planning programs — the Tennessee Valley Authority (TVA) in the USA and the Bratsk-Ilimsk Territorial Production Complex (BITPC) in the USSR [1]. The Shinkansen will be the third such study undertaken by the Management and Technology Area. I shall not present the complete analysis used in the previous case studies, but only enough to present the basic idea of the types of information we desire and how this information is used in our basic framework.

Figures 28.1 and 28.2 depict the hierarchical interests we want to deal with. Figure 28.1 shows that the TVA was examined not only on the basis of its internal organizational structure, but also in relation to a system of organizational interactions external to the TVA. These external organizations follow from the international to the national level, proceed to the sectoral level, then to the regional level, and finally to the subsystems which operate in

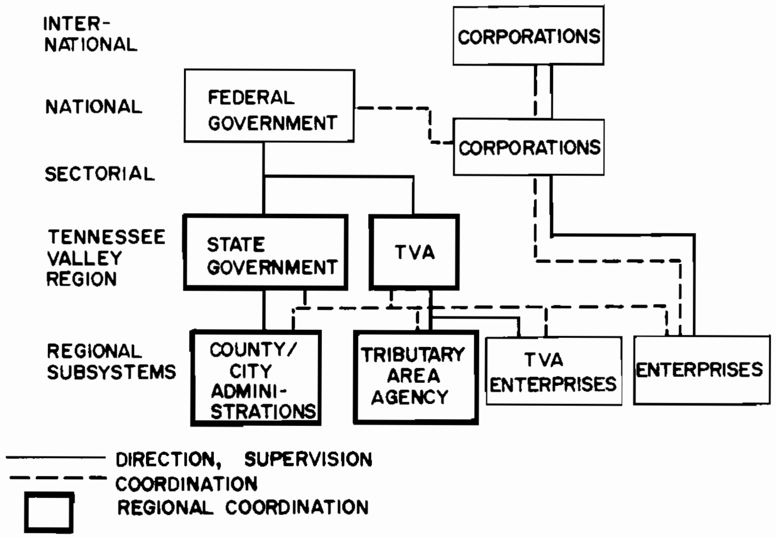


Fig. 28.1. Management of Tennessee Valley Region.

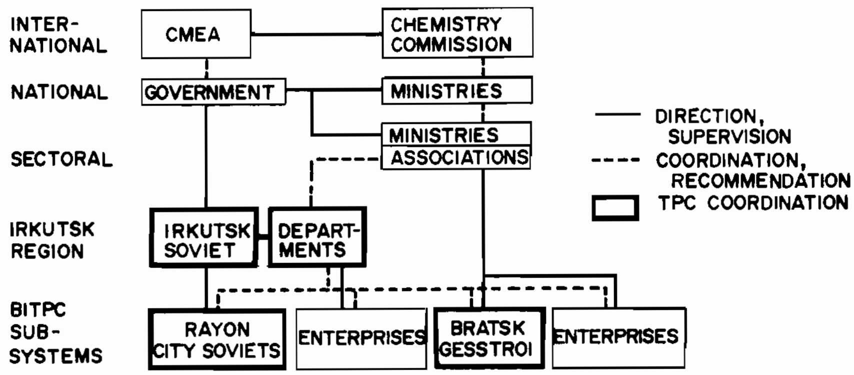


Fig. 28.2. Management of the BITPC.

the region concerned. We try to trace the authority and communication lines and the systems of coordination that are developed or being developed.

The same basic approach was applied to the Bratsk-Ilimsk study. The role of Bratsk is first examined in its relation to the existing socio-economic system in which it operates according to the same levels of interest: international, national, sectoral, regional, and its subsystems (Fig. 28.2).

The next stage of analysis deals with the internal organization of the object under study. We define the following (Fig. 28.3):

Changes in organizational structure and impetus for these changes.
The primary organizational factors and their roles in the internal management system.

- IDENTIFICATION OF CHANGES IN ORGANIZATIONAL STRUCTURE
- IMPETUS FOR CHANGES
- THE IDENTIFICATION OF THE PRIMARY ORGANIZATIONAL ACTORS
- THEIR ROLES IN THE INTERNAL MANAGEMENT SYSTEM
- THE ROLE OF ORGANIZATIONAL UNITS IN FIVE MAIN CATEGORICAL FUNCTIONS:

POLICY FUNCTIONS
↓
PLANNING FUNCTIONS
↓
CONTROL FUNCTIONS
↓
COORDINATION FUNCTIONS
↓
IMPLEMENTATION FUNCTIONS

IMBEDDING OF THE MANAGEMENT SYSTEM INTO THE TOTAL SYSTEM OF THE CASE UNDER STUDY

Fig. 28.3. Analysis of the internal organizational system.

The roles of organizational units in five main categorical functions: policy functions, planning functions, control functions, coordination functions, and implementation functions.

And finally, define the imbedding of the management system into the total system of the case under study.

Using the above basic approach, let us now turn to the Shinkansen to bring out the organizational information presented in the papers, and raise questions to start the present discussion and to prepare for the field study which is to follow.

Mr. Hoshino has given us a very good basis for discussion. He opened with a concise history of JNR, compared it with international experience, and made special reference to the public-corporation aspect of JNR. He pointed out some of the advantages and disadvantages of this relationship.

Mr. Hoshino's account of the relationships between the State and JNR are of special interest in the light of the basic approach we have followed with the two previous studies. However, this account is mainly concerned with JNR as a whole and not with the Shinkansen. Figure 28.4 attempts to clarify this idea. It shows in diagrammatic form the imbedding of JNR into the external systems. The main encompassing area is, of course, the national system. Within this national system we find the regional, or prefectural system, and the local or subsystem levels. We see that JNR serves as a connection between all of the external-system components and operates on the same plane. The Shinkansen, however, as interpreted from the papers, operates within JNR but on a different plane. We could call the Shinkansen system a "third-dimensional component" of JNR. If this concept is accepted, we need to procure information not only on the JNR but also on the Shinkansen component of JNR.

Figure 28.5 gives a rough idea of the imbedding of the JNR management system into the total system. In this figure, Shinkansen administration is

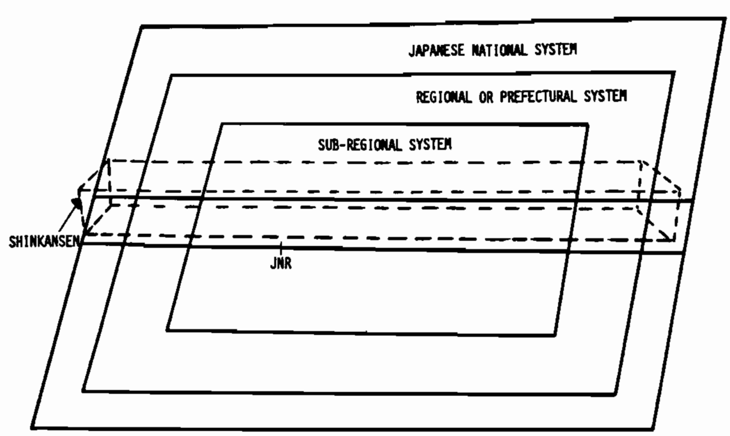


Fig. 28.4. Imbedding of JNR into the external systems in diagrammatic form.

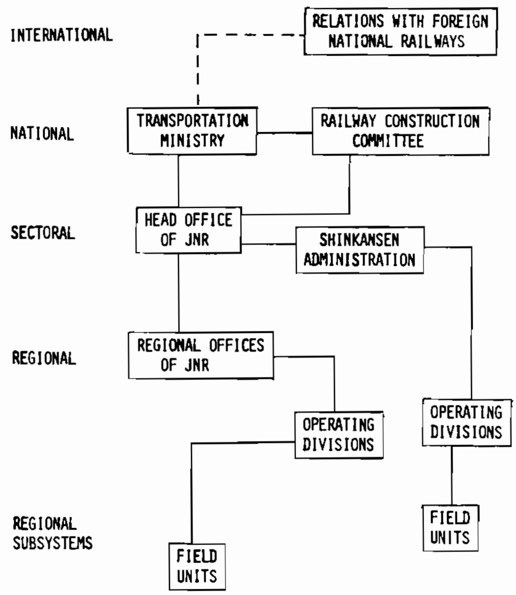


Fig. 28.5. Imbedding of JNR management system into the total system.

depicted as a separate sectoral-regional section of JNR. This special relationship is also brought out in Mr. Hoshino's paper.

In line with the external management relations of both JNR and Shinkansen, I should like to direct the first set of questions on this subject.

1. Could we be provided with more information about the management system of JNR and Shinkansen in its external relationships at each level?
2. In line with this, is there a special relationship between Shinkansen administration and the external system?
3. If so, what are the organizational relationships designed to accomplish this?
4. Are any plans currently being undertaken to improve JNR and Shinkansen relations with the external hierarchical systems?

The next set of questions deals with the internal management system of JNR and Shinkansen. The basic structure of JNR management was given by Mr. Hoshino but, unfortunately, he only touched on some of the particular relationships of JNR management with Shinkansen management. From other papers in these Proceedings we learned that, initially, the Shinkansen administration was located within the Head Office of JNR. Mr. Hoshino has stated that the present administrative status of Shinkansen is outside the Head Office and functions as a regional unit of JNR. What was the impetus for removing the Shinkansen administration out of the Head Office, and at what stage in the Shinkansen's development was this accomplished? Is there at present a special division for Shinkansen within the Head Office?

Mr. Hoshino also touched on some of the difficulties being encountered between Shinkansen administration and JNR normal administration. This implies that attempts towards conflict resolution are being undertaken. It would be interesting to know what are the present mechanisms employed for conflict resolution among sectoral and regional objectives, among objectives of different sectors, and among objectives of different operating divisions and field units. Do conflicts occur because of the nature of the budgetary system, i.e. is the budgetary system of Shinkansen separate from that of other JNR lines?

The remaining questions are concerned specifically with the management of Shinkansen. To what extent does the management system of Shinkansen differ from that of the more conventional lines? What types of management system are being considered for the future?

These questions, dealing with the internal and external management relations of JNR and Shinkansen, do not, of course, cover the full spectrum of information we shall need to conduct the field study. Hopefully, the questions will serve as a catalyst for the participants of this session. During the remainder of the conference the members of the Management and Technology Area will work together with our Japanese colleagues and with the conference participants to clarify both these and other questions relating to the management of the Shinkansen and JNR. It should be borne in mind that the main information we desire is on the Shinkansen management system coupled with the internal JNR management and the external relationships of both.

Reference

1. Knop, H. and A. Straszak, eds., *The Bratsk-Ilimsk Territorial Production Complex: A Field Study Report,* RR-78-2, International Institute for Applied Systems, Analysis, Laxenburg, Austria, 1978.

29. *Discussion*

The Role of Technological Innovation in the Decision Process

(a) It was suggested during the presentations that the choice for the development of the Shinkansen was perhaps a biased one, in that the alternatives were weighted so as to foreordain a decision in favor of the new and advanced technology of the Shinkansen. This view would seem to show a bias that appears to be built into evaluative processes; a bias against the new and the innovative. Reference was made to the opinion of the Austrian economist, Joseph Schrumpfrader, that innovation made progress, that old and proven methods should be replaced by new and radical ideas. He would like to encourage individuals to take risks and to receive fair reward for those risks because they are necessary for progress.

Institutions which analyze decision processes appear to start off by saying, quite correctly, that various driving forces are involved in a project proposal. We could go a step further and define these driving forces as being of the problem type or of the opportunity type. Having said opportunity, the usual course appears to be to return to the problem or need, and then generate the logical structure that leads to a decision involving the alternatives A, B, or C. It was suggested that nine out of ten such procedures have a built-in tacit assumption — that technology stays constant; nothing can be done about the technology. It just has to be decided what costs the most and who will benefit the most.

If the delegates did not believe this, they need only examine the history of past innovations and ask how they would have fared under the evaluative processes now in use.

Since the discussion took place on the 109th anniversary of Nicholas Otto's first run of the internal combustion engine, the history of the automobile in society was reviewed. The first production automobile appeared around 1908, some 30 years after Otto's engine. The airplane is another good example of innovative use of technology. Before either of these developments took hold in society, there were a number of inventions that were technological and economic flops; it was only through continuous development and improvement that their value was proved.

It was suggested that what appears to be happening today in modern societies is a shifting of decisions for innovation from the private to the public sector. Society appears to be making it harder for the private sector to decide what to do. The private sector does not really need a process of decision-making because the individual in charge has the option of operating on intuition — if he is wrong he gets fired, but if he is right he is a hero.

The shift of decision-making responsibility to the public sector suggests that the public will not make decisions without wrapping them in the cloak of respectability. It was suggested that this cloak of respectability is analysis; analysis of the type evolved in such places as IIASA where scientists are examining how decisions are made and how large projects happen.

It was suggested that a new type of research emphasis may be needed, where the present standard of technology is given and then projected. How would improvements in technology contribute towards the advancement of society? It was suggested that this type of research is very necessary and very useful.

What is vitally needed in modern societies is the cloak of respectability, a way of thinking about making innovations in the public sector that represents a more radical change of technology, and which may not come to total fruition for 25 or 30 years. Public decision-makers need a process by which they can analyze and choose without fear of possible repercussions — an analytic procedure that is scientifically respectable and has scientific support. It was suggested that institutions should pay more attention to problems of this nature.

(b) The preceding comments led to a discussion of the role the Railway Technical Research Institute played in the development of the Shinkansen. It was mentioned in the presentations that the Institute played a very strong role in the development and application of technology. Questions were asked about the organization of this research and its management, and the importance of foreign technology at the time.

(c) It was difficult for the delegates from JNR to remember the situation when research on the possibilities of Shinkansen started — the time span is 25 years. However, one of the delegates who was present during that period was able to describe the basic organization structure. The organization of research was loosely controlled by one office with an overall director. Meetings were held once a week for progress reports and discussion. The spirit of the researchers and the sense of mission were very important factors, neither of them easy to quantify.

(d) The transfer of foreign technology was not an important factor in the Shinkansen development. The main support for Shinkansen technology was derived from the 100 years of Japanese railway experience and from the many workers from military and aviation research institutes who transferred to JNR and the Railway Research Institute after the Second World War.

(e) Research on railway technology is continuing. There are still many problems to be solved such as noise and vibration control, increase of speed, and the development of new guidance systems such as the high-speed (500 km/h) magnetic levitation system.

The Options and Cost Estimates Presented by JNR for Government Approval

(a) A question was asked about the models prepared for estimating costs of the Shinkansen development. The reply was that no "models" in today's sense were available at the time of the original proposal. Predictions or projections were made, based on past and expected experience, but the expenses turned out to be about twice the original estimate, using constant yen. The most important factor for this discrepancy was the unexpected growth of the Japanese economy and of inflation, both of which doubled during the period of construction of the Tokaido Shinkansen.

(b) The discrepancy between the actual and predicted costs did not affect the completion of the project. Competition for government funding and approval was very high at that time, but the economy was increasing so fast that the Shinkansen was not seriously affected once the decision to construct was made.

Operating Costs and the Effects of the Shinkansen on Development

(a) No precise data is available for comparison of operation costs with construction costs. JNR separates operation costs into three parts: personnel, goods and maintenance. Projections of operation costs for the Shinkansen were made on this basis, but the higher than expected number of passengers made expenditure on operation lower than was originally calculated; the net result was increased operational efficiency, an operating ratio of about 62%.

(b) It is still difficult to determine all the effects of the introduction of the Shinkansen on its sphere of operation. It most certainly participated in the growth of the Japanese economy. The most obvious result was the remarkable passenger acceptance and use of the new system, and a certain promotion of industry. The latter was not expected by JNR at the beginning of the Shinkansen development.

The Use of Advanced Technology and Why It Was Cheaper Than More Traditional Technology

(a) The reason why the most advanced technology was the cheapest was the following. The Tokaido corridor is the most densely populated in Japan. Expansion of existing lines would have required the purchase of highly priced land in populated areas. The Shinkansen line could be routed through less populated and cheaper land.

(b) It was asked why the limit of 220 km/h was chosen as a target, and why not 250 or 300 km/h? The answer was that JNR pursued the most advanced ideas available at the time.

Organization of the Shinkansen

(a) The Shinkansen Administration controls the operation division of the Shinkansen. In the other JNR lines, operational supervision is divided between the regional offices and the field units, the latter having a high degree of competence in train operations. The Shinkansen lines, however, are more firmly controlled by the Shinkansen Administration.

(b) The stations are the most important for external relations, but they are under the control of the conventional divisions. The Shinkansen has its own relationship with the external systems, but much less than the normal operating divisions. Responsibility for conventional lines is set according to divisional boundaries. The Shinkansen, however, is completely separate from the normal territorial divisions, which results in some minor conflicts but no serious problems. It is planned to bring the administration of Shinkansen lines into line with that of the conventional lines.

(c) Before the official opening of the line, the Shinkansen Administration was one department in the Head Office of JNR. On opening day, the Shinkansen Administration was raised to the level of a local office. The reason was that planning and construction were finished, and only the operational function remained. The change was carried out very smoothly. Six months before the Shinkansen opening, the Shinkansen Administration had the characteristics of both a departmental division in the Head Office and a local office.

(d) No major problems are anticipated in the coming changes of Shinkansen Administration when it fits into the conventional administration. The management system of the Shinkansen is fundamentally the same as that of the conventional lines, and technological innovations have also been made on the narrow-gauge lines, so that the technological level of both lines is similar. The main future problem for improved management will be the reaction of employees to the necessary management changes.

The Construction of Rail Lines

(a) Two bodies are involved in the construction of rail lines; one is JNR and the other is the Railroad Construction Company (RCC). The RCC was formed by the Government when JNR found it impossible to construct the necessary local lines and still maintain their responsibilities on the major trunk lines. Had JNR been forced to construct the large number of local lines required, it would have found itself in a very difficult financial situation.

(b) Shinkansen lines are at present being constructed by both JNR and RCC. JNR construction is usually done on a short-term contract basis after planning and designing is completed. The lines for construction are usually divided into stages, with contracts running for a 1- or 2-year period; usually fixed-term contracts, but in case of high inflation the terms of the contract may be changed.

High-Speed Operation, Train Safety, and Operational Management

30. *The Role of Transportation Studies at IIASA*

H. STROBEL

It could be asked why such a specific engineering and technical topic as the Shinkansen is a relevant research subject for an institute like IIASA, especially in view of the limited resources of IIASA in comparison to much larger research institutes in other countries.

A partial answer to this question was given by IIASA's first Director, Howard Raiffa, in a speech delivered at the first IIASA Conference in 1976. He quoted an American writer: "There are two ways of spreading light — the first is to be a candle, and the second is to be a mirror and reflect the light generated by other candles." If one accepts this analogy, then the candle is IIASA's role in fundamental research while the mirror characterizes IIASA's "clearing-house" function, which includes the exchange of information between IIASA's NMO countries, the preparation of state-of-the-art surveys, and evaluation of the experiences gained in advanced large-scale development projects.

It is obvious that IIASA's Shinkansen research activity is related more to its "mirror" than to its "candle" function. This is expecially true for the technologically oriented part of the study. Nevertheless, any fundamental research at IIASA dealing with socio-economic, environmental, or regional development aspects of high-speed ground transportation systems needs input information on the following question: What contribution towards the solutions of major transportation development projects could one expect from the application of advanced technologies and management methods?

The papers presented in this technologically oriented section provide information for answering this question. Two different categories of technology can be distinguished: (1) guideway and vehicular technologies, and (2) systems technologies.

The papers by T. Yorino and S. Kubo give a very good overview of the first category of technology, i.e. of the design principles for vehicles and ground facilities, as well as the organization of the R&D work.

The significance and the management of the maintenance tasks are discussed by S. Kubo in regard to vehicles and Y. Muto in regard to fixed facilities — the guideway, communication, and control systems. One is impressed to learn that when the trains reach the end of their normal life-span of about 12 years they are destroyed in a specially equipped workshop and replaced by new trains. No other railway organization in the world applies such strict rolling-stock replacement rules.

The second aspect of technologies, the systems technology, deals with the application of sophisticated control and computer systems. A characteristic feature of the Shinkansen is that it makes extensive use of this type of technology according to the following hierarchy of control and management tasks.

1. Computerized Top Management: the "Resource Control-Statistic" software package and the telecommunication network control system DACS (**D**ata **A**gent **C**ontrol **S**ystem).
2. Computerized Sales Management: the **M**agneto-electronic **A**utomatic seat **R**eservation **S**ystem (MARS) and its touchtone telephone-based version.
3. Computerized Operation Management containing two parts:
   the **Com**puter Aided **Tra**ffic **C**ontrol (COMTRAC) System used for optimal planning and real-time control of train operation:
   the **S**hinkansen **M**anagement and **I**nformation **S**ystem (SMIS) used for making up daily maintenance programs of tracks and rolling stock as well as for cost analysis of the jobs.
4. Accident prevention and train control carried out by the following subsystems:
   the **A**utomatic **T**rain **C**ontrol (ATC) System, which includes a speed control and **A**utomated **T**rain **S**top (ATS) system installed aboard the vehicle;
   the **C**entralized **T**raffic **C**ontrol (CTC) system; and
   the **A**utomatic **R**oute **C**ontrol (ARC) system.

The systems for accident prevention at the lowest level of this control and management hierarchy are described by Y. Muto. He shows that the highly sophisticated electronic control systems are of vital importance for the implementation of a high-speed train of the Shinkansen type. Y. Oguro's paper on the Train Operation Control System covers topics of the third and fourth levels, the COMTRAC system for the former, and the ATC and CTC systems for the latter. Of special interest are his comments on the distribution of the whole supervision tasks to the different dispatchers and the resulting problems of the design of a combined man-computer real-time management system. The management of maintenance problems, a level-3 task, is discussed in the paper by S. Kubo.

The two highest levels of the hierarchy are considered in the paper by M. Harada. The seat-reservation system MARS is discussed, followed by a general survey of computer applications at JNR. The Seat Reservations Computer Complex represents one of the largest computer centers in the whole of Japan. One of the outstanding features of the MARS system is the possibility of reserving seats by means of a touch-tone telephone keyboard. Here, the prospective Shinkansen passenger can communicate directly with the seat reservation computer. He puts the required data (date, train number, etc.) into the touch-tone telephone keyboard and gets the answers from the computer acoustically, i.e. in the form of recorded human language.

The second part of Harada's paper makes it clear that JNR is operating a large number of computerized management systems. The systems developed for the first (administration-management) level of the hierarchy led to a remarkable manpower saving on the order of more than 1800 employees. In addition to the Shinkansen system, other computerized management and control systems installed by JNR include:

Yard **A**utomatic **C**ontrol **S**ystem (YACS);
Kojo (workshop) **I**nformation **C**ontrol **S**ystem (KICS);
Effectual **P**lanning and **O**peration of **C**ontainer **S**ystem (EPOCS);
Freight **O**perational **C**ontrol **S**ystem (FOCS);
and five other minor systems.

The resulting manpower saving as a result of the installation of these systems is shown to reach a total of 3250 people.

This final section of the Shinkansen Conference provides a unique opportunity to learn from JNR scientists who were deeply involved in the creation of Shinkansen, and to obtain an excellent survey of the technological and management aspects of this high-speed ground transportation system. The papers in this section represent one of the most comprehensive explanations of the Japanese experience on the Shinkansen given from a systems analysis point of view outside Japan, and in a language other than Japanese. It is very difficult to deal with questions of fundamental research in socio-economic, environmental, population, and other aspects of a large program without a good background on the management and technology side of the program. This section presents the necessary background for such continuous research activities.

31. *High-Speed Operation System: Ground Facilities*

T. YORINO

Primary Conditions

The Construction Standards for the Tokaido Shinkansen were established in August 1961 by the Investigation Committee for Construction Standards. The Committee was set up in April 1958 and held twenty committee meetings and nine subcommittee meetings before establishing the Standards.

The Standards intended to meet the following three requisites for constructing adequate ground facilities for high-speed train operation:

sufficient bearing strength of structure to sustain the load of high-speed trains;
alignment of the track to ensure stability of high-speed running; and
adequate power supply to high-speed trains.

System for Supporting High-Speed Trains

LOAD CONDITIONS

At the early planning stage of the Tokaido Shinkansen, it was assumed that the line would offer only passenger services for some time after inauguration and that freight services would be added later. It was therefore decided that the construction and track structure should be capable of meeting both passenger and freight loads.

The principal dimensions of the rolling stock were decided according to the transportation and rolling stock operation plans. The load conditions were then set up for the purpose of structure design, as shown in Fig. 31.1.

The standard live loads for passenger electric railcars (P-load) and freight electric railcars (N-load) were decided as in Fig. 31.2, which shows that each axle load is 16 tons, whether for passenger or freight train. The difference in axle arrangements has varying effects on the structural bearing power of bridges, and therefore the bridges on a very small portion of the line for exclusive passenger service were designed to meet only the P-load.

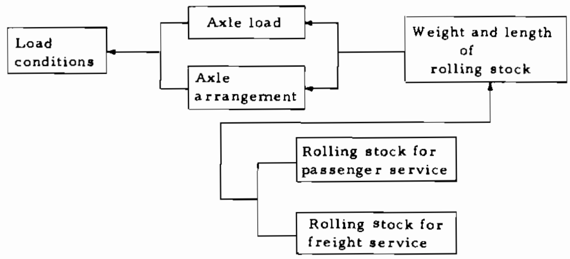


Fig. 31.1. Load conditions.

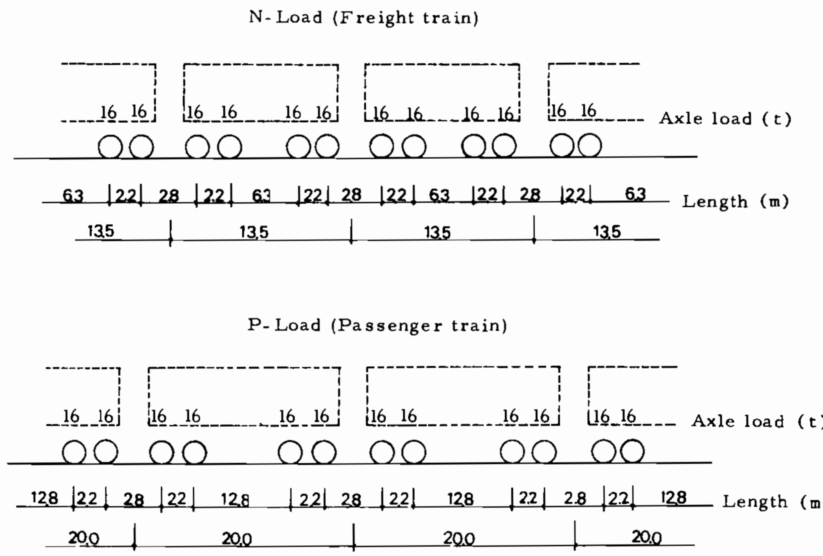


Fig. 31.2. Standard loadings.

TRACK STRUCTURE

It was at first suspected that ballasted track could not bear the 200-km/h impact loads which might cause loosening and creep of ballast gravels and make maintenance work difficult. Asphalted track and ballastless track were at one time considered as alternatives. Continued research on the ballasted track led to the conclusion that even under very heavy high-speed loads, the rate of ballast sinking and deterioration could be kept down to the same limits as for conventional railway track standards. This conclusion was based on the assumption that the designs of the rails, rail-fastening devices, and sleepers would be improved. The development work included the theoretical calculation of the ballast deterioration, model tests, and field experiments on the test-run section. In view of all these factors, it was decided that the track structure should, except in special cases, be composed of stone ballast, prestressed concrete sleepers, double elastic fastening, long-welded rails, and movable nose turnout.

Estimation of track deterioration

The magnitude of external forces which cause track deterioration is proportional to the train load (i.e. annual passing tonnage and train speed) and is also related to the spring performance of rolling stock and to the ratio of sprung to unsprung load. To express the influence of these external forces in quantitative terms, the idea of the load coefficient (L) was conceived. The degree of track deterioration due to external forces depends, however, on the type of track structure and is proportional to the ballast pressure and ballast vibration acceleration. This liability to deterioration was represented by the structure coefficient (M). The dimensions and speed of rolling stock determine the value of the coefficient L. Various values of the coefficient M were obtained by combining different types of rails, sleepers, rail fastenings and ballasts. Therefore, the product of $L \times M$ showed the degree of track deterioration (see Fig. 31.3).

The calculation analysis showed that the coefficient (L) of the Shinkansen was about 1.5 times as large as that of conventional 1067-mm gauge railways, and the coefficient (M) was only 0.6 times as large. This is why, at the planning stage, the degree of track deterioration of the Shinkansen was estimated to be almost the same as that of the conventional track.

Rail

Use of 50-T rail (53.4 kg/m). In deciding the rail type to be adopted, the rail shape, the weight per unit of length and the composition of the material must be considered (see Fig. 31.4).

In determining the rail weight per unit length, the following points had to be considered:

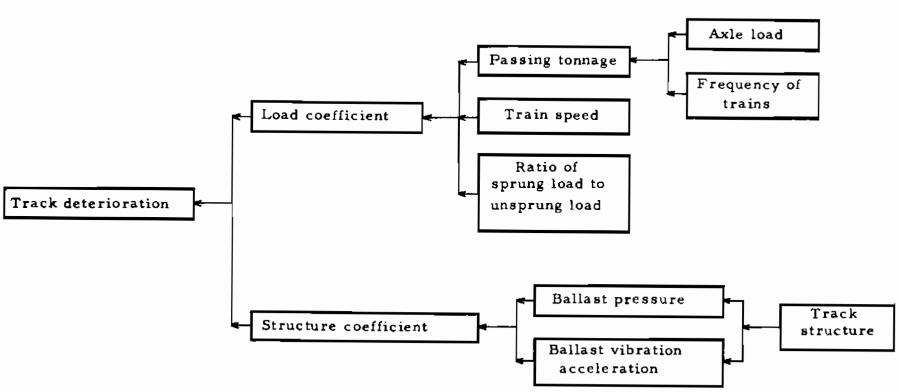


Fig. 31.3. Track deterioration (block diagram).

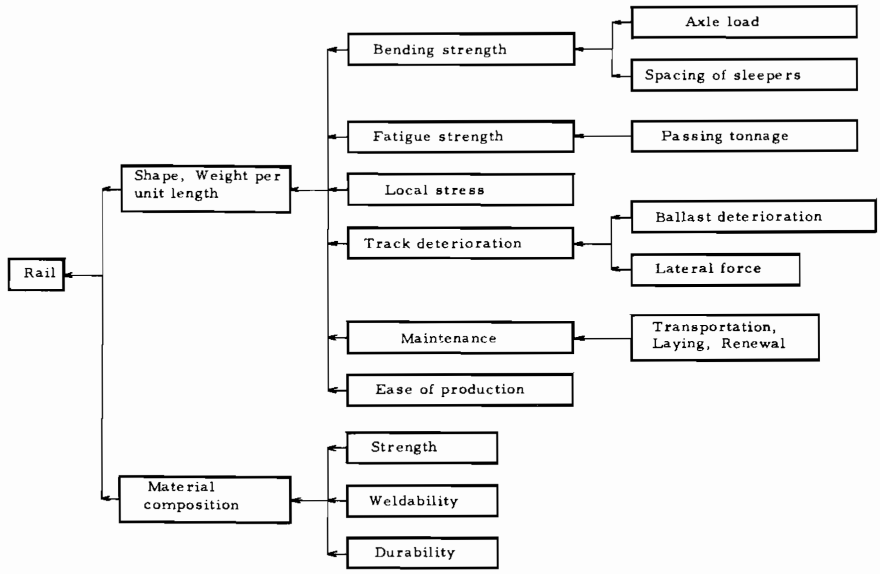


Fig. 31.4. Factors in the choice of rail type (block diagram).

bearing and fatigue strength of rail against the axle load and passing tonnage;
capacity of maintenance work to cope with track deterioration (particularly ballast); and
economic feasibility.

The adoption of 50-60-kg/m rails presented few problems of internal stress from the axle loads in the range of 15 to 25 tons (16 tons in the case of the Tokaido Shinkansen). Therefore, maintenance was the principal factor in choosing the unit weight of the rail. There are two ways of preventing increasing track deterioration: qualitative and quantitative improvement of maintenance work and adoption of stronger track structure.

For the improvement of maintenance work on the Shinkansen, it was expected that efficient mechanization could be realized by working at night when trains are not running. To strengthen the track structure, heavier rails, better rail fastening systems, stronger sleepers, and ballasts are required.

The unit rail weight was decided by economic comparison. The heavier the rail, the stronger the track, and the less the maintenance cost, but, on the other hand, the construction cost is higher. These comparisons were made on the assumption that general repair work takes place every year and renewal work every 15 to 20 years. The proposed passing tonnage was estimated at 30 million tons per year in 1969 (fifth year after inauguration) and 36 million tons from 1972 to 1975.

The calculation to minimize the annual track maintenance and construction costs led to the conclusion that the most economical rail weight was 52 to 53 kg/m, corresponding to the passing tonnage for the year 1969, and 54 to 56 kg/m from 1972 to 1975. Consequently, the 53.3-kg/m rail was adopted for the Tokaido Shinkansen.

The 60-kg/m rail in place of the 50-T rail. The rail for the Tokaido Shinkansen was chosen to have the least possible cross section and the lightest possible unit weight. After inauguration, however, a heavier rail was found to be more desirable because the volume of maintenance work and passing tonnage was greater than expected. The scarcity of maintenance labor was also unexpected.

On the Tokaido Shinkansen, the 50-T rails are now being replace by 60-kg/m rails because the 60 kg/m rails can be easily fitted to the present 50-T rail fastenings and heavier rails help to reduce vibration and noise.

The Sanyo Shinkansen planned from the beginning to use the 60-kg/m rail.

Ballast

At the early stage of planning, it was proposed to make the specification for ballast quality and grading stricter than for the conventional 1067-mm track structure. However, the short period allowed for laying, and the massive quantity of 2,000,000 cubic meters of ballast required, forced the adoption of the same specification as for the conventional narrow-gauge line.

The minimum depth of ballast was determined at 300 mm, except in special cases, according to the theoretical calculation of track deterioration and economic considerations. From the experience of actual maintenance work on ballast structure on the Tokaido Shinkansen, it had become necessary to develop new track systems such as direct fastening of track (slab track) to ensure accurate alignment and maintenance free performance. On the Sanyo Shinkansen, the slab track without ballast has been employed on a large scale.

Sleepers

Research was carried out on conventional prestressed concrete cross sleepers. Others examined were longitudial sleepers, 10 m long, and frame-type sleepers 1.0 to 1.9 m long. These two types have the advantage of greater bearing area, heavier track skeleton weight and increased resistance against ballast. This is offset by the high production cost, the length of time required for fabrication, the laying cost and the difficulty of maintenance.

After analysis and comparison of these three types, it was concluded that prestressed cross sleepers would be most suitable after study and improvement.

The design requirements for cross sleepers were:

- sufficient bearing strength for the repeated loads of high-speed trains;
- utilization of technical data already available at home and abroad to offset the short study period;
- possibility of mass production.

Roadbed structure

The roadbed consists of materials such as earth, concrete, and steel, which take the form of embankments, elevated tracks, and bridges. The design criteria for roadbed structures were drawn up taking into account the load conditions and safety factors (see Fig. 31.5).

Table 31.1 shows the breakdown of structure on the Tokaido Shinkansen. The embankments are built mainly in rural districts. In urban areas, where the acquisition of right-of-way is expensive, elevated tracks were built to economize on space.

Wide-span bridges over roads and rivers were constructed of less steel. These, however, have been causing environmental problems of noise, and sound-proof work is now being done on some of the steel bridges on the Tokaido Shinkansen. After this experience, bridges on the Sanyo Shinkansen, including wide-span bridges, were built of ballasted concrete.

System for Stability of High-Speed Operation

TRACK GAUGE

The adoption of the standard gauge (1435 mm) was based on such fundamental conditions as transporting capacity, travelling time, running

TABLE 31.1. Breakdown of structures on the Tokaido Shinkansen

Type of structure	Length (km)	(%)
Embankments	274.3	53
Elevated tracks	115.8	23
Bridges	57.1	11
Tunnels	68.6	13
Total length	515.8	100

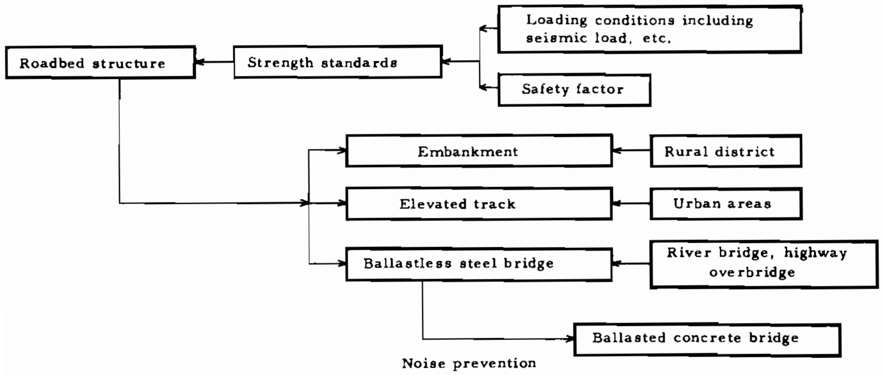


Fig. 31.5. Roadbed structure (block diagram).

safety and possibility of incorporating modernized systems (see Fig. 31.6). The main technical reasons for the choice of gauge were the following:

At the early stage of the Shinkansen planning, speed records of 331 km/h had already been recorded on the standard-gauge railway by the French National Railways (SNCF) and more than 200 km/h in the United Kingdom, the Federal Republic of Germany, and Italy. Although these were only trial run records, they indicated good prospects for commercial operation at 200 km/h.

Some railways in other countries have a gauge of more than 1500 mm, but they do not always show good performance in high-speed running and riding quality. Further enlarged track gauge and car width would not necessarily result in improved riding comfort and economy. Increasing the number of seats on each side of the center aisle from two to three or four would not be conducive to passenger comfort, and would only increase the weight and width of the cars.

A track gauge of more than 1500 mm was therefore not considered advantageous, and the international standard gauge (1435 mm) was adopted for the Tokaido Shinkansen.

MINIMUM RADIUS OF CURVATURE

The minimum radius of curvature is one of the most important factors limiting maximum train speed, and the maximum speed on a straight line would not be restricted by curvature.

In determining the minimum radius of curvature the following criteria must be satisfied (see Fig. 31.7).

Stability against car overturning

The quantity of actual cant should be set so that the high-speed train passing on the curved track would be secure from outward overturn due to centrifugal force and outward-directed wind force.

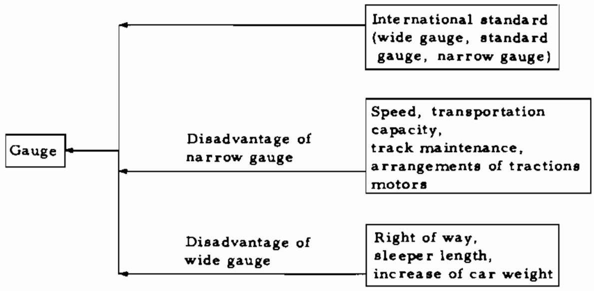


Fig. 31.6. Track gauge (block diagram).

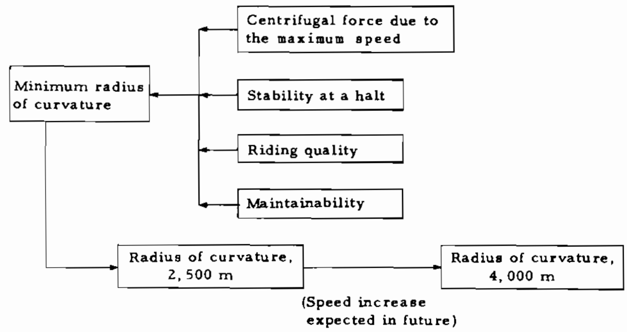


Fig. 31.7. Minimum radius of curvature (block diagram).

The car should also be safe from inward overturn caused by the force of gravity and inward-directed wind when the train is running at a low speed or is at a halt on a curved track.

Influence on riding quality

The limit value of lateral acceleration from riding quality is estimated to be under 0.1 g when the train runs on a curved track.

Maintenance work

The actual cant should be properly set so that the increment of maintenance work due to unbalanced loads could be maintained within the allowable limits.

After due consideration, the Construction Standards of the Tokaido Shinkansen prescribed that the minimum radius of curvature be 2500 m, except in special cases, and that the maximum cant be 200 mm.

For the Sanyo Shinkansen, the minimum curvature radius was 4000 m on ordinary sections and 3500 m in unavoidable cases, so that almost the same riding quality could be attained as for the Tokaido Shinkansen, even at a future speed of 250 km/h.

MAXIMUM GRADE AND LENGTH OF GRADE SECTION

The factors influencing the choice of maximum grade (see Fig. 31.8) are the temperature rise of electric traction motors on an uphill grade, and the temperature rise of the dynamic control resistor for braking on a downhill grade. The temperature-disposing capacity of the latter being greater, it follows that the temperature rise of the traction motors is the dominating factor.

One car for the Tokaido Shinkansen was equipped with four traction motors, each with an output of 185 kW. Under these conditions, the grade and

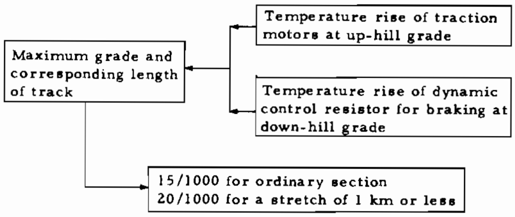


Fig. 31.8. Maximum grade and corresponding length of track (block diagram).

corresponding length of track are limited as follows from the temperature rise of the main electric traction motors:

about 7 km — a grade of 15/1000,
about 1 km — a grade of 20/1000.

Accordingly, the Construction Standards provide that the maximum grade should be:

15/1000 or less for the ordinary section,
18/1000 or less for a stretch of track not exceeding 2.5 km,
20/1000 or less for a stretch of track not exceeding 1 km.

The traction motors of the car for the Sanyo Shinkansen were increased to an output of 200 kW × 4. Thus, the Standards for the Sanyo Shinkansen stipulate that the maximum grade should be 15/1000 for the ordinary section and the average grade 12/1000 or less for a 10-km stretch.

MEASURES FOR REDUCTION OF IMPACT FORCES DUE TO HIGH-SPEED RUNNING (FIG. 31.9)

There is a growing tendency for many railways in the world to adopt long-welded rails so as to get rid of rail joints — the vulnerable portion of the track. For high-speed operation, the long-welded rails are necessary to keep the ballast from deteriorating at rail joints and to lengthen the cycle of maintenance work. These rails not only reduce the wheel pressure due to the

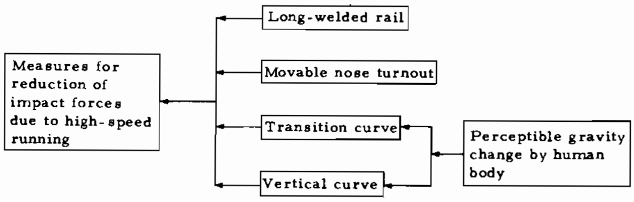


Fig. 31.9. Measures for reduction of impact forces due to high-speed running (block diagram).

rail joint impact and diminish vibration acceleration of the rails but also decrease environmental nuisances such as vibration and noise outside the track structure.

A new type of movable nose turnout has been developed and used on the Shinkansen. This turnout avoids the mechanical shock which occurs at the joint gap between the wing rail and the nose part in the conventional fixed crossing. The movable nose turnout has a longer nose rail, and the nose tip can be turned so as to be fixed to the wing rail. The train can then run on a continuous line of rail without any joint gap at turnout.

The riding quality during high-speed operation is affected by the radius of vertical curve and of transition curve. For the vertical curve, the vertical acceleration acting on the rolling stock becomes a problem. The actual acceleration of the conventional railway (maximum speed 110-120 km/h) is about 0.033 g. For the Tokaido Shinkansen, the value of the vertical acceleration was to be 0.03 g, and the corresponding radius of vertical curve was chosen to be 10,000 m.

The length of the transition curve was chosen so as to maintain the lateral acceleration within the limit of 0.03 g. The length of the transition curve was chosen from the longer one, L-1, L-2, or L-3 described below.

L-1 is the length of transition curve necessary for comfortable riding based on the time-rate change of the deficient cant. The deficient cant is the difference between the theoretical and the actual cant, the theoretical cant being calculated from the train speed and the radius of curvature. L-2 is the required length of transition curve determined from the limit of time-rate change of actual cant. L-3, which is calculated from the train operation safety, is far smaller than L-1 and L-3 and is not a detemining factor.

MEASURES AGAINST AERODYNAMIC IMPACT OF HIGH-SPEED OPERATION

The relative speed of two trains passing each other at the same speed of 250 km/h reaches 500 km/h and causes aerodynamic impacts. The results of aerodynamic research on the conventional 1067-mm gauge line at the relative speed of 200 km/h showed maxium air pressure of 37 kg/m^2 (the equivalent wind velocity is 20 m/s).

On the basis of this research, it was found that the air pressure could be kept below the region of 37 kg/m^2 at the relative speed of 500 km/h if the following conditions (see Fig. 31.10) were satisfied:

streamlined train shape,
smoothly finished exterior surfaces of the carbody,
distance between trains of 0.8 m.

The distance between track centers was therefore set at 4.2 m by adding 018 m to the width of the vehicle gauge, which was 3.4 m.

The distance between the car side and the inner edge of the workers' passage was determined so as to secure a safe space where the workers could take

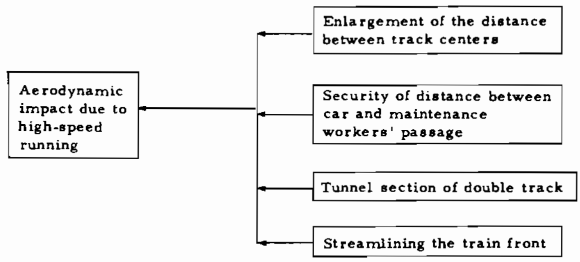


Fig. 31.10. Aerodynamic impact due to high-speed running (block diagram).

shelter safely. This distance was set at 0.8 m so that the wind velocity would be less than 17 m/s, which is the limit for the safety of the workers. All tunnels were double-track sections since a single-track tunnel section would not allow the track maintenance workers to carry out inspection safely under the aerodynamic impacts.

TESTING OPERATION ON THE MODEL LINES

To hasten the design process of the Shinkansen, a number of high-speed experimental operations were carried out together with laboratory tests, model tests, and theoretical analyses.

High-speed test on the conventional 1067-mm gauge line

In 1960 a single-track test line was constructed over a distance of 1.3 km in parallel with the Tokaido Line, and full-size field tests were conducted for various types of track structures, bridges, and overhead lines. Conventional electric express trains were employed for the tests and a maximum speed of 175 km/h was recorded.

The measured data for the ground facilities concerned were: stress of track components, impact force, displacement, aerodynamic impulse due to high-speed running, noise, vibration, lateral forces, track irregularities, derailment coefficient (the ratio of lateral force to axle load), current-collecting performance, etc.

The basic factors necessary for the Shinkansen design were confirmed by three field tests.

High-speed running tests on the model section of the Tokaido Shinkansen

Although the fundamental design data were obtained from the field tests, it was still necessary to carry out actual running tests on the Shinkansen in order to prove the safety and stability of high-speed operation before putting it into service.

The test section, a distance of about 40 km, was completed between Yokohama and Odawara in June 1962, more than 2 years before the inauguration of the line. Test runs were immediately conducted on the section and the speed of test trains was gradually raised until it reached 210 km/h in October 1962.

These runs tested the safety by measuring the wheel lateral force and derailment coefficient. The lateral force did not exceed the previously fixed limit value of 6 tons. The derailment coefficient did not exceed the safety limit. The oscillations of the vehicles were measured on the floor just above the bogie center. The test results showed that there was ample margin for safety. The maximum amplitude of vertical acceleration was 0.2 g and that of lateral acceleration 0.25 g.

The experiments also measured rail stress, the stress of rail-fastening devices, lateral forces acting on rails, displacement of trolley wires, wind velocity, and aerodynamic forces caused by high-speed trains. The data confirmed that performance was maintained almost within the desired limits. Improvements based on these results were adopted for the actual system.

Power-Supply System

The Tokaido Shinkansen connects Tokyo and Shin-Osaka, a distance of 515 km, in about 3 hours at a maximum speed of 210 km/h. This remarkable operation demands the most reliable and economical power supply, the technical success of which is attributable to the completion of both the electrification and current-collecting systems. The studies for their development were based on experiments and experience on the conventional lines.

SELECTION OF ELECTRIFICATION SYSTEM

The choice between AC and DC was one of the most important (see Fig. 31.11). DC electrification has two advantages: light weight and simplification of rolling-stock construction (the DC cars do not need to be equipped with transformers and rectifiers); and ease of current insulation because of lower supply voltage.

The DC feeder voltage, however, is limited in actual practice to about 3 kV, and a train such as the Shinkansen, with a big output, requires large feeding current. DC electrification therefore has the following disadvantages:

- greater voltage drop and consequently increased number of substations shorter interval of substations);
- the need to augment current capacity of feeder line (larger lines);
- increased abrasion of pantograph and contact wire due to large amount of current collecting at the pantograph.

The AC electrification system can supply a high voltage (20 kV or more)

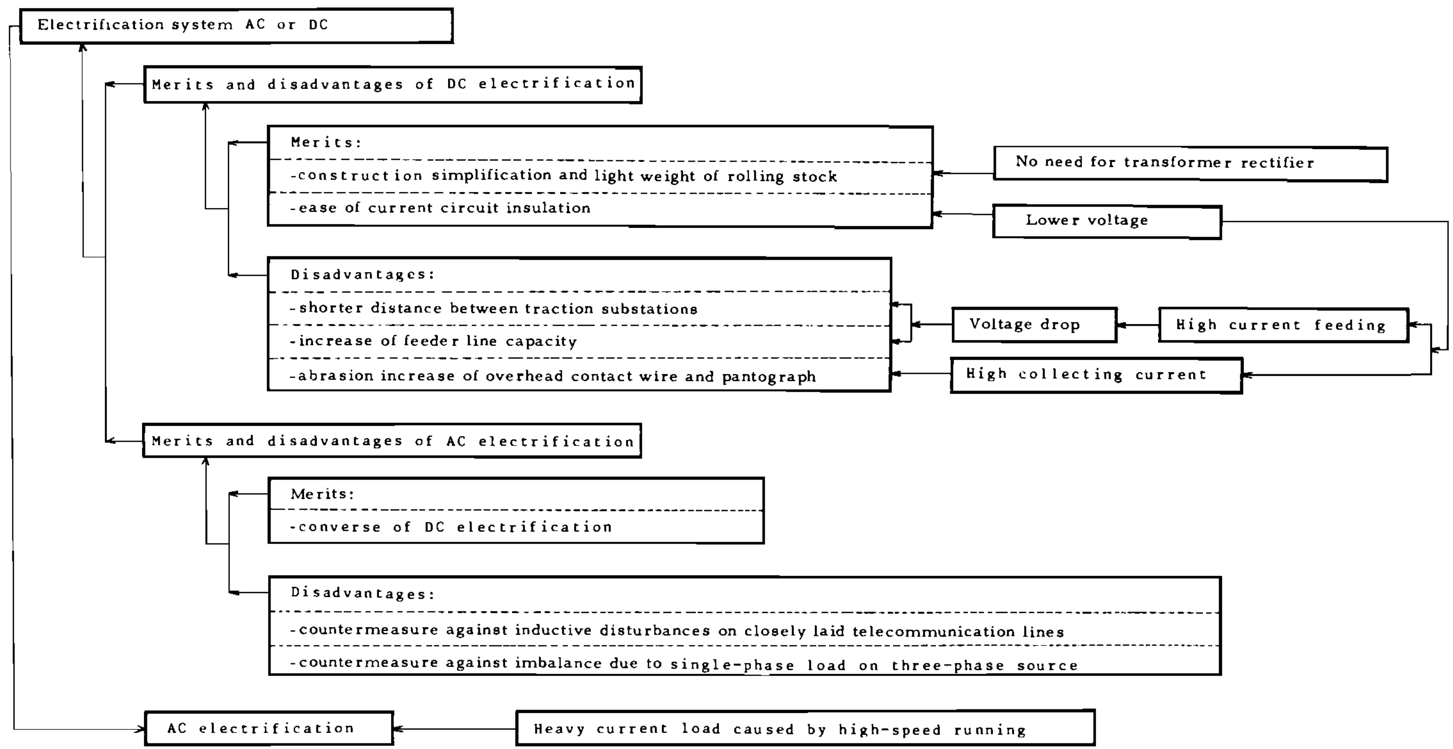


Fig. 31.11. Selection of electrification system (block diagram).

with lower currents, and this results in very much more favorable substation intervals, feeder line capacity and current-collecting capacity than for the DC system.

The AC system, however, has a disadvantage of inductive disturbances on telecommunication lines and imbalance due to single-phase load on three-phase power surfaces. To combat the inductive disturbances, a method of reducing the rail and earth current was adopted. The installation used is composed of a negative feeder and a booster-transformer (BT) (Fig. 31.12) which have been applied on the conventional AC electrified sections.

The effects of unbalanced loading on the three-phase power sources were also expected to be diminished by increasing the three-phase short circuit to the utmost capacity at the receiving point, and by using Scott-connected transformers employed by the conventional electrified sections.

The AC system was finally adopted for the Tokaido Shinkansen. However, one of the disadvantages of the BT system is the complicated feeder network necessary to counteract the electric arc that occurs at the booster sections required by the BT system.

The Sanyo Shinkansen has adopted the new auto-transformer (AT) system (Fig. 31.13), constructed of positive feeder and transformer, as an improved measure against the inductive disturbance on telecommunication lines. The AT system contributes to improved performance of the Shinkansen system in the following ways:

there are no sections where complex devices against electric arc are required;
the feeder voltage from the levels of substations is twice the value of the BT system;
the feeder distance can be theoretically lengthened four times as much as the BT system.

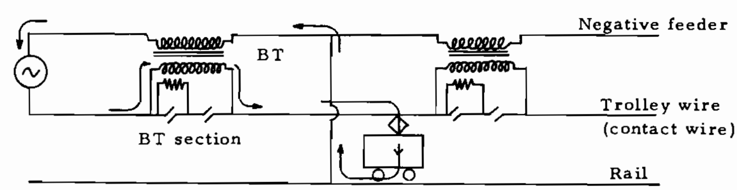


Fig. 31.12. Booster-transformer (BT) system.

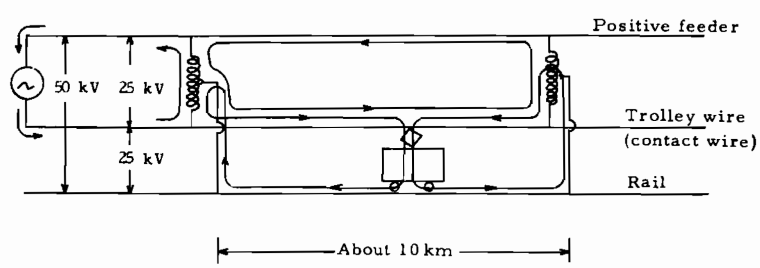


Fig. 31.13. Auto-transformer (AT) system.

The reasons why the AT system was not employed from the very beginning of the Tokaido Shinkansen are as follows:

the calculations of the inductive voltage and current influencing telecommunication lines are so complicated that they need the aid of electronic computers which were not available at the initial stage of the Shinkansen;
it was estimated that the BT system which had been adopted on the conventional lines could also be applied to the Shinkansen.

Thanks to the AT system, the distances between substations on the Sanyo Shinkansen were increased, with the results that substations with greater capacities were required to cope with the increased number of trains running on the feeder section of substations.

It followed that substations had to receive their power supply by extra-high-tension transmission line, and therefore special transformers were studied and developed which considerably reduced the cost.

The average distance between substations on the Tokaido Shinkansen is 20 km, and on the Sanyo Shinkansen 50 km.

CHOICE OF FEEDER VOLTAGE

The AC system on the conventional line has been provided with a single phase of 20 kV. For the Shinkansen, however, a system of higher feeder voltage and lower feeder current is desirable as trains demand a greater power run at frequent intervals on the line (see Fig. 31.14).

The AC system economizes on electric ground facilities by allowing a greater distance between substations and ensures a trouble-free feeder system. The feeder voltage for the Shinkansen was not restricted to the 20-kV voltage of the conventional line. Three proposals were accordingly submitted for consideration:

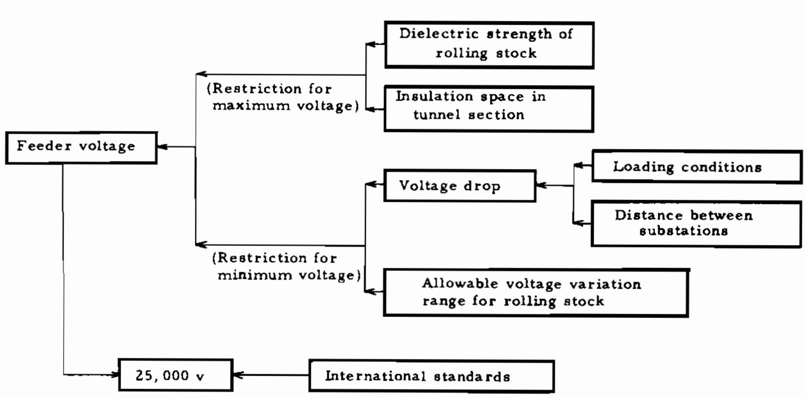


Fig. 31.14. Choice of feeder voltage (block diagram).

20 kV (conventionally employed);
20 kV (international standard);
40 kV (voltage to ground of 70-kV three-phase power, which is commercially supplied to most parts of the Tokaido area).

The determining factors in choosing the feeder voltage were:

insulation space in tunnel sections;
dielectric strength of rolling stock;
voltage drop due to load;
distance between substations;
critical voltage and shielding problems due to accident current on telecommunication lines.

Tunnel cross-section and insulation space

The present route of the Tokaido Shinkansen mainly follows the route of the ''bullet-train'' project planned between Tokyo and Shin-Osaka in 1940. The standard tunnel section of the Tokaido Shinkansen was chosen on the design of the Tanna Tunnel of which some sections had already been constructed.

The three voltage proposals were studied with special attention to pantograph height of the rolling stock, structure of the overhead contact line, and assurance of sufficient insulation space. The result of the study has shown that the 20-kV and 25-kV systems are both technically possible, while the 40-kV system would involve difficulties in maintaining the required insulation space in the standard tunnel section.

Dielectric strength of rolling stock

The AC 20-kV system already in use on the conventional line suggested that the AC 25-kV system would pose few problems, although the AC 40-kV system might give rise to disadvantages such as enlargement of rolling-stock gauge, increment of axle load and, finally, economic penalties.

Voltage drop and distance between substations

In comparison with the conventional lines, the Shinkansen has a larger headway of train schedule due to the high speed and very much greater electric loads.

For voltage drop, the distance between substations is nearly proportionate to the square of the voltage ratio. Calculations based on some assumptions indicate that the distance of substations corresponding to feeder voltages of 20 kV, 25 kV, and 40 kV are 15 km, 25 km, and 40 km, respectively, i.e. the higher the voltage, the greater the distance between substations.

Shielding for induction on telecommunication lines

The shielding ratio of telecommunication lines should be kept at about 60%, 40%, and 30% against the feeder voltages of 20 kV, 25 kV, and 40 kV, respectively, in order to prevent inductive disturbances on the telecommunication lines, especially in view of the critical voltage in the case of accident current. There are technical and economical difficulties in maintaining the shield ratio at 30%.

Locations of substations and transmission equipment

It is desirable to locate substations at favorable places where suitable power sources could be found and connected easily with the shortest link to the commercial power sources. The Tokaido Shinkansen runs almost parallel with the Tokaido Line and DC substations are distributed along these lines and connected with suitable power sources. It is therefore comparatively easy to select the ideal locations of power-receiving points for the Shinkansen. Taking this into consideration, discussions concentrated on a comparative study of 20 kV and 25 kV systems. In view of the advantages of a longer distance between substations and since 25 kV was chosen for the AC electrification system in Europe, the 25-kV system was adopted for the Tokaido Shinkansen.

HIGH-SPEED CURRENT COLLECTING

Even before the planning stage of the Shinkansen, research on increasing the maximum running speed of conventional trains up to 130 km/h had been carried out for pantographs and catenary systems as well as for rolling stock and track. On the basis of these studies, a new pantograph and catenary system adequate for 210 km/h high-speed operation has been developed.

One difficult problem was the design of a pantograph that would not suffer uplift changes due to the wind pressure from 210-km/h operation. High-speed current collecting (see Fig. 31.15) presented problems in an almost unknown field, since there was little previous experience at a speed of 210 km/h. The test-manufactured pantographs finally chosen, which, after testing, showed little upward force change and identical characteristics regardless of wind direction, were put through a series of wind-tunnel tests and test-run operations. In this way, a pantograph for the Shinkansen was designed, small in size and about half the working height of the conventional pantograph.

Aluminum was chosen for the pantograph shoes and the linked frames which support the shoes, in order to realize a lightweight pantograph, which could follow car oscillations well during high-speed operation and would not affect current-collecting efficiency. The standard effective range of working height of the pantograph for the Shinkansen and for the conventional lines are 500 mm and 1000 mm, while the standard upward force of both pantographs is 5.5 kg.

The overhead contact line was studied for stabilizing current collection during high-speed operation under three basic conditions: uniformity of

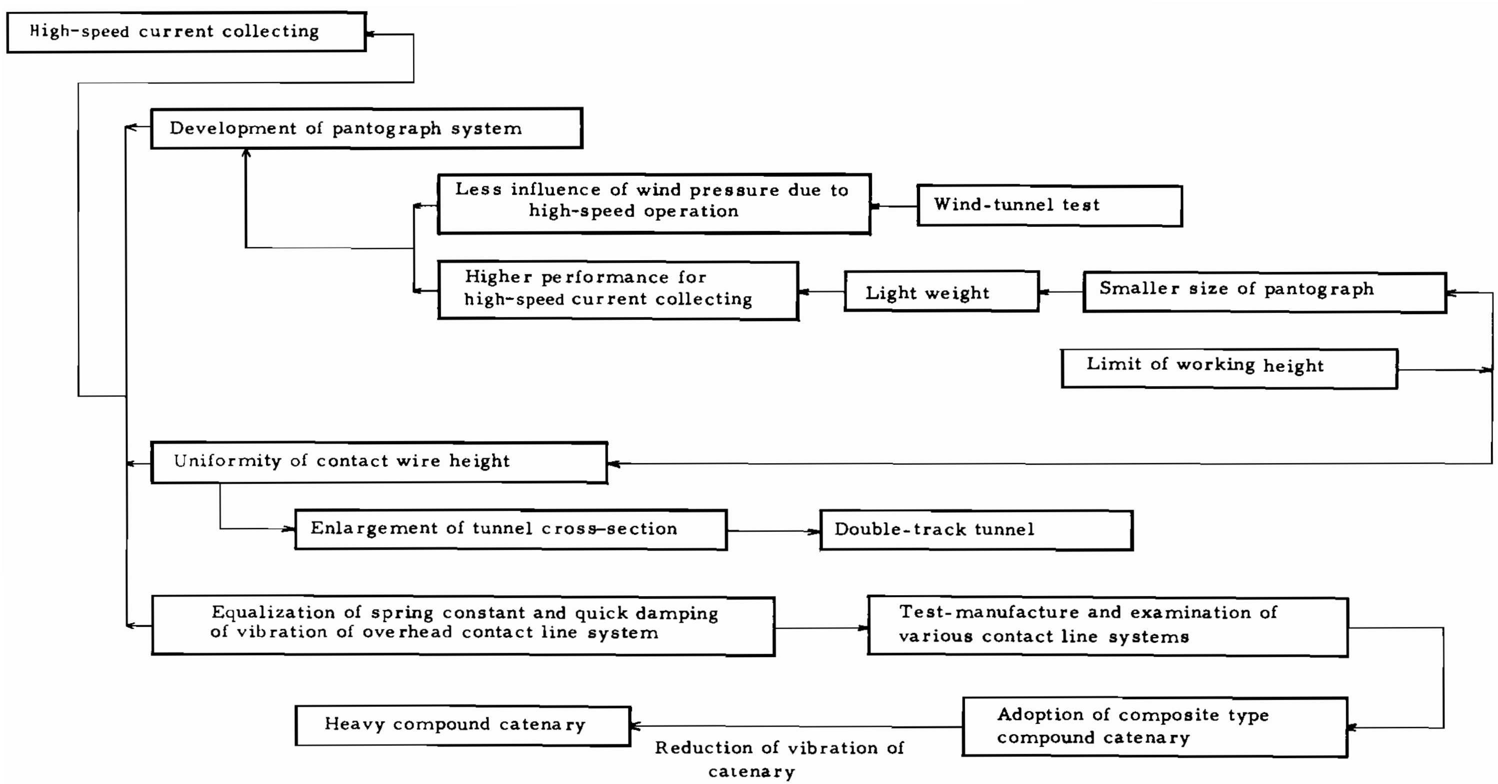


Fig. 31.15. High-speed current collecting (block diagram).

contact line height; unvarying state of spring constant; and quick damping of contact line oscillation.

The uniformity of contact line height from the rail level reduces the working range of the pantograph, resulting in a smaller pantograph and therefore a reduced effect of wind force. The height is kept uniformly at 5 m. The overhead height of the conventional lines, however, ranges from 4.6 m at tunnel sections to 5.2 m at grade crossings.

To ensure uniformity of spring constant in the overhead contact line system, the following four catenary systems were chosen and given static laboratory tests and repeated high-speed operation tests on straight tracks on the conventional lines (maximum speed 175 km/h):

continuous mesh catenary (Fig. 31.16);
Y-line compound catenary (Fig. 31.17);
twin-simple catenary (Fig. 31.18);
composite type compound catenary with elastic and damping adjuster (Fig. 31.19).

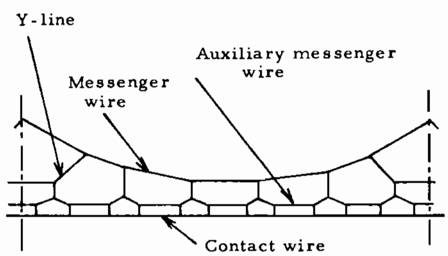


Fig. 31.16. Continuous mesh catenary.

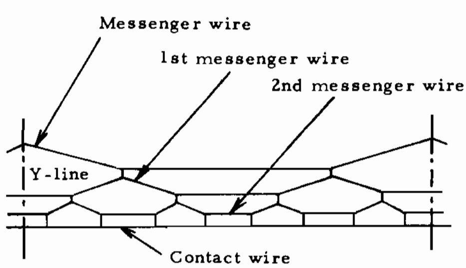


Fig. 31.17. Y-type compound catenary.

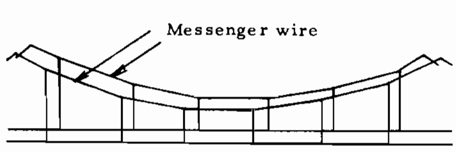


Fig. 31.18. Twin simple catenary.

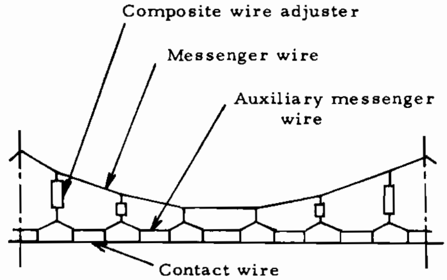


Fig. 31.19. Composite type compound catenary.

It was decided to use the composite-type compound catenary for the Tokaido Shinkansen in view of its low construction cost and ease of assembly at the site. However, this system showed somewhat flexible constructional characteristics which caused great push-up deviations and vibrating movements of contact lines every time the train passed. The metal fittings which suspended the catenary system were very frequently loosened or broken owing to vibration fatigue.

Temporary measures were taken to reinforce the metal fittings. For a basic solution, however, a catenary system had to be devised that would permit little push-up displacement. This took shape as the heavy compound catenary type overhead line developed and adopted for the Sanyo Shinkansen. This overhead line is equipped with thicker contact wires, stronger tension force, and rather rigid catenary characteristics which reduce the upward deviations due to pantograph uplift.

The total tension of the messenger wire, auxiliary messenger, and contact wire of the composite type compound catenary system for the Tokaido Shinkansen is 3 tons and that of the heavy compound catenary type for the Sanyo Shinkansen is 5.5 tons.

The catenary system of the Tokaido Shinkansen is reaching the end of its service life and requires replacement work. It is planned to replace the old system by the heavy compound catenary type overhead line. Renewal work is now under way along some sections of the Tokaido Shinkansen.

32. *High-Speed Operation System: Vehicles*

S. KUBO

The structure and the performance of railway vehicles are governed by the specifications of existing track, and new vehicles have to be operated together with older ones. It is therefore often impossible to meet the optimum conditions expected of new vehicles.

The Shinkansen was constructed as a new railway, independent of other lines, and, in designing it, there was much discussion of how rationally the specifications, particularly those for track and vehicles, should be coordinated. The vehicle system was therefore not determined independent of the track. For convenience, however, it is dealt with in this paper separately from the fixed facilities.

Multiple-Unit Train System

For a high-speed railway, the form of traction is no less important than the track gauge and form of electrification when deciding on the system of train operation (see Fig. 32.1). For the Shinkansen, the choice was made in favor of electric multiple-unit traction, with motors on every car, for the following reasons:

The dispersion of motive power over the whole train and the equalization of wheel loads would reduce weight and size in the specifications for track and structures, leading to reduction of initial construction cost.

The multiple-unit form of train facilities reverse movement, leading to simplified facilities and operations at the terminal and to greater utilization of station platform.

Sole reliance on the friction brake for a train running at the high speed of about 200 km/h incurs not only danger but also enormous costs for expendables, and it would be more rational to resort to the dynamic brake. For this reason, a multiple-unit train with a motor on each axle was considered suitable for such high-speed operation.

A multiple-unit train can continue to run even if some of the cars are out of order.

An electric multiple-unit train can easily supply power to service facilities such as air-conditioning.

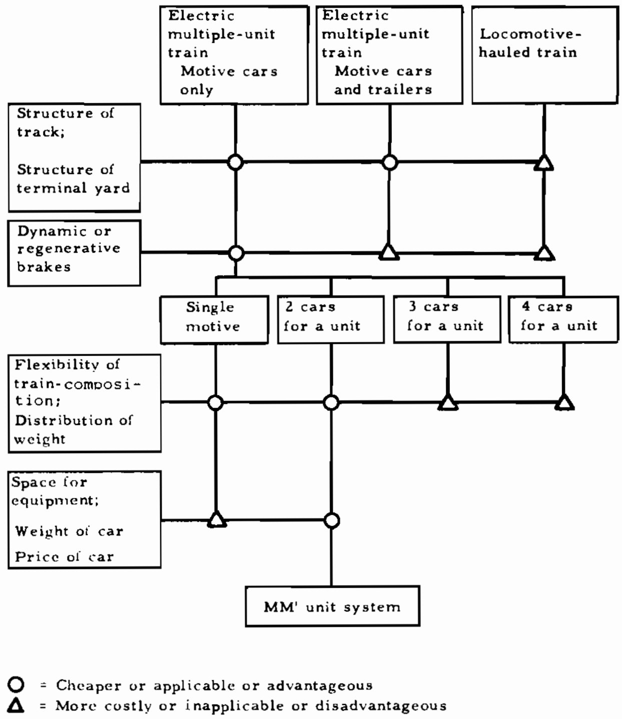


Fig. 32.1. Form of traction.

As to the composition of the multiple-unit train, it would be preferable, in terms of electric circuit, to combine several cars into a unit, because to make each car an independent motive unit would increase the weight and cost. Hence, it might have been economically more advantageous to increase the number of cars making up a unit, but two cars were chosen as a unit because a larger one would impair the advantages of the multiple-unit system for the following reasons:

It would be difficult to equalize the weight of each car owing to the increased weight of the power source equipment, such as the transformer. Further, there would be less freedom of car employment in train composition and, if a car went out of order, the burden imposed on the rest of the train would increase.

The two cars are usually handled as a permanently coupled unit, but the combination can be altered when it is desired to change the order of the train composition or the kinds of cars. The Shinkansen cars vary in their accommodation facilities, but they always have the same arrangement for the main equipment installed under the floor. It is designed so as to enable repair and inspection to be conducted in a standardized manner.

Determination of Vehicle Structure

As a railway exclusively for passengers, the Shinkansen aims at mass transport, hence the vehicle gauge and structure gauge have been specified a little wider than the UIC standards, weighing construction cost and transport capacity (see Fig. 32.2). A major factor is the five-seat arrangement abreast, two on one side of the aisle and three on the other, for the ordinary accommodation car, which can seat a maximum of 110 passengers.

The length of the car should be determined so as to provide sufficient space for passengers and space for housing the main equipment under the floor. Further, to limit the total weight of the car to 64 tons, the length was specified at 24 m, and the car body has been lightened by the use of thin weather-resistant steel plate.

With the exception of the pantograph and air-conditioner, which are mounted on the rooftop, the electric equipment and brake equipment are all installed under the floor, so they must be both light and compact. Even the high-voltage electric equipment, usually installed on the roof, is accommodated under the floor, inside a locked high-voltage equipment box, so as to protect the pantograph from air disturbances and avoid saline contamination. The underfloor equipment is grouped into comparatively big blocks to facilitate repair and inspection.

The toilet, provided in the odd-numbered cars, has a soil tank equipped with a circulation-type disposer to keep the waste from being strewn. The train can

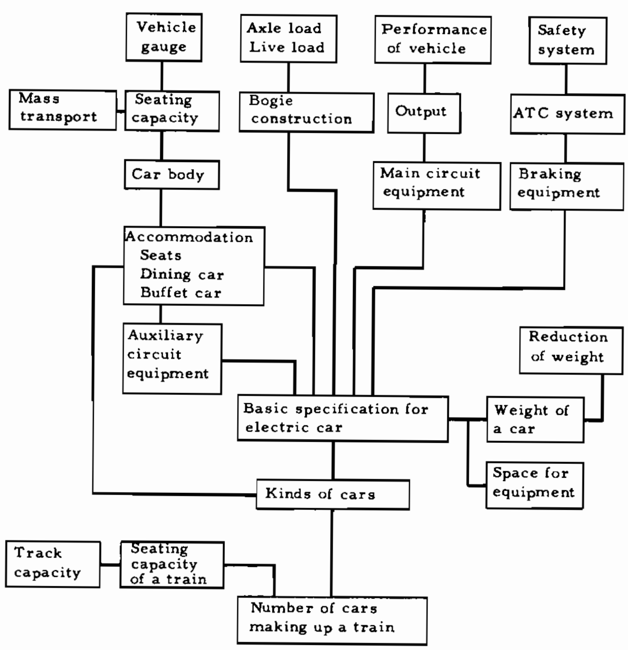


Fig. 32.2. Determination of vehicle structure.

keep running for some 48 hours without returning to the base for the disposal of human waste.

The basic structure of the car body and the arrangement of the equipment follow the ordinary coach design, with whatever modifications are necessary to suit specific use, e.g. special equipment such as power source for cooking and kitchen appliances in the dining car.

The kinds of cars built first were the ordinary car, the "green car" (with superior accomodation) and the buffet car. When the line was extended to Hakata, a dining car and a car with facilities for the physically handicapped were added.

The safety system is explained in the next paper (by Y. Muto). Here it is only mentioned that the car body is constructed with non-combustible materials and that the dining car is equipped with a fire sensor and fire extinguisher.

Table 32.1 gives the main features of a Shinkansen train, and Fig. 32.3 shows the structure of the Hikari train.

Determination of Vehicle Performance

Several factors must be taken into account in determining the performance of rolling stock. It is impossible to change the performance character of the all-motored multiple-unit train by changing the number of cars, although this can be done with locomotive-hauled trains; neither can surplus output be allowed since it would increase the weight and price of the cars. Therefore, a compact, rigidly trimmed vehicle design is required (see Fig. 32.4).

The performance characteristics of the vehicle were taken into account in choosing the route and location of the stations for the Shinkansen, and a standard was set on the maximum grade and the minimum station-to-station distance.

Once the detailed plan for tracks is established, it is possible to determine the performance characteristics required of the vehicles minutely by computerized simulation, based on such data as the track grade, and the location of tunnels and stations.

The maximum permissible speed of the vehicles in use at present is 210 km/h but, for speedier service in the future, vehicles capable of running at 260 km/h have also been produced on a trial basis. Unlike ordinary trains, the Shinkansen train is run at 200 km/h constantly between stations, so it is required to attain the maximum speed in a comparatively short time. Its average acceleration rate is therefore 1 km per second.

The tractive force of the vehicle, which is directly related to its output, is determined from the track gradient, running resistance, the interval between start and stop, etc. The maximum grade is specified as 15 per mil, or 12 per mil if continuous, so that high-speed operation may be maintained and the braking distance and brake capacity may not become unduly great. The running resistance naturally increases with the speed. As this is particularly so in a tunnel, this effect cannot be overlooked in Japan where there are many tunnels. The distance between stations also has a great effect on the output. Since the Kodama train, which stops at each station, runs equally as fast (200

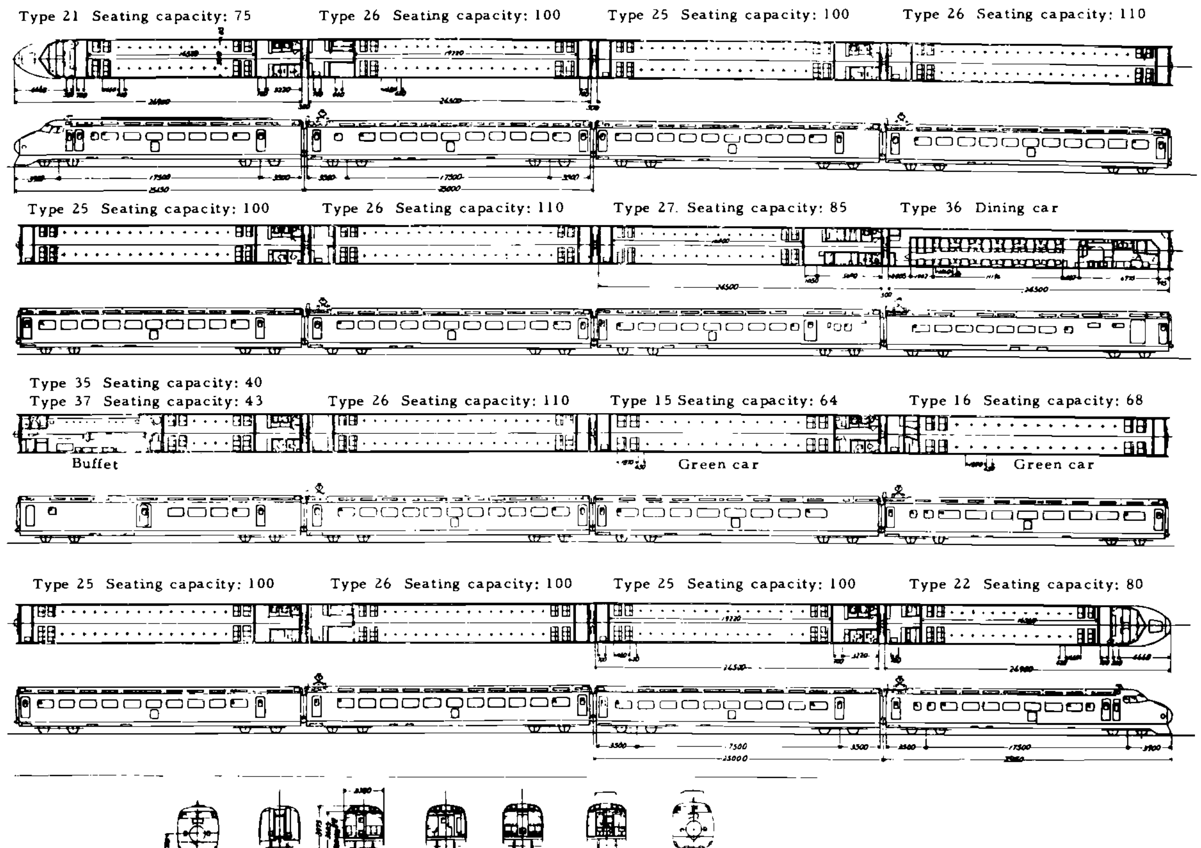


Fig. 32.3. Super-express Hikari train set.

TABLE 32.1. *Main features of a Shinkansen train*

Item		Description
Overall dimensions (mm)	Length over couplers	25,000. 25,150 (Mc, Mc')
	Width of car body	3383
	Maximum height	3975 (M). 4325 (Mc). 4490 (M')
	Distance between bogie centers	17,500
Bogie	Type	DT200 type two-axle bogie, IS type axle-box supporting device and air-spring are used
	Wheel base	2500 mm
	Wheel diameter	910 mm monoblocked wheel with brake disks
Performance of two-car unit (cont.)	Electric system	25 kV, 60 Hz
	Output	1440 kW
	Tractive effort speed	3700 kg/167 km/h
	Maximum speed	210 km/h
Traction motor	Type and connection	MT200B type DC series winding motor, 4S-2P
	Rated capacity	185 kW, 415 V, 490 A (cont.) 225 kW (1 h)
Running gear	Type	Parallel cardan driving system with gear coupling
	Gear ratio	Helical gear 29:63 = 1:2.17
Main transformer	Type	TM201 shell type, silicone-oil circulating, forced ventilation
	Rated capacity	Primary: 1650, Secondary: 1500 Tertiary: 150 kVA
Main rectifier	Type	RS201 type silicon rectifier, forced ventilation
	Rated capacity	1627 kW (cont.)
	Number of elements	S1800 type (2500 V, 800 A) diodes 6S-IP-4A
Control system and type of controller	Powering	Low-tension side tap control, LTC 200A type motored cam-shaft controller (25 steps)
	Braking	Dynamic brake and electropneumatic straight air brake, CS46 type motored cam-shaft controller
Service power	Main transformer	Tertiary (single phase) 220 V
	Motor-generator	Two-phases 100 Vm 60 Hz, 20 kV
	Invertor	Single-phase 100 V, 60 Hz
Passenger service device	Ventilation	Sirocco-fan 380 mm Aq, 30 m^3/min (for air intake and exhaust)
	Air conditioning	Unit type heat pump mounted on the ceiling, 7-12 units/car 4500 kcal (cooling) unit 2500 kcal (heating) unit
ATC system	Signal receiver	Single side band, frequency modulation type
	Speed checker	Speed-pattern comparison type
	System construction	Duplex plus checking system Command in accordance with two out of three

km/h) between stations as the Hikari train, which makes only limited stops so as to maintain the "parallel diagram", enlargement of the output would be inevitable if the distances between stations were short.

As the average distance between stations was shorter and the tunnel sections greater on the Sanyo Shinkansen than on the Tokaido Shinkansen, the output of the traction motor of the newly built cars was made larger. For this

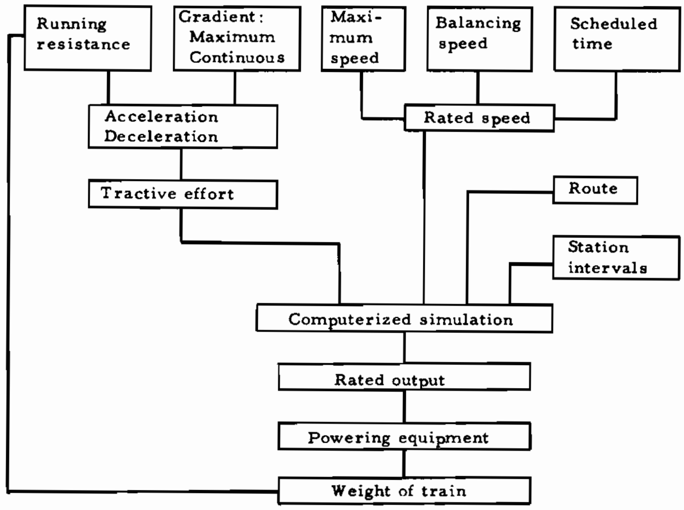


Fig. 32.4. Determination of vehicle performance.

purpose, the temperature rise of the traction motor and main transformer was calculated beforehand by simulation.

To enable the train to keep running without any delay, and make use of the advantages of the multiple-unit system, even when one unit of cars is out of order, the cars are designed to have a margin of output to cover the output of the dead unit.

Factors Making High-Speed Operation Possible

HIGH-SPEED BOGIE

Running stability

In designing vehicles for high-speed operation, the securing of running stability is fundamental, since the conventional bogie construction is apt to cause self-exciting hunting motion. To solve the problem, the present bogie design evolved from comparative studies of several types of bogies produced on trial and the improvements after basic research at the Railway Technical Research Institute (see Fig. 32.5).

The methods for preventing bogie hunting motion are as follows:

minimal inclination of wheel tread;

assurance that there is no play in the axle box supporting device which connects the wheel set with the bogie frame, and that it has appropriate longitudinal as well as lateral rigidity; and

suitable resistance in rotation between bogie and car body.

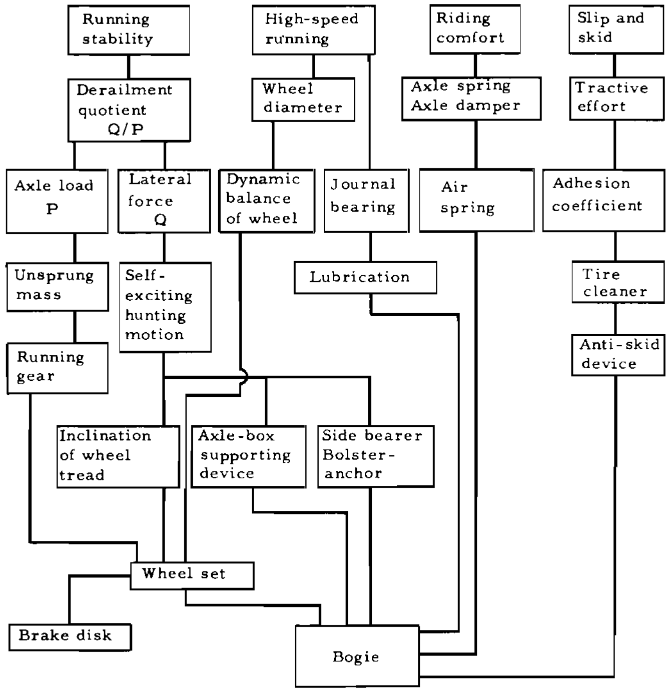


Fig. 32.5. Bogie construction for high-speed running.

The incline of the wheel tread, 1/40, was made smaller than that of the cars for other lines, and the IS type axle box supporting device is a new idea which combines flat springs and rubber bushings.

The body weight is supported by side bearers and, for suitable resistance in rotation, a synthetic resin bearer seat is fixed on the bogie frame.

In addition to suppressing hunting motion and reducing lateral force, it is important to minimize wheel-load fluctuation. Although this is closely related to the evenness of the track, it is one of the major concerns of railway vehicle designers, since a heavy wheel load accelerates the deterioration of the track and a light wheel load increases the derailment quotient. To reduce wheel-load fluctuation for vehicle structure, the significant factors are: reduction of unsprung mass, true circularity of the wheel, and dynamic balance of rotating parts.

As the traction motor is mounted on the bogie and connected with the gear rigging by toothed wheel coupling, the unsprung load is the weight of the wheel and axle and about half of the gear box. The whole surface of the wheel is machined as the brake disk is fitted on the side, so dynamic balance of the wheel is very good. The brake disks are symmetrical, which also contributes to good dynamic balance.

Securing adhesion

The securing of adequate adhesion between wheel and rail is very important for high-speed operation. A multiple-unit train with all cars powered does not require so high an adhesive force for acceleration as the locomotive, but it is apt to skid when braked. The adhesion coefficient decreases remarkably when the rail is rusty, as in the early morning, and when it is snowing or raining.

A wheel tread brake is not used in case it should deform the tread, but a tire-cleaner is used to rid the surface of contamination, thus preventing degradation of the adhesive force. There is also a skid-detecting device to control the brake force and prevent wheel flats.

Strengthening of bogie parts to withstand repeated fatigue

If the vehicle is to run at 200 km/h over most of the line, as for the Shinkansen, it must not only have good running stability, but also a bogie strong enough to withstand the heavy repeated stress sustained by its parts.

JNR's Railway Technical Research Institute has a machine to test the repeated fatigue of the wheel, axle, and bearings, and has obtained data for improvement of materials and shape. But, in view of the extremely high working rate of the Shinkansen cars, amounting to an average of 1200 car-km per day, their wheels, axles, bearings, and springs are closely examined whenever the cars undergo general overhaul, and thus field data on metal fatigue have been obtained.

Based on those data, repeated improvements have been made since the opening of the line on the shape of the axle, the method of heat hardening, the material of bearings, the processing method, etc., and the reliability of the product has been raised.

AERODYNAMIC PROBLEMS

Considering the high speed of the train, the air resistance and aerodynamic problems cannot be overlooked. As regards the shape of the car body, a contour determined by wind-tunnel experiments to be least liable to resistance was chosen. The rooftop was made as flat and smooth as possible by removing any projecting objects that might adversely affect the stability of pantographs, and housing them all under the floor. Wind-tunnel experiments were also made to determine the shape of the pantograph which would minimize the effect of wind pressure on its push-up pressure.

The train speed affects the intake and discharge of the air used for cooling the equipment, and therefore the vanes shaped for small head loss were chosen after the wind-tunnel experiments.

The air pressure changes abruptly when a high-speed train enters a tunnel, and although its impact on the window pane and car body is not great, it is unpleasant to the ear of the passenger. Therefore, the vehicle as a whole is made airtight and ventilated through a duct provided with cutoff valves. The valves are worked by a device placed at the entrance of the tunnel, and the whole car is shut off from outside air while the train is in a tunnel. By this method, the ventilation becomes inadequate as the tunnel becomes longer. For this reason, the Hikari cars, which run straight to the Sanyo Shinkansen, are ventilated by the subsequently developed turbofan and the inside air pressure is kept constant.

MOTIVE POWER CONTROL SYSTEM

To determine the appropriate system for the traction motor and its control, a number of parts were produced on trial and compared. It happened to be the time when the silicon rectifier elements for electric power conversion were beginning to find practical use. Reliability tests on this type of rectifier produced good results, so it was decided to adopt the rectifier method using a DC motor of simple winding (see Fig. 32.6).

It was known that the rate of pulsating current in the rectified circuit accounted for different degrees of inductive disturbance of telecommunication lines. Hence, a car whose rectified circuit had a pulsating rate of about 30%, as had been used in the past, and another of high pulsating rate (50%), with laminated yoke traction motor, were produced for testing. The commutation of the traction motors and inductive disturbance was also investigated. Based on the findings, the rectifier of higher pulsating rate was adopted.

For the control of the traction motor, the voltage control was adopted,

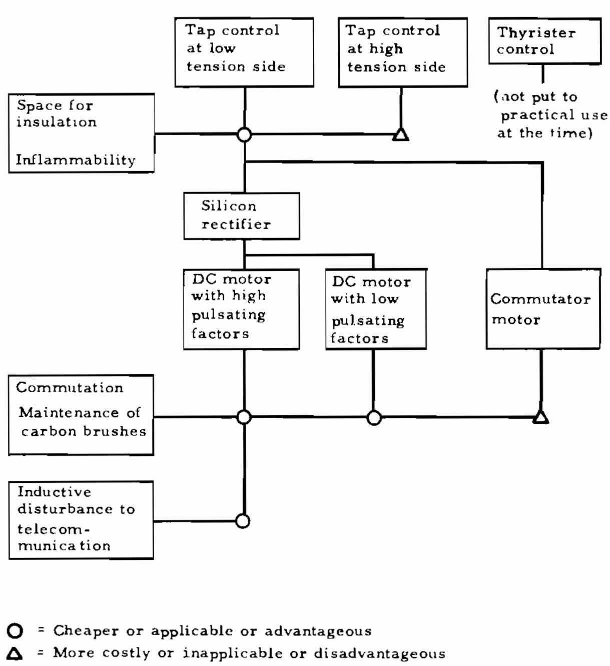


Fig. 32.6. Power control system.

which made the most of the characteristics of the AC vehicle. To safeguard the equipment housed under the floor, the low-voltage tap-changing method was adopted, and noncombustible silicon oil was used for the insulating oil of the main transformer.

Since the traction motor is affected directly by high-speed operation, its centrifugal force and commutation characteristics have been carefully attended to. Reduction of weight was of great importance to the equipment of the main circuit as a whole. A great effort was therefore made to design a small, lightweight, structure, employing new insulating materials and to make the allowable limit of temperature rise as high as practicable.

BRAKE CONTROL SYSTEM

The braking system of a high-speed railway is one of the most important for safe operation at high speed. The brake should be capable of absorbing the extraordinary energy and, preferably, should not increase the volume of maintenance work. Its control should be failsafe and its reliability maintained by multiplex systems and other means (see Fig. 32.7).

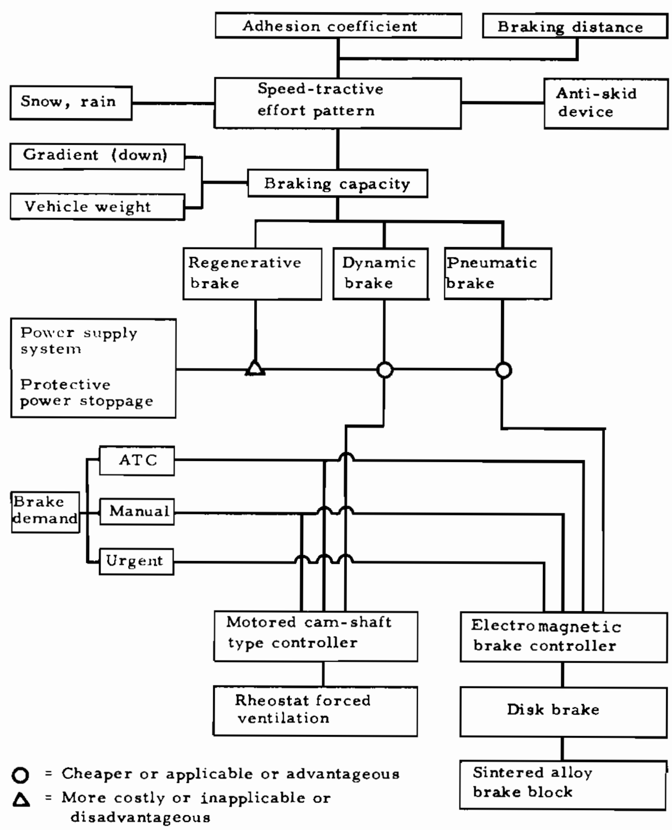


Fig. 32.7. Brake control system.

Normal braking consists of the dynamic brake and the pneumatic brake, each working with a varied braking force depending upon the following speed range:

210-160 km/h	1.5 km/h per second
160-110 km/h	1.9 km/h per second (on level track)
110- 70 km/h	2.4 km/h per second
70- 0 km/h	3.6 km/h per second

Normally, the dynamic brake precedes the pneumatic brake and is automatically switched over to the pneumatic brake when the train speed has lowered to 50 km/h or below, or when it has failed.

When the train is running on the main line, the ATC (Automatic Train Control) system normally issues the braking command, and hence the driver works the manual brake only when he adjusts the train halting spot at stations or when the speed has to be further stepped down in a low-speed section.

Before arriving at the present system, the following brake control systems were studied and compared:

(1) *All-electric control system*
A system where brake commands are analog-controlled from the head-end car.

(2) *Pneumatic pressure-control system by straight air pipe*
- (i) Brake commands are given by pneumatic pressure to the brake controller of all cars, and their feedback is made by a straight air pipe extending through the whole train.
- (ii) Brake commands are given by electric circuit to the brake controller of all cars, and their feedback is made by the straight air pipe extending through the whole train.

(3) *Pneumatic pressure-control system by brake pipe*
The brake pipe pressure is controlled directly by brake valve or the electric analog controller which is worked by ATC commands, and the brake pipe pressure is fed back electropneumatically by pneumatic pressure convertor.

Method (1) had not been developed when the Shinkansen was being designed. Of the two methods under (2), the first had been tried with the vehicles on the other lines, and the second was tested to ascertain its reliability, but adequate results were not obtained. Method (3) was found to be no better than the SAP system as it required increased equipment.

The electromagnetically controlled straight air-pipe system previously used was eventually adopted, and, as a supplement, an urgent brake worked off-control by electric circuit was additionally installed to back up the regular braking in cases of failure of the straight brake or other exceptional cases such as separation of the train. This is a very simple system and its braking force is constant irrespective of train speed.

Research and Development

In developing the technology for the Shinkansen vehicles, fundamental problems of high-speed running were studied by the Railway Technical Research Institute, based on experiences with the high-speed electric multiple-unit trains and AC vehicles used on the existing JNR lines. Table 32.2 gives the

TABLE 32.2. *Sequence of research and development*

	Parts	Combination test	Vehicle
Railway Technical Research Institute	Basic Study		
Existing line			High-speed test (175 km/h)
Rolling Stock Design Office	Designing of parts for trial production		
Manufacturer	Trial production Main circuit equipment Bogie Brake equipment		
Railway Technical Research Institute	Wind-tunnel test	High-speed test Bogie Running gear	
Hamamatsu Workshop			Trial production of steel body and strength test
Rolling Stock Design Office	Designing of test purpose vehicle		
Manufacturer	Production of parts on trial	Test of main circuit equipment combination Test of auxiliary circuit equipment combination	Production of test-purpose vehicle A:2 cars B:4 cars
Railway Technical Research Institute	Wind-tunnel test	High-speed test of bogie	
Model line			Test run of test-purpose vehicle Record:256 km/h
Rolling Stock Design Office	Designing of commercial vehicle		
Manufacturer	Mass production of parts for commercial-use vehicle	Test of main circuit equipment combination Test of auxiliary circuit equipment combination	Production of commercial-use vehicle
Railway Technical Research Institute		High-speed test of bogie	
Model line			Test run of first 6 cars of commercial-use vehicle

sequence of research and development work. Trial parts were designed by a project team, including the engineers of manufacturers, in accordance with the standard specification laid down by the Rolling Stock Design Office, an organ of the JNR Head Office. The performances of the trial-produced parts were checked and their various combinations with other kinds of equipment were tested and compared. Data for the bogie and traction motor were obtained at the high-speed bogie testing plant in the Railway Technical Research Institute. The pantograph, which is much affected by wind velocity, underwent repeated wind-tunnel experiments with actual models. When new materials were to be used, their reliability was tested by repeated load and heat cycle tests.

All these data constituted the foundation for the manufacture in 1962 of six cars built for test, arranged so that several different kinds of parts could be used and compared. The six cars were brought to the test-run section (model track) completed earlier in the same year, and given overall tests, including interaction with the way facilities. The speed was successfully raised to 256 km/h, and much valuable data was obtained. The change of air pressure when a train rushes into a tunnel at high speed was one of the phenomena discovered on this model track.

The vehicle judged from the test results to be the most stable was selected from the trial cars, and further improvement was made on it from the maintenance standpoint. Thus, the vehicle for commercial service was created. The vehicles and the numerous parts are manufactured by more than one company, but all deliveries are of exactly the same construction, since all parts are standardized through joint design by the Rolling Stock Design Office and the manufacturer. This is important for interchangeability and maintenance practice.

A series of tests was made for mass production of the parts: first with the individual part, and then with the individual part used in combination with other parts; finally, the overall performance test was made with the first six cars produced ahead of the rest, and run on the model line. In this way, the improvements made were incorporated in the subsequent commercial vehicles.

Despite these precautions, some problems remained after the inauguration of the line; for example, the effects of weather conditions such as snow, and certain passenger amenities. These problems were solved whenever they arose, and 3 years after inauguration, stability was achieved.

33. *Accident Prevention System*

Y. MUTO

Aims of the System

The system for preventing accidents during train operation is designed to satisfy the following conditions:

the designated speed should not be exceeded;
there should be adequate preventive measures against obstruction on the track, but in the event of obstruction, the train should be adequately protected;
natural disaster should be forecast and damage minimized;
disruption of train operation due to installation breakdown should be small, and in the event of such disruption, rehabilitation should be adequate.

Speed-Control System

To keep the train within the designated speed is an essential point in railway accident prevention. (The term "designated speed" includes 0 km/h, i.e. stopping of train.)

The framework of the speed-control system for the Shinkansen train, running at 210 km/h, is as follows (the design principles of signalling facilities are also given):

determination of the designated speed;
notification to the driver of the designated speed; and
method of compliance with the designated speed.

DETERMINATION OF DESIGNATED SPEED

The maximum speed for the Shinkansen train is 210 km/h, on the basis of the available railway technology and the potential for further technological development. Although the feasibility of 250 km/h was suggested by engineers of the JNR Railway Technical Research Institute, the maximum speed was set at 210 km/h after analysis of the factors concerned, including economy (see Fig. 33.1).

This maximum speed applies when there are no special speed-limiting conditions. In the following conditions, however, speed must be decreased:

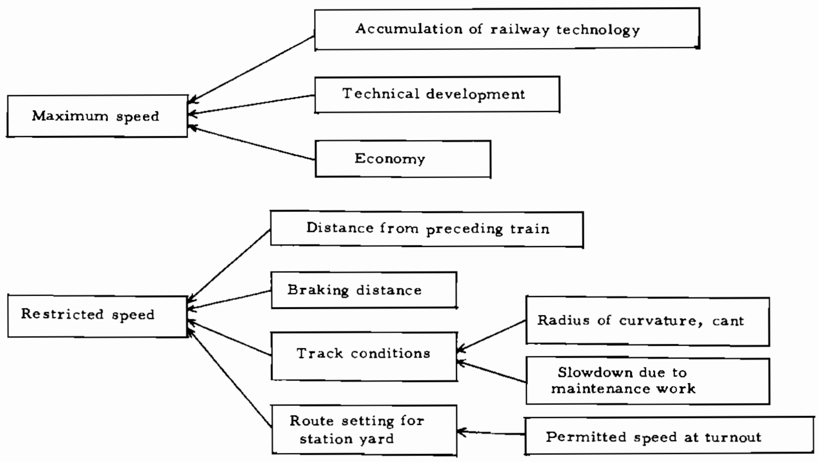


Fig. 33.1. Determination of designated speed (block diagram).

on approaching a preceding train;
on entering a station;
when the radius of track curvature is small;
when track maintenance work is under way, or track condition is not good.

The braking distance of a train at 210 km/h is about 3000 m in a level section, and reaches 4000 m in a descending grade. To stop the train at a required point, the stop signal must be indicated at a point 5 to 6 km in front, because allowance must be made for the time lag between the driver's signal identification and his brake handling, and the resulting difference in braking distance. If this section of 5 to 6 km is treated as one section of the stop signal, the train would stop at a point far in front of the required spot when it enters the section at low speed. Therefore, this section is divided into two, with the 160-km/h speed indication given in the first 3-km section, and the stop signal in the remaining section.

The speed of 160 km/h was chosen because the braking distance for reducing speed from 210 km/h to 160 km/h is about the same as for reduction from 160 km/h to a stop. For the 3-km section with stop signal indication, the actual handling is, however, as follows:

the 30 km/h signal is indicated first;
when speed has been reduced to below 30 km/h, that speed is allowed;
the stop signal is indicated at about 100 m in front of the required stopping point.

This 3-km section, called a block section, is set up by making use of the track circuit, i.e. rails, partitioned by insulation every 3 km, are used as conductor of the track circuit. When a train enters a block section, the rails are short-circuited by the wheels and axles, thus indicating the presence of a train and showing the 30-km/h signal in the section 3 km behind and the 160 km/h signal for the section a further 3 km behind, as shown in Fig. 33.2.

In addition to these four kinds of speed limit for the Shinkansen (210 km/h, 160 km/h, 30 km/h and 0 km/h), two other speed limits have been set: the 110-km/h limit for the section with small radius curvature and the 70-km/h limit when the train passes over the turnout side on entering a station. The length of the block sections for these special signals is less than 3 km, according to each braking distance, as shown in Fig. 33.3.

For slowdown due to track maintenance work or for other reasons, the 160-km/h and 70-km/h signals are used. In this case, when the required procedure is followed, even if there is no train ahead, speed signals exceeding 160 km/h or 70 km/h will not be indicated.

Table 33.1 shows the designated speeds for the Shinkansen.

TABLE 33.1. *Stages of speed control by ATC*

Stage of speed control (km/h)	Controlled item
210	Maximum speed for commercial operation
160	Gradual speed decrease, speed limit for sharp curve, slowdown operation
110	Speed limit for sharp curve, slowdown operation
70	Speed limit for passage over turnout side, slowdown operation
30	Last stage of gradual speed decrease
0	Stop

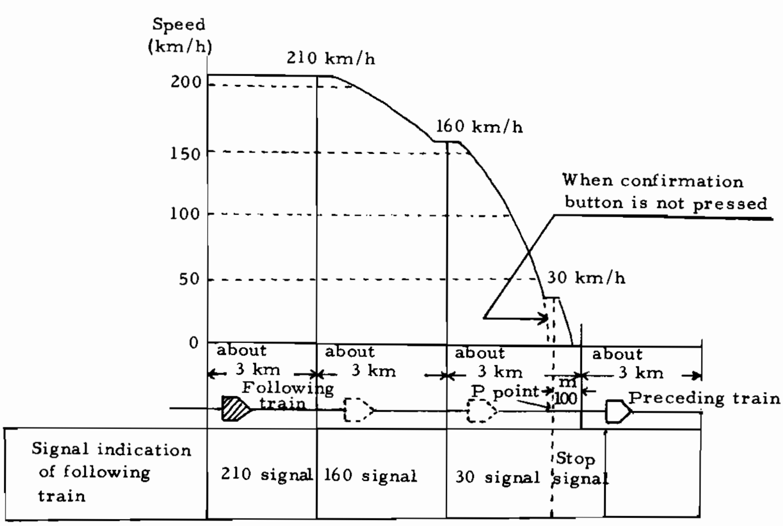


Fig. 33.2. Function of ATC between stations (when a train approaches a preceding train).

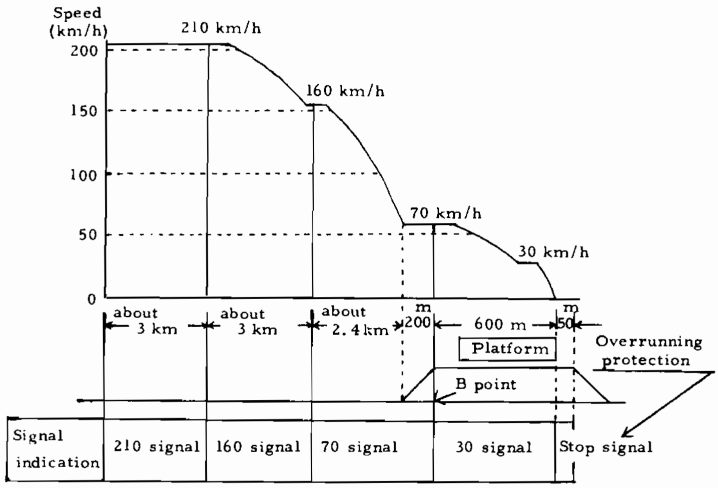


Fig. 33.3. Function of ATC when coming to a stop at station.

METHODS FOR INDICATING DESIGNATED SPEED

On the conventional lines, the driver is notified of the designated speed by the wayside signal that indicates three kinds of color signs: blue for proceed, yellow for caution, and red for stop. When the train approaches a red signal, an alarm sounds in the cab and warns the driver to use the brake. If he fails to do so, the Automatic Train Stop System (ATS) functions and stops the train automatically.

It is not sufficient, however, to apply this method to the Shinkansen because first, it is almost impossible for the driver in the cab to distinguish wayside signals when the train is running at 210 km/h, and, second, there are numerous kinds of speed limit. The Automatic Train Control System (ATC) was therefore developed (see Fig. 33.4) in which the designated speed is indicated on a panel in the driver's cab. The actual speed is compared with the designated speed. Being interlocked with the brake device, the actual speed is automatically lowered to the designated speed and the brake is then automatically released.

In this system, the information on the designated speed is composed by the relay equipment in the signalling device room, on the basis of factors such as the distance from the preceding train and route conditions in the station to be entered. This information is transmitted as AC of about 1 kHz to the track circuit forming the block section described above. The signal current is induced in the receiving antenna installed under the car body, causing the ATC receiver to indicate the designated signal.

If there is no train, the signal current running through the track circuit goes back to the signalling device room to be received by the ATC receiver there.

When a train enters the track circuit, the signal current to the ATC receiver in the signalling device is interrupted owing to the short-circuit of the current

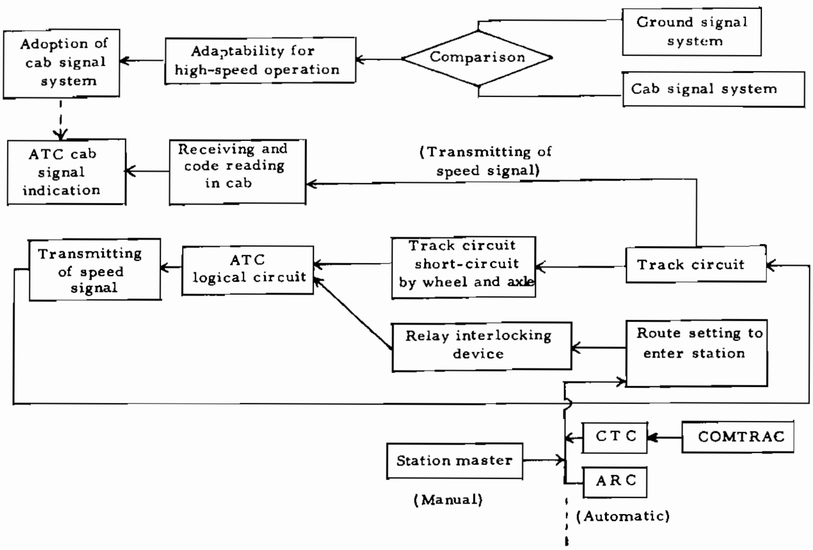


Fig. 33.4. Methods for indicating designated speed (block diagram).

by the wheel and axle, thus detecting the presence of the train. This information is put into the logical circuit of the ATC, and by deciding the speed conditions in the block sections (track circuits) behind, corresponding ATC signals are formed and transmitted. These actions are carried out each time the train enters adjacent block sections. The framework of ATC is as shown in Fig. 33.5.

When the train is running outside the station yard, speed conditions in the track circuits behind the train are decided by the position of the preceding train. In the station yard, the route condition in the yard is also dealt with, i.e. setting the turnout for the direction of the track which the train is to enter, locking it to prevent turning before the train passes through, and then indicating the "proceed" signal.

In the conventional lines, each track has its home signal and starting signal to let the train enter or leave the station. To secure safety by connecting these signal indications and route setting, including turnout locking, the relay interlocking device is used. This device is also applied at the Shinkansen stations to secure the safety of the route. The ATC speed is used for home or starting signals, indicating in the driver's cab the speed signal corresponding to the speed restriction when passing through the turnout. The following signals are shown:

for a train not scheduled to stop at the station — 210-km/h signal;
for a train scheduled to stop — 70-km/h signal for passing through the turnout, and 30-km/h signal on reaching the platform at which it is to stop.

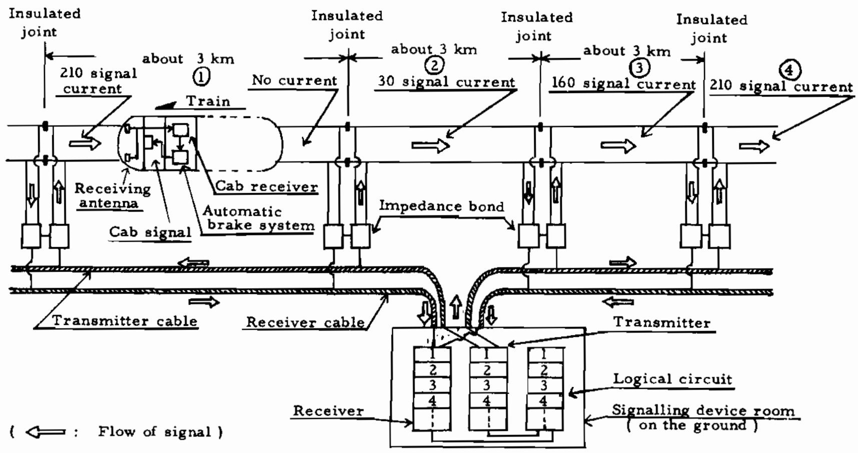


Fig. 33.5. Framework of ATC.

There is therefore no wayside starting or home signal for each track.

In the conventional lines, route setting at the station is carried out by the stationmaster according to the scheduled arrival or departure time of the train. For the Shinkansen, this process is centralized in the General Control Center in Tokyo. The Centralized Traffic Control System (CTC), which had been experimentally used in a few of the conventional lines, has been improved to a high standard by the introduction of modern electric technology, and is used on the Shinkansen. With this system, the location and number of every train can be known at the Control Center, and in case of disruption of operation, adequate counter-measures can be swiftly taken. Every train is equipped with wireless telephone so that the engine-driver and the dispatcher can communicate directly.

In the early stages of the Shinkansen, route setting at each station was carried out each time by the dispatcher in the Control Center with the aid of the train location and number indication panel. As the number of trains increased, however, this process had to be automated. The Automatic Route Control System (ARC) was therefore introduced in the first stage and the Computer-aided Traffic Control System (COMTRAC) in the second.

In ARC, automatic route setting for intermediate stations is carried out as follows:

a train approaching a station sends out a signal electric wave toward the track surface to indicate whether it will stop at the station.

the receiver coil on the track, on receiving this signal wave, sends the information to the route-controlling device, which sets the route for the train.

In COMTRAC, the train diagram (time-table) for the day is stored in advance in the computer, and the location and number of the trains are input by CTC so that the proper route will be outputted to operate the route-controlling device through CTC when a train approaches a station. In this system, automatic route-setting can be performed not only for intermediate stations but also for terminal stations with several tracks.

COMTRAC also has the following functions:

to monitor constantly the state of train operation;
to calculate train delay time and display it whenever required by the dispatcher;
to warn of considerable delay so that appropriate measures, such as modification of the train diagram, can be taken.

Should COMTRAC break down, the following alternatives take its place:

ARC, the first-stage automatic system, is used for route setting in intermediate stations;
route setting in terminal stations is done manually by the dispatcher in the Control Center;
in case of breakdown of CTC itself, route setting is done by the stationmaster in the same way for conventional lines in which case, ARC can be used for intermediate stations.

Recently, CTC has also been widely applied to conventional lines, bringing the lines under CTC to about 4500 km.

Misoperation by COMTRAC or dispatcher in route setting for a station or misinformation to the station route-setting device due to lowered performance of CTC transmission can be checked by the relay interlocking device. For example, route setting into a track already occupied by another train, or indication of a 210-km/h signal for passing into the turnout side, can be prevented without fail.

Even when a train scheduled to pass through a station erroneously takes the route of a train scheduled to stop at the station, the speed when passing through the turnout is automatically brought to under 70 km/h, and finally to a stop. Measures for prevention of train accidents such as rear-end collision and derailment are thus performed through both ATC and the relay interlocking device equipped at each station, independently of CTC or COMTRAC.

SPEED-CONTROL SYSTEM

The speed-controlling function of the ATC system is characterized by automation of deceleration control, i.e. when the actual speed exceeds the designated speed, it is automatically braked to the designated speed (see Fig. 33.6). Acceleration, however, is performed solely by the driver, with only the cab signal rendered. Furthermore, the speed range subject to ATC automatic deceleration control is, as a rule, from 210 km/h to 30 km/h, and the action for stopping a train at the station is performed manually by the driver.

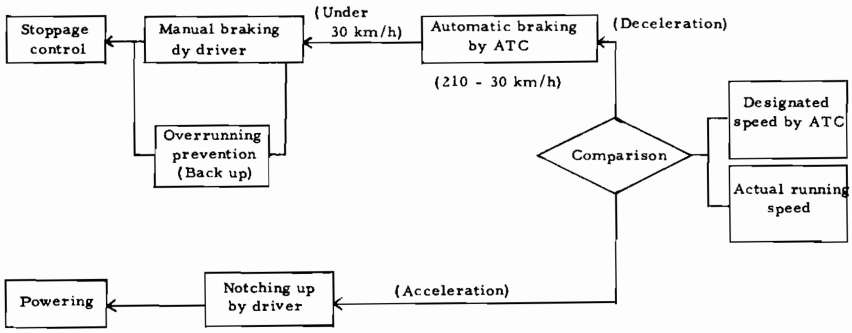


Fig. 33.6. Speed-control system (block diagram).

To prevent overrunning due to the driver's mishandling in stopping, an overrun-protection device is installed about 50 m in front of the point where the train has to stop absolutely. The stop signal transmitted from this device is received by the receiving antenna, causing the emergency brake to be applied automatically. The length of 50 m corresponds to the braking distance of the emergency brake at the train speed of 30 km/h. The guiding stop mark for the driver has therefore been placed at a point about 60 m in front of the absolute stop point.

For completely automatic operation without a driver on board, technical development and tests for practical use have been completed for both the designated constant-speed operation and stopping of the train at the designated point by mini-computer. However, it is not at present planned to put this into practice because even during automatic operation, at least one technician is needed on board for temporary repairs of the rolling stock in case of trouble, and the passengers would become uneasy if there were no driver. In addition, the driver also acts as monitor. Various disorders have often been detected at an early stage through the driver's report by train radio of abnormal phenomena perceived during operation, e.g. excess vibration and instantaneous change of cab signal indication.

PRINCIPLES IN DESIGNING SIGNALLING DEVICES

New systems for train control, such as ATC, CTC, ARC and COMTRAC, have been developed and put into practice in a short time. This is mostly due to the earlier efforts of JNR staff in introducing new technology to the conventional lines. For example, the adoption of the AC electrification system made it impossible to use the track circuit of commercial frequency which had been used for the DC electrified section, but the audiofrequency AC track circuit of the 1-kHz band had already been developed. Also, the introduction of the cab alarm equipment for preventing signal violation established the system for taking the information transmitted from the track into the cab. These technical achievements have greatly contributed to the development of the ATC system.

The principles in designing these signalling devices (see Fig. 33.7) are as follows:

to increase the reliability of the device in order to prevent its breakdown;
to design the device to work on the fail-safe principle.

The principal measures for increasing the reliability of signalling devices are as follows:

to duplicate the system, and detect and repair at an early stage any disorder on one side by constant monitoring and periodical inspection;
to replace the electronic tube and relays by solid-state electronic equipment such as the transistor and to replace the rotary equipment by stationary equipment;
instead of accommodating instruments separately in boxes near the wayside, to house them together in a strongly built air-conditioned room unaffected by the vibration of passing trains, in the optimum environment for stable operation;
for quick repair of equipment, to set up a device indicating the point of failure and the measuring terminal for failure detection and to design unit parts so that they can be replaced;
to establish substitutive measures in breakdown of equipment.

To secure "fail-safe", equipment has also been designed to stop the train when the system fails. The principal methods are:

to construct the wiring of the relay so that the proceed signal is indicated when the moving contact touches the upper terminal, and the stop signal

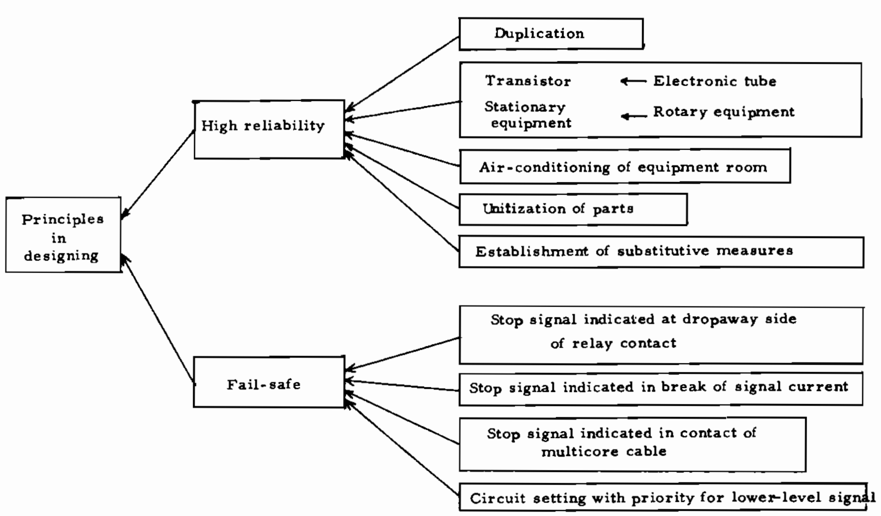


Fig. 33.7. Principles in designing signalling devices (block diagram).

is indicated when it touches the lower terminal. In this way the contact touches the lower terminal by gravity when the relay fails, indicating the stop signal.

to construct the wiring of the relay so that the proceed signal is indicated when the electric current flows, and the stop signal or no signal is indicated when the current stops. In this way, the stop signal or no signal is indicated when the relay coil breaks or the cable on a route breaks or short-circuits, and the train is then made to stop.

to constantly monitor multicore cables by means of the core contact-detecting device so that the device may work automatically to suspend all transmission through the cable concerned in case contact is detected. This is because, when multicore cable is used for transmitting ATC signals, the possibility exists that a signal may be changed to the improper upper-level signal by the contact of cores in the cable.

to construct the circuit with enough noise-suppressing characteristics for the ATC not to indicate erroneous signals due to the noise induced from the power source or to the cross-talk of different circuits and to form the circuit so that preference will be given to the lower-level signal when two or more signals are erroneously received.

Track-Obstruction-Protection System

When there is an obstacle in the way of a train on the Shinkansen track, the train must be stopped. When the obstacle is the preceding train, the following train is automatically stopped by ATC. When the obstacle is not a train, however, it cannot be detected by ATC.

In the conventional lines, the driver constantly watches ahead, and when he finds an obstacle he stops the train by using the emergency brake. Moreover, ground patrolmen notify the engine-driver of the obstacle by a signalling detonator or a signalling fuse.

These methods are not adequate for the Shinkansen trains because of their extremely high speed and long braking distance. The roadbed structure itself has therefore been devised to prevent obstacles, and a system has been introduced to detect an obstruction and to make the train stop immediately.

PREVENTION OF TRACK OBSTRUCTION

As most track obstructions on the conventional lines occur on rail/road crossings, the following protective measures have been taken for the Shinkansen:

to construct all crossings on a different level from the road;

in making the separate levels, to erect protective fences to avoid damage to the girders by the cargo of automobiles when the road goes under the track and to prevent the automobiles from falling when the road goes above the line;

to fence off the entire line from intruders and enact special laws to prohibit trespass on the track.

DETECTION OF TRACK OBSTRUCTION AND TRAIN PROTECTION

In addition to the above preventive measures, the following steps have been taken to deal with obstruction on the Shinkansen line.

Clearance-obstruction indicator

Clearance-obstruction indicators have been installed at points where any other railway line or road runs very near, in order to detect the intrusion of automobiles or other trains on the track. When an intrusion occurs, the detection rods of the clearance indicator are knocked down, cutting the electric circuit, and making the ATC indicate the stop signal.

In this system the priciple of fail-safe has also been applied, i.e. even in the case of breakdown of the clearance-obstruction indicator itself or breakage of the cable connecting this indicator with the ATC equipment room, ATC indicates the stop signal. Such breakdowns can thus be detected immediately, and trains are made to stop.

Detection by patrolmen of danger to trains

Train-protection switches are installed along the pathway at 250-m intervals to be used by the equipment maintenance patrolmen. By pushing this switch, the track circuit is short-circuited in an emergency and ATC indicates the stop signal.

Train protection by driver

The emergency ground switch (EGS) installed in the cab is handled by the driver of the train to cut the electric power for train operation, making all trains nearby stop running.

Other methods

A strong guard is installed at the front end so that the train itself can remove obstacles such as stones from the track. The front part of the cab is also strongly built.

Maintenance work on the Shinkansen track is carried out at night during a special time zone. When the work is over, a confirmation car is operated prior to the operation of the first commercial train for the day.

Measures have been studied for automatic detection of obstacles on the track by the running train itself and methods of constant watch on the ground, but effective and economical measures have not yet been found. Even if found, they would not prevent an accident if an obstacle suddenly appeared in front of the running train.

Preference was therefore given to construction work to prevent automobiles and rocks from falling on the track, and to strengthening slopes to prevent landslides.

System for Prevention of Accidents due to Natural Disaster

Natural disasters must be taken fully into consideration in securing safe operation of trains. Japan is subject to natural disasters owing to its geographical situation, and special measures must be taken to deal with them immediately and adequately.

For the Shinkansen, the following measures for safe operation, including improvement of the weather-information system, have been achieved by utilizing statistical studies and past experience.

WIND

The main winds affecting train operation in Japan are typhoons and monsoons. Typhoons strike Japan in late summer and early autumn, and monsoons blow with the passing of atmospheric depressions in late winter and early spring. The velocity of the typhoon is, in most cases, 20 to 40 m/s, and in rare cases about 50 m/s. The velocity of the monsoon ranges from 15 m/s to 20 m/s.

It is considered that a train will not be overturned by wind of velocity less than 30 m/s, allowing for a margin of safety, and for the conventional lines, the train operation regulations were established on this principle.

For the Shinkansen, the following regulations have been set up:

Wind velocity	Train speed
20-25 m/s	160 km/h
25-30 m/s	70 km/h
Over 30 m/s	Stop

Anemometers have been set up at places where a strong wind or gusts are likely, such as river basins and gorges. The information on the wind velocity is transmitted to the nearest station and is automatically recorded there.

When the wind velocity exceeds 20 m/s, 25 m/s, and 30 m/s, respectively, the caution, warning, and danger signal is indicated and the alarm is sounded in the station and the General Control Center. The dispatcher in the Control Center, on receiving these signals, designates the ATC signal for the section concerned at 160 km/h or 70 km/h and notifies the engine-driver through the train radio.

In designing the overhead line, the supporting span has been designed so that the line will not go off the pantograph even when a 30-m/s wind expands it in a bow shape. Supports have been built strong enough to withstand a wind of 40 m/s and, at places where the wind is especially strong, of 50 m/s. The strong-wind sections and locations for the anemometer were designated by specialists from the Meteorological Agency based on past statistical records.

RAIN

As measures against heavy rainfall and flood, bridges have been built at an ample height above the water level, on the basis of the past maximum water level. In banking sections, the parts up to about 50 cm above the flood water level are protected by concrete retaining walls. Hyetometers are installed along the track at intervals of about 10 km, to automatically transmit the intensity and duration of rainfall to the track maintenance organs concerned. Water level surveillance under the bridge is carried out in accordance with the information on the rainfall in the upper stream. According to this information, the necessary track patrol and train operation restrictions, such as speed control and suspension of operation, are executed.

As the effect of rainfall or the water level of a river varies according to the roadbed structure, lapse of time, and special conditions of the region, a "standard value" was chosen for each region and place. On request by the maintenance organ concerned, the dispatcher in the Control Center starts to regulate the train operation, on the basis of the actual situation and the standard value.

SNOW

In the early phase of the Shinkansen a train running fast in a snowy section would often drive the snow upwards and this would damage the insulation of underfloor equipment. Also, lumps of snow clinging to the underpart of the floor would loosen and drop on the track when the train entered a snowless section, breaking equipment and window panes.

In the conventional lines, the main-snow measures consisted in removing snow from the track and in melting snow that hindered the movement of the switch; the problem caused by adhesion of snow under the floor and falling lumps of snow had not been experienced.

For the high-speed Shinkansen, the effect of snow on train operation is greater than for the other lines, even in light snow which would not hinder high-speed operation itself; speed has to be lowered to that of conventional lines to prevent the snow from being driven upwards. The underfloor equipment of the Shinkansen was therefore more tightly enclosed and the insulation strengthened. In addition, sprinklers were installed in snowy sections to dampen the snow and prevent it from being driven upwards. In snowy seasons, sprinklers are used according to reports on snowfall by track-maintenance patrolmen and reports by engine-drivers. Speed is regulated according to the snowfall and the snow adhering to the car bodies.

Removal of snow adhering to the rolling stock is carried out at a station outside the snowy section, in preparation for high-speed operation in the snowless section. When snow accumulates during the night, the snowplough at the nearest maintenance base clears the track for the first train of the following day.

EARTHQUAKES

Japan has many seismic zones, and measures against earthquake are essential. In the Shinkansen system, structures have been designed for resistance to earthquakes.

When an earthquake occurs, operation is suspended and is resumed only when safe running is assured. Anti-earthquake measures are as follows:

- two kinds of seismometers are installed at substations 20 km apart, one for medium and the other for severe earthquakes;
- when any one of the seismometers responds, the circuit breaker in the substation works in combination with it, stopping the supply of electric current for train operation;
- when the electric current is cut, the trains in operation are stopped automatically by the emergency brake;
- whichever of the two seismometers has been activated is automatically indicated in the Control Center;
- when only the seismometer for the medium-intensity earthquake is activated, the dispatcher in the Control Center switches on the circuit breaker in the substation through the remote-control equipment.

In resuming train operation, the maximum speed of the train running in the section to which power is fed by the substation concerned (about 20 km) is as follows:

- the first train runs cautiously at 70 km/h, watching the state of the track;
- the second train runs at 160 km/h when no abnormality is found;
- the third and subsequent trains run at 210 km/h.

When both seismometers are activated, train operation is not resumed until safety is confirmed by a track patrol on foot, on the assumption that a severe earthquake has occurred. The speed on resumption of operation is the same as for a medium-intensity earthquake.

Measures against Breakdown of Installations

The preventive measures described so far are mainly against such accidents as collision, derailment, and overturning of trains. However, the suspension or disruption of operation due to such incidents as breakdown of equipment and facilities could severely affect the high speed and frequent service of the Shinkansen. In the event of an incident between stations, passengers could be kept in the train for a long time since the distance between stations is fairly great. Highly reliable equipment and adequate maintenance are therefore necessary to minimize installation breakdown. Also required is a system that will facilitate rapid repair of a breakdown combined with adequate adjustment of the train diagram in order to keep the disruption to a minimum.

CENTRALIZED MONITORING OF INSTALLATION BREAKDOWN

The breakdowns of ground installations that would hamper the operation of the Shinkansen trains can be roughly classified into damage to the rail, damage to the overhead line, breakdown of a substation, and failure of signalling equipment. Most of these breakdowns can be detected immediately by the centralized monitoring device in the Control Center; their location is indicated, in the case of overhead line or rail breakage, within an error range of 1-2 km, and, moreover, details of breakdowns are often obtained from engine-drivers nearby through the train radio.

Dispatchers in the Control Center, on the basis of this information, carry out the following measures without delay:

instruct the maintenance organs concerned to begin the repair work;
investigate the scale and situation of the breakdown;
when necessary, after conference among dispatchers, adjust the train diagram, and communicate the information to stations and passengers.

REPAIRS

Following the repair order from the Control Center, maintenance men hurry to the spot, investigate, detect the cause of breakdown, and make repairs. Usually, temporary repairs are executed first in order to resume train operation, even at low speed, as soon as possible. During the period set aside for maintenance work after train operation for the day is over, full-scale repairs are carried out to ensure normal train operation the following day.

The Shinkansen installations are standardized in design and manufacture. When it is feared that similar breakdowns may occur at other places, an overall inspection is carried out to look for similar weak points and, if necessary, they are strengthened and specifications for the next order modified.

ADJUSTMENT OF TRAIN DIAGRAM

When normal train operation is hampered by the breakdown of installation, the train diagram must be adjusted quickly. The dispatcher in the Control Center carries out the following measures:

understands the nature of the breakdown as soon as it occurs;
estimates the time required for repairs;

takes such improvized steps as guiding a train stalled between stations to the nearest station.

The dispatcher then simulates and decides the conditions for train operation after repair, such as permissible passing speed, train cancellation and diagram adjustment, program of rolling stock and train-crew rotation. In some cases, he may have to arrange for the rescue of stalled trains and guiding of passengers to other trains. The diagram adjustment system, with the General Control Center as its core, was established to allow overall adjustment, including these steps according to the scale and nature of the breakdown.

CHECK SYSTEM BY ACCIDENT-PREVENTION COMMITTEE

Accident-prevention committees have been established at the JNR head office and regional organs. These committees, consisting of staff in charge of every field, hold regular monthly meetings to review the accidents that have occurred during the previous month and to establish measures for ensuring safety by studying the statistics of past accidents.

To deal adequately with possible accidents on the Shinkansen, the Accident-prevention committee reviews the counter-measures taken in past incidents, from investigation of the cause to the decision on counter-measures, the breakdown repair system, the diagram adjustment, and guidance for passengers.

Moreover, by understanding statistically the trend of incidents since the opening of the Shinkansen, effective preventive measures have been developed and the effectiveness of these measures determined.

34. *Train Operation Control System*

Y. OGURA

General

The Shinkansen went into operation in October 1964 with 60 up- and down-trains, 29,000 train-km and 360 vehicles. With the opening of the extension down to Hakata in March 1975, these increased to 260 trains, 155,000 train-km and 2224 vehicles. In June 1977, there were 275 trains, 176,000 train-km and 2336 vehicles. To operate these trains punctually and safely, up-to-date technical devices have been adopted and every conceivable care is taken.

The General Control Center

NEED FOR A GENERAL CONTROL CENTER

To maintain the high-speed and high-frequency train operation that characterizes the Shinkansen, it is necessary to decide what to dispatch and to transmit the decision to the trains in operation and the field organs concerned promptly and precisely. For this reason JNR, since the opening of the Shinkansen, has housed all its passenger service, operation, track maintenance and electric dispatchers in a General Control Center in Tokyo for gathering information, transmission of dispatches and control of train operation, supervising the service on the whole line as an integrated system. It is the nerve center for control of the Shinkansen train operations. The layout of the General Control Center is shown in Fig. 34.1. A total of 240 staff are assigned to the General Control Center. The organization and numbers of staff on duty are shown in Fig. 34.2.

THE SHINKANSEN DISPATCHING SYSTEM

The Shinkansen uses Centralized Traffic Control (CTC) and Centralized Substation Control (CSC) to control in groups the trains and the substations operating on and along the line. The operating conditions of the trains and the action of the substations are directly monitored. Wireless telephones are installed for direct communication between the dispatchers and the crews of trains in operation.

For punctual and safe operation of Shinkansen trains, the following

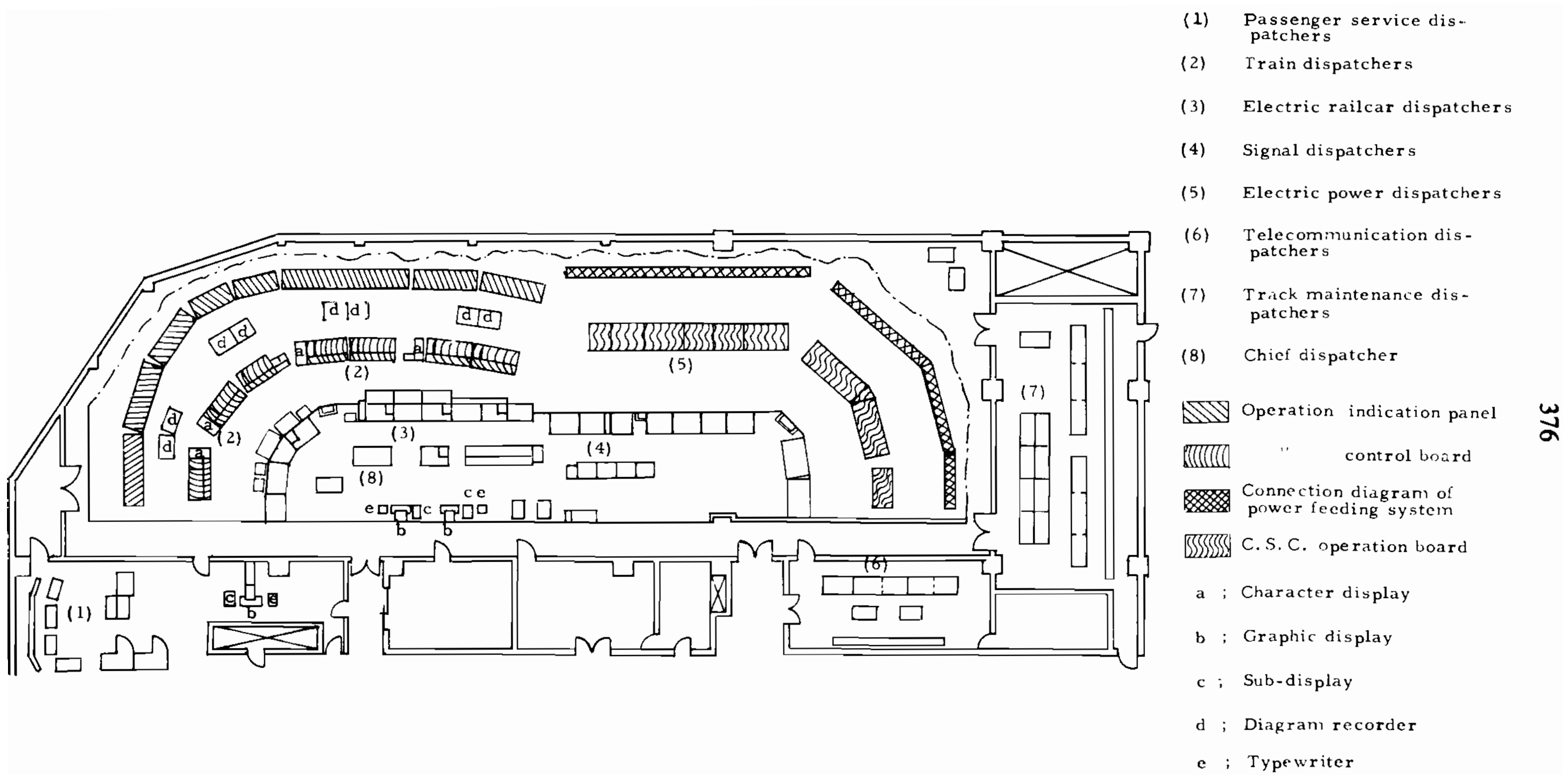


Fig. 34.1. Layout of the General Control Center.

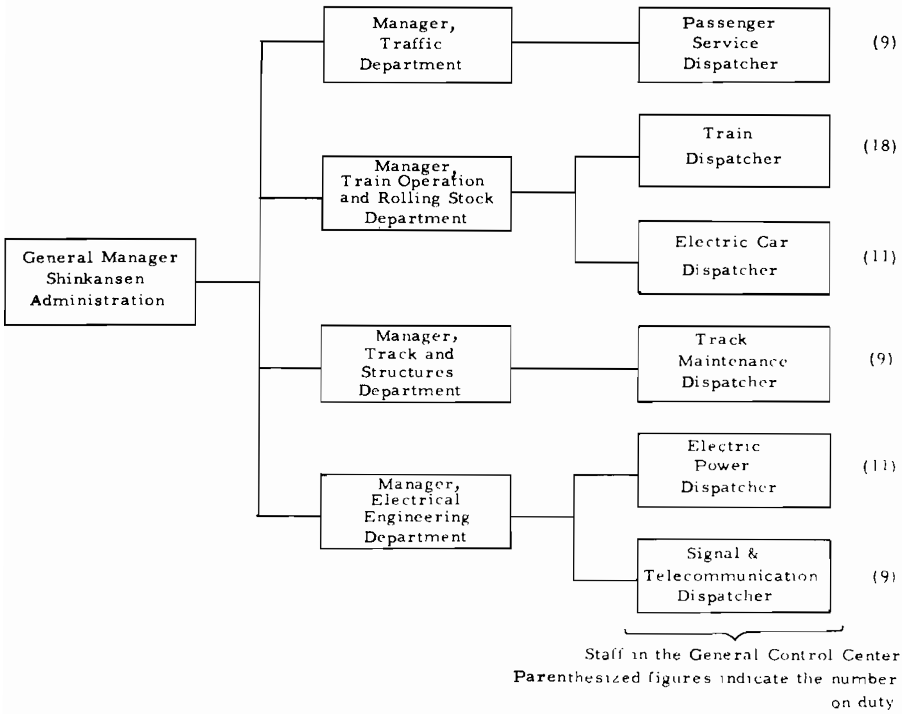


Fig. 34.2. Organization chart of Shinkansen administration.

telecommunication installations, including the wireless telephones, have been adopted:

- train radio telephones for the exclusive use of operation dispatchers;
- dispatching telephones for the entire passenger service; operation, track maintenance, and electric dispatchers (to the stations and car-operating and repair depots);
- telephones for the exclusive use of maintenance operations (to the ground facilities and rolling-stock maintenance bases);
- facsimile telegraph;
- protective wireless telephone.

These installations are shown in Fig. 34.3.

Once train operation is disturbed or a disaster occurs, all these telecommunication devices are activated at the General Control Center, where all the dispatchers are housed on the same floor, so that they can work in close cooperation and make prompt and precise arrangements for restoration of normal train operation.

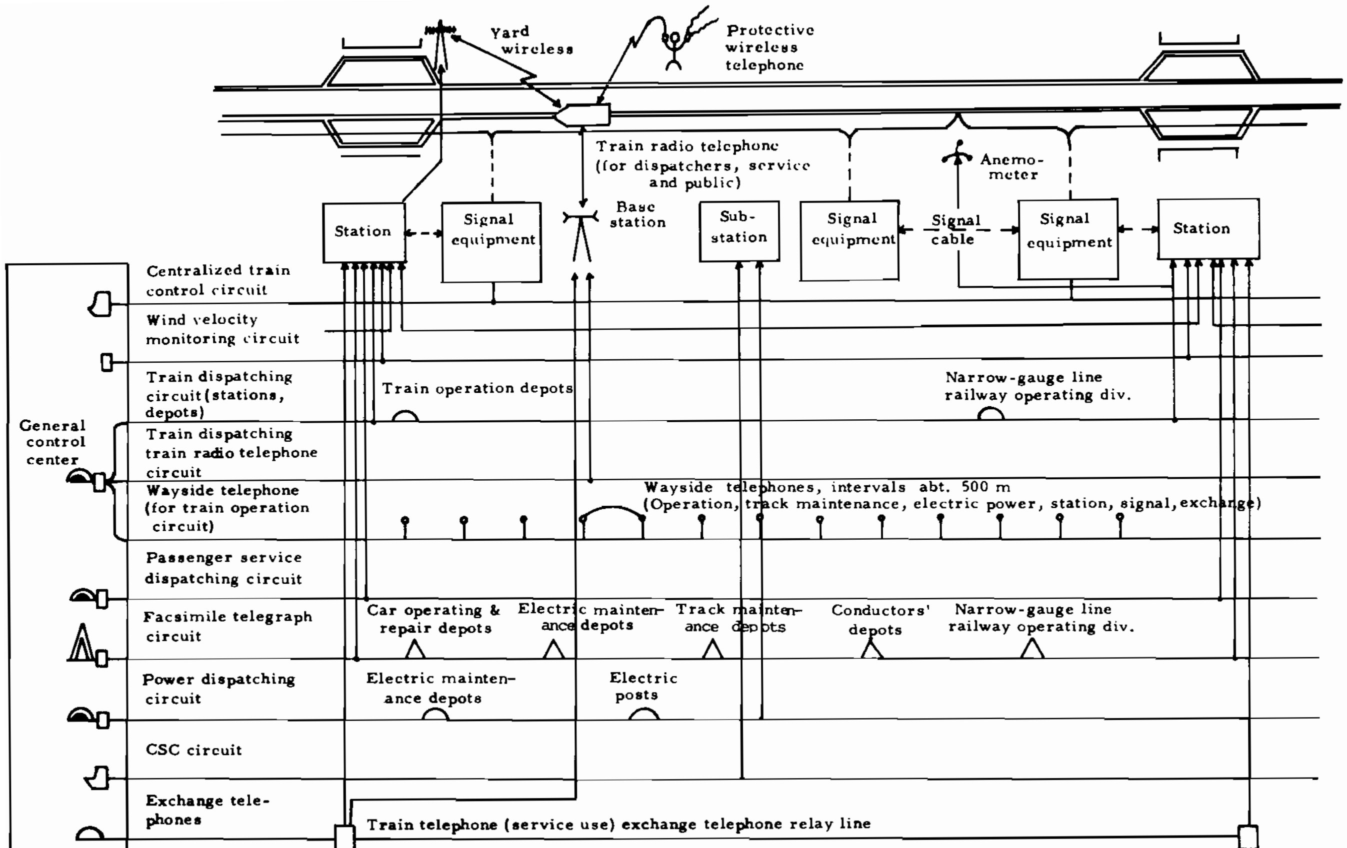


Fig. 34.3. Block diagram of telecommunication facilities.

Passenger service dispatchers

These dispatchers make sure that passengers travel in great comfort with no hitches; they make various arrangements and control the traffic.

Should trains be delayed far behind schedule owing to an accident or a disaster, or be damanged on the way, these dispatchers must grasp the situation, transmit the information to the stations and conductors' depots, indicate the proper way of guiding the passengers and keep the conductors of trains in operation informed of the constantly changing situation, using the wireless telephones that are for their exclusive use. They also make special arrangements for connections with the conventional-line trains in consultation with the dispatchers in charge of these lines.

In the Passenger Service Dispatchers' Room, an indication panel shows the numbers and locations of all trains operating between Tokyo and Hakata. Two sets of Character Display (CD) are linked to COMTRAC, and the field data are monitored on demand.

Train dispatchers

These dispatchers know precisely at all times how the trains are running and keep them operating according to the train diagram. If an abnormality arises in train operation, the train dispatchers, according to the gravity of the situation, change the refuge stations, the arrival and departure tracks, the order of train operation; they stop trains, suspend some train operations, run extra trains and instruct "recovery" train operation. They must also know the exact meteorological conditions along the whole line and regulate or suspend train operation, according to the standards provided, in order to protect the trains from natural disasters, such as heavy rain, snow, and earthquakes. They also give final confirmation of the beginning and end of track-maintenance work during the night and indicate the time confirmed to all other dispatchers to ensure the safe operation of trains.

The equipment for collecting information, dispatching trains, transmitting information, and carrying out route control in all the stations for controlling trains in groups, consists of the centralized train control system (indication panel and control board), COMTRAC, train radio telephones linked directly to the trains in operation, dispatching telephones and facsimile telegraph linked directly to car-operating and repair depots, conductors' depots and stations.

Electric railcar dispatchers

While keeping in contact with the train dispatchers, the electric railcar dispatchers change motormen's trips, change rolling stock rotation, and reassign the kind of car cleaning required for train operations. They also draw up the rolling-stock commissioning plan and rewrite the monthly inspection plan on the basis of the long-range rolling stock inspection program. When a car is out of order or breaks down, they use the train radio telephone to instruct the crew to take emergency steps.

Track-maintenance dispatchers

These dispatchers give instructions to begin maintenance work and deal with the arrangements required on its completion. They receive applications for the use of track-maintenance cars, compile maintenance work and confirmation-car operating schedules. They are aware of the weak spots requiring care, as recorded by the general electric and track inspection cars, and of other irregularities detected by the confirmation car and they instruct the organ concerned in checking up or emergency patrolling, as the situation demands. In case of an accident or a disaster, they, in cooperation with the train dispatchers and others, request slow-downs of train operation as an emergency measure, arrange for emergency track-maintenance work and instruct the organ concerned to make the repairs. Control of job performance in the field is exercised by the local track-maintenance dispatchers assigned to each track maintenance depot.

Electric-power dispatchers

The electric-power dispatchers control remotely thirty-six substations, three sub-feeder sectioning posts, and thirty-five sectioning posts set up along the whole line, and supervise maintenance operations for these installations to ensure normal train operation and safety in execution of work. For this, the Centralized Substation Control (CSC) has been adopted. They are informed of any accident or disaster by the indication on the supervisory remote-control panel and they exercise any necessary control.

Signal and telecommunication dispatchers

These are divided into three groups, in charge of signals, telecommunication, and COMTRAC. Their responsibilities are as follows:

Group in charge of signals. The dispatchers monitor irregularities of CTC and ATC (ground facilities) and control the job performance of these systems. Irregularities of signals are indicated on the signal supervisory panel. When an irregularity is indicated, the dispatchers promptly notify the train dispatchers to restrict train operation and at the same time instruct the local signal and telecommunication dispatchers to investigate the situation and its causes.

Group in charge of telecommunication. These dispatchers supervise the coaxial cable circuit used as the carrier of CTC and CSC control and indication codes. They also supervise telecommunication lines, such as the train radio telephone which is essential to the smooth operation of the Shinkansen trains; they regulate the maintenance operations and set up temporary circuits in the event of a disaster.

Group in charge of COMTRAC. These dispatchers control a group of computers for two systems of EDP for train operation adjustment and three systems of PRC for train route control and the group of terminals. They monitor the performance of the installations of these systems, repair any system failure, and carry out an inspection.

TRANSMISSION OF DISPATCHING ITEMS

Dispatching items are transmitted by dispatcher telephones, train radio telephones, facsimile telegraph, exchange telephones, and COMTRAC terminals. They are transmitted to stations, car-operating and repair depots, conductors' depots and motormen on duty. They are of two kinds, dispatch transmission and information transmission, and are made either to all at the same time or only to those concerned.

Dispatch transmission

Changes in safety system and cancellation of temporary safety system.
Emergency train operation and its cancellation.
Reverse operation.
Changes of arrival and departure tracks.
Suspension of train operation.
Changes in operating time.
Operation of extra trains.
Emergency feeder cut.
Emergency slowdowns.
Changes in rolling stock rotation.
Changes in the rotation of crew members.
Others.

Information transmission

Everything other than the items for dispatch transmission is called information transmission and this is sent to motormen as reference for their train operation.

EMERGENCY MEASURES

Classification of emergencies

An emergency is the general term for "a state in which normal train operation is incapacitated owing to some trouble". For the Shinkansen, the measures to be taken in each emergency are prescribed in the *Train*

Dispatchers' Rule Book for Job Performance and the Work Guide. Training meetings are periodically held to keep the organization ready to cope promptly and precisely with an emergency. Emergencies are classified as follows:

When a train accident occurs.
When a safety installation for train operation goes out of order:
 when CTC goes out of order,
 when the track short-circuits,
 when the station departure route or the entry route is not in order,
 when the turnout goes out of order.
When train protection goes into force:
 when the train protection switch is turned on,
 when the clearance obstruction alarm goes into action,
 when the protective grounding switch is turned on.
When emergency stop is demanded of a train in operation.
In case of emergency train operation.
In case of train operation under the substitute safety system.
When rolling stock goes out of order.
When track disorder is noted.
When power supply is not in order.
When a disaster occurs:
 outbreak of fire on a train,
 earthquakes,
 strong winds,
 heavy rain,
 snowfall.

In these emergencies, train operation is adjusted according to the place and time of occurrence, rolling-stock rotation, passenger conditions and the effect on other trains. When drawing up a plan for suspension of service, account is taken of the order of trains, congestion at stations, and the sale of reserved seats.

Adjustment and arrangement of train operation and dispatchers concerned

Although it is desirable that trains operate in accordance with the diagram, in reality interruptions and disasters of varying magnitude take place daily to interrupt the services. When services are interrupted, operation is adjusted so as to minimize the effects and restore normal services as quickly as possible. The main steps usually taken for train operation adjustment and the dispatchers responsible are shown in Table 34.1.

Dispatching Equipment

CTC

CTC stands for the Centralized Traffic Control apparatus. With CTC, the train dispatchers control from the Center the turnouts and signals in the stations and monitor the operating conditions of the trains. CTC has an operation indication panel, control boards and diagram recorders.

TABLE 34.1. *Details of train operation adjustment and dispatchers responsible*

Details	Dispatchers					
		Operation dispatcher				
	Passenger service dispatcher	Train dispatcher	Electric railcar dispatcher	Track maintenance dispatcher	Electric dis-patcher	Dispatcher of Head Office
Connection (waiting)	○	○	○	○	○	○
Changes in shuttling	○	○	○			
Changes of arriving and departing tracks	○	○	○			
Changes in the order of train operation (when first train is involved)	○	○	○	○	○	
Changes in halts at passing tracks — Normal time	○	○				
Changes in halts at passing tracks — When the last train is changed	○	○		○	○	
Postponement of train operation	○	○	○	○	○	○
Emergency stop	○	○	○	○	○	○
Operation restriction	○	○	○	○	○	○
Rolling stock exchange	○	○	○			
Extra train operation	○	○	○	○	○	○
Suspension of service	○	○	○	○	○	○
Discontinuance of operation	○	○	○	○	○	○
Emergency operation	○	○	○	○	○	○

Operation indication panel

When the Shinkansen opened between Tokyo and Shin-Osaka, an operation indication panel was installed fan-wise, composed of four blocks, each 2 m high, 5 m wide, and 20 m long. When the Shinkansen was extended down to Hakata, the length was increased to 27 m. The following items are indicated on the panel:

Train location (band-shape indication lights are fitted for each track circuit and a white light comes on when a train enters the circuit. In the section of a station that indicates the approach of a train, a red light comes on.)

Train number.

Route opening.

Stop control. (When the 03 signal, which orders an absolute stop, is transmitted on the stop control track circuit, an orange light comes on.)

Wind velocity warning.

COMTRAC behavior.

Temporary speed limitation signal.

Control board

Four control boards are set up about 3 m away from the operation indication panel to face the train-operation indication panel. Their control ranges are:

Board A	Between Tokyo and Shin-Yokohama
Board B	Between Odawara and Kyoto
Board C	Between Shin-Osaka and Fukuyama
Board D	Between Mihara and Hakata

Levers, such as the ATC route lever for each station, as well as the telecommunication apparatus panel, are set in the control board. The dispatchers, watching the indication panels, handle the levers and talk with the men in charge at the stations and with the train crews, and give any necessary instructions.

The levers set in the control boards are as follows:

Route levers. Two levers are built in, one for the ATC route in each station and the other for the route to be indicated by the wayside signal for train operation within the station yard. When the lever is lowered to the "L" or "R" side, the route is set.

Automatic levers. These are built in for each station and for each up- and down-train track. When a lever is lowered to the "R" side, the route is set by the automatic route-setting apparatus. When a lever is lowered to the "L" side, the route is set by COMTRAC.

Station-handling levers. These are built in for each station and up- and down-train track. When a lever is lowered to the station-handling side, route setting by CTC handling is shifted to station handling.

Passing track levers. Set up also for each station and up- and down-train track, when a lever is lowered to the passing track side, the departure route of the train at a stop is set after a passing train has run past. Pulled down to the "keep-on" side, the departure route of the train at a stop is set as soon as the following train comes to a stop.

Diagram recorders

There are eight of these, each of which is capable of recording data on the trains in operation in 160 track circuits. As the movements of the trains on the track circuit are recorded every 10 seconds, the dispatchers can easily check whether they are running according to the pre-set diagram.

COMTRAC

Aims of the system and details of system development

Since its opening, the Shinkansen has been well equipped with CTC, train radio telephones, facsimile telegraph transmission apparatus, and other information systems. Centralized control of train operation has made it possible to adjust the operation of numerous trains promptly and precisely.

However, the increasing number of trains put into service, the further extension of the line, and the diverse types of train caused the volume of information to increase rapidly and the work load of the dispatchers engaged in route control to become heavier. Their primary work of collecting information, making decisions, and transmitting their instructions has increased, and in order to continue to offer a smoothly running service, more efficient operation-control systems were studied. It was decided to use computers to process information for route control and train operation adjustment. This system was named COMTRAC (COMputer-aided TRAffic Control system) and its construction began in September 1970.

The system developed at the first stage was put to practical use at the opening of the Shinkansen down to Okayama in March 1972. Later, to enlarge and consolidate the system, the second-stage development was launched, and the use of COMTRAC capable of covering the whole line began in March 1975 when the Shinkansen was extended down to Hakata.

COMTRAC and operation dispatchers

At first, the dispatchers had to handle, among other things, route levers pertaining to train operation and rolling stock rotation by watching the indication panel at all times. They had to decide on operation adjustment and make the necessary arrangements and issue instructions. After the introduction of COMTRAC, the computer issues alarms to the dispatchers through Character Display (CD) and Graphic Display (GD) and attracts their attention dialog-wise, so that they can now concentrate on their main job of making decisions.

Basic composition of COMTRAC

Linked to CTC, COMTRAC takes information from it such as train numbers and locations, compares it with the information stored in its train file for processing, and outputs the route control information to CTC. In the course of processing, the system, in close man-machine contact, simulates the tracing of train groups and adjusts train operation. The basic composition of the system is shown in Fig. 34.4.

System structure

Hardware composition. The hardware of COMTRAC consists of the computers of the route-control system, the train operation adjustment system and the execution planning system, and the machines surrounding the computers. Its structure is shown in Fig. 34.5.

(a) *Route-control system.* The route-control system, directly linked to CTC, performs on-line real-time control, such as route control and departing train control. As its performance directly affects train operation, great reliability is required. Three control computers are therefore used in triangle formation, two for ordinary use and the other in reserve, so that the system can work in duplication.

(b) *Train operation adjustment system.* This system goes into action when services are interrupted. It adjusts train operation, transmits instructions and information, and allocates vehicles. As this job involves voluminous data and bulky processing but does not need to be as reliable as route control, one general-purpose computer is used. In case of system failure, however, the execution planning system computer is used to back up the capacity.

(c) *Execution planning system.* This system performs the batch processing in preparing the execution diagram file and statistics. For the same reason as in (b) above, only one general-purpose computer is used.

Input/output machine. In COMTRAC, coordination between man and machine is stressed. On the principle of having a machine do the work that it can do best and a man do the work that he does best, a rational man-machine system setup is designed so that the burden on the dispatcher is not too heavy. CD and GD are used in this man-machine communication. As the input/output equipment, the system has terminals at the necessary places for transmission of instructions and information.

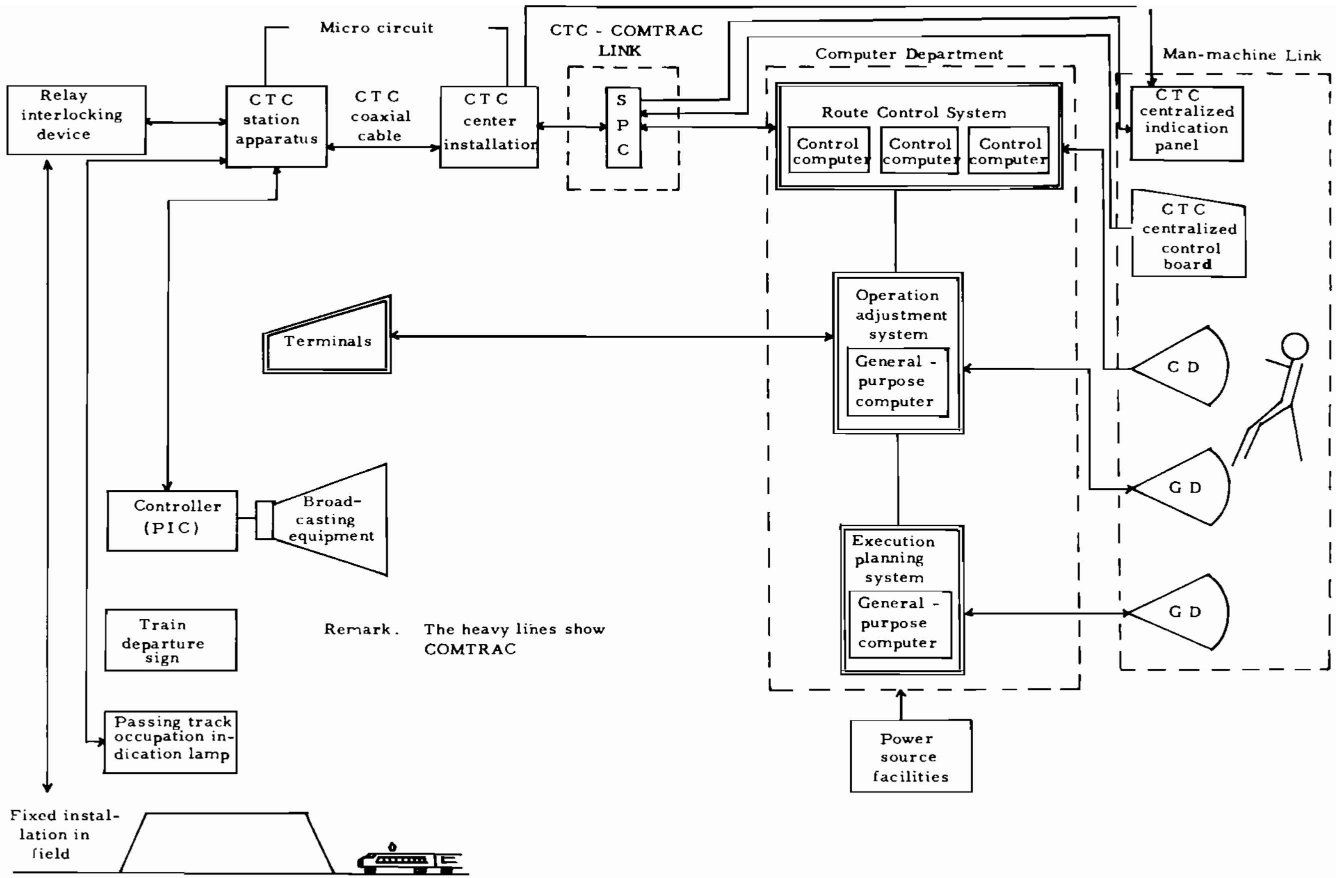


Fig. 34.4. Block diagram of COMTRAC.

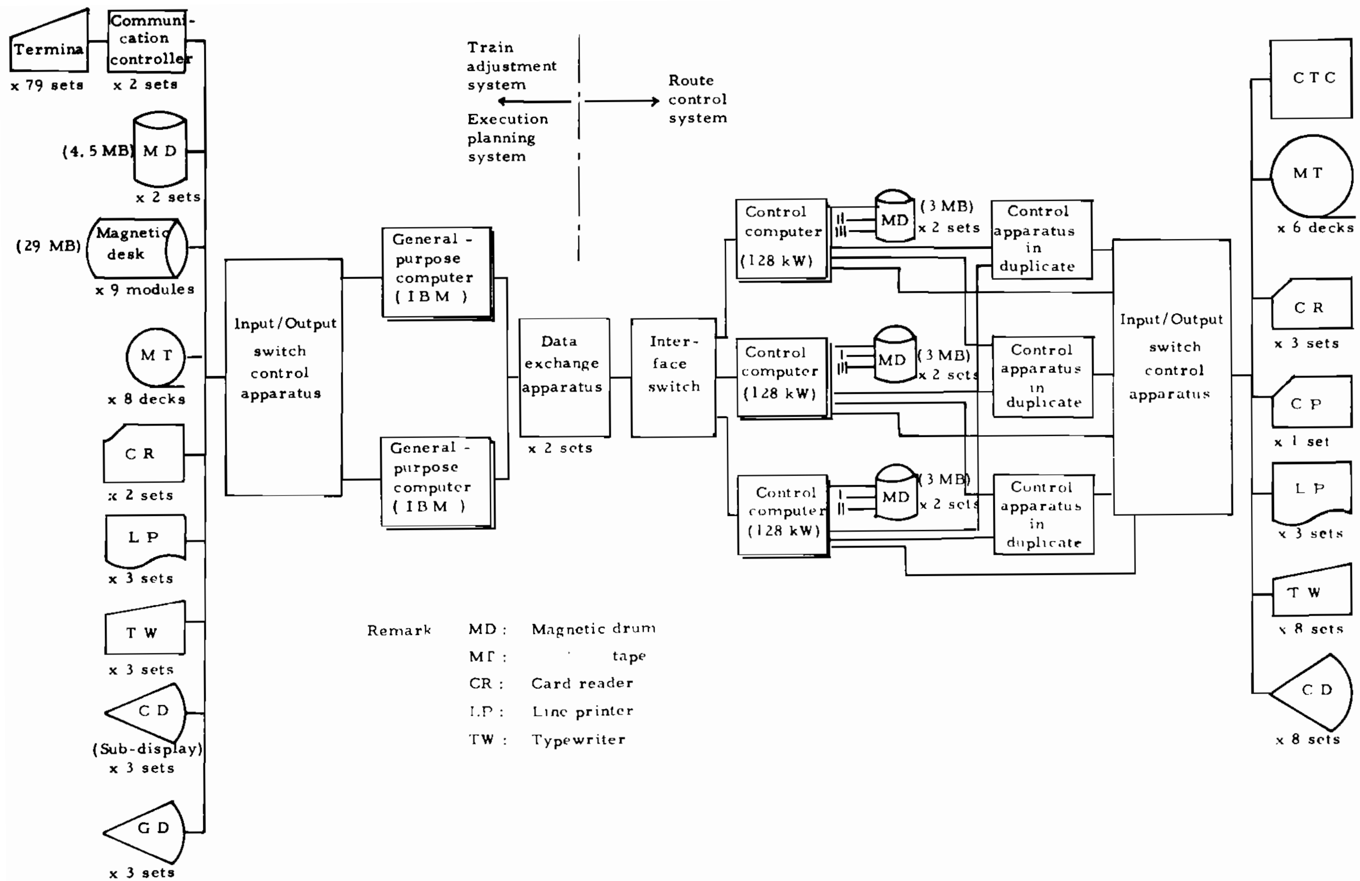


Fig. 34.5. Block diagram of COMTRAC hardware.

Functions of COMTRAC

Operation execution planning. For the various judgements on route control and adjustments of train operation, a train diagram for the day is required. This diagram is called the execution diagram. From the basic train diagram and basic rolling-stock rotation, which are prepared at the time of timetable revision, the execution diagram is adjusted by changes as notified by directives from the Shinkansen Administration. In COMTRAC, the details of the basic plan prepared at the time of diagram revision are fed in as inputs in advance as the basic diagram file; the additional data sent in from the Administration are input as they arrive. The computer combines the diagram file and the elements for change to adjust the execution diagram 7 days before the day of operation execution, and stores it as the execution diagram file.

Route control. In COMTRAC, train positions and operating conditions are known at all times from the information taken from the train position detecting points set up in and between the stations, and these are compared with the time of the execution diagram and with the order of trains stored in the memory of the computer, and the route is automatically set when needed. When disorder of train operation compels revision, the execution diagram is revised by input of the dispatchers' instructions and the route is set according to the revised diagram when required.

The position of the train is detected at the following five points, as shown in Fig. 34.6.

(a) *Point N (train number detecting point).* A train number detector is installed at a point 800 to 1200 m outward from Point R. When a train passes this point, the train number is detected. When this is the number stored in the memory of the computer, the train route is set as prescribed.

(b) *Point R (the point of train approach to the station).* The route setting is checked by the data obtained at Point R. Point R is used as the back-up point of Point N.

(c) *Point H (station entry route point).* With Point H data, the entry of the train into the station is detected.

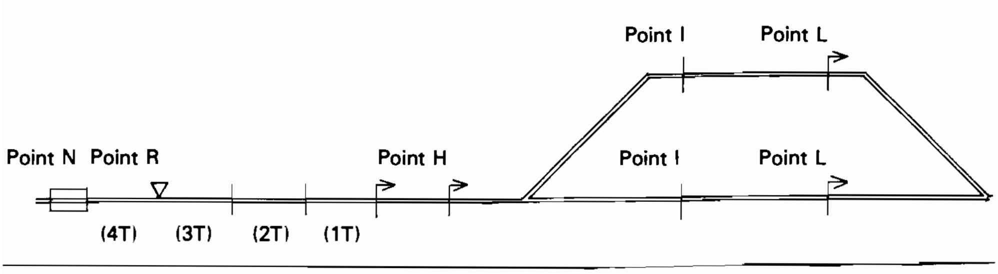


Fig. 34.6. Train position detecting points.

(d) *Point I (stopping point).* When a certain time elapses after Point I data are produced, it is assumed that the train has come to a stop, and the arrival time is noted. At an intermediate station, the departure route is set.

(e) *Point L (departure route point).* From Point L data the departure or the passing of the train is detected.

Operation adjustment

In COMTRAC, train operation adjustment is performed by the dispatcher and the computer engaging in a dialog by means of CD and GD, with the computer providing information to help the dispatcher reach his judgement, and the dispatcher making his decision on operation adjustment after scrutinizing the very intricate general situation. He then instructs the computer to carry out his decision. Among the operation-adjusting functions of the computer are:

(a) *Alarm.* The computer keeps constant watch on the operation conditions of the trains. When it detects something that must be brought to the dispatcher's attention, it gives an alarm and displays a description on CD. Alarms are for train delay, coincidence in the use of arrival and departure tracks, and warning of the running kilometerage of rolling stock.

(b) *Questions to the dispatcher.* When there is disorder in train operation and the computer detects a situation where train operation needs adjustment, it displays on CD its suggestion for the procedure based on the logic that is preset in it, and asks the dispatcher for the final decision. Such questions as the placement of a train in the passing track and its cancellation, changes in the order of a train originating at an intermediate station and a through train, and in the order of train arrival and departure, are put to the dispatcher. On these questions, the dispatcher has to input his decisions and the computer carries them out.

(c) *Direct input.* When the dispatcher is to motivate some action by the computer, he inputs the description of the action through CD or GD. Suspension and resumption of train operation, changes in schedule, changes of arrival and departure tracks, changes in rolling-stock rotation, and other items needed in train-operation adjustment can be fed in as inputs.

(d) *Monitoring.* Complying with the demand by the dispatcher, the computer indicates on CD the data it holds and prints them out by is line printer. It thus monitors trains in operation and shows how many minutes they are behind schedule, the order of trains leaving each station, and rolling-stock rotation.

(e) *Diagram forecasting.* With the current train positions as the starting-point, the computer forecasts a diagram when the trains are operated as they are, based on the travelling time between stations of each type of train, their stopping time and delay time resulting from slow-downs and other information stored in its memory. The forecast diagram is shown in a figure on GD. Two kinds of forecast are made: forecast diagram and adjustment suggestion diagram.

1. The forecast diagram predicts the diagram when the trains are operated according to the plan as it stands. The diagram is constantly being composed from the latest data and the computer sends out alarms on the interferences anticipated, continuously indicating the interferences, so that the dispatcher may know exactly how the trains are operating.
2. The adjustment suggestion diagram forecasts the diagram-to-be when train adjustment is enforced. When the main points of operation adjustment are input, such as suspension of service, operation of extra trains and changes in rolling-stock rotation, a forecast is given of the changes in the order of trains and the changes of the arrival and departure tracks included. The dispatcher then changes this diagram. The adjustment suggestion diagram is made repeatedly and the final plan for operation adjustment is quickly and precisely produced. When the dispatcher issues the instruction for operation as diagrammed, the computer controls the order of trains and sets routes as shown in the diagram.

The flow of information in train operation adjustment by COMTRAC is shown in Fig. 34.7.

Transmission of dispatching items

When, among the operation adjustment items that the dispatcher has instructed the computer to carry out, there are items to be transmitted to stations, car-operating and repair depots and conductors' depots, the computer automatically prepares notices of instruction and transmits these as printed outputs through the terminals installed at the places concerned. As the instructions must be transmitted precisely, the stations and depots that receive the instructions are obliged to input their responses to confirm receipt.

Transmission of information on operation delay

The computer constantly checks all the trains in stations from the information collected from the train-position-detecting points and calculates the delay times of all the trains for transmission to the organs concerned.

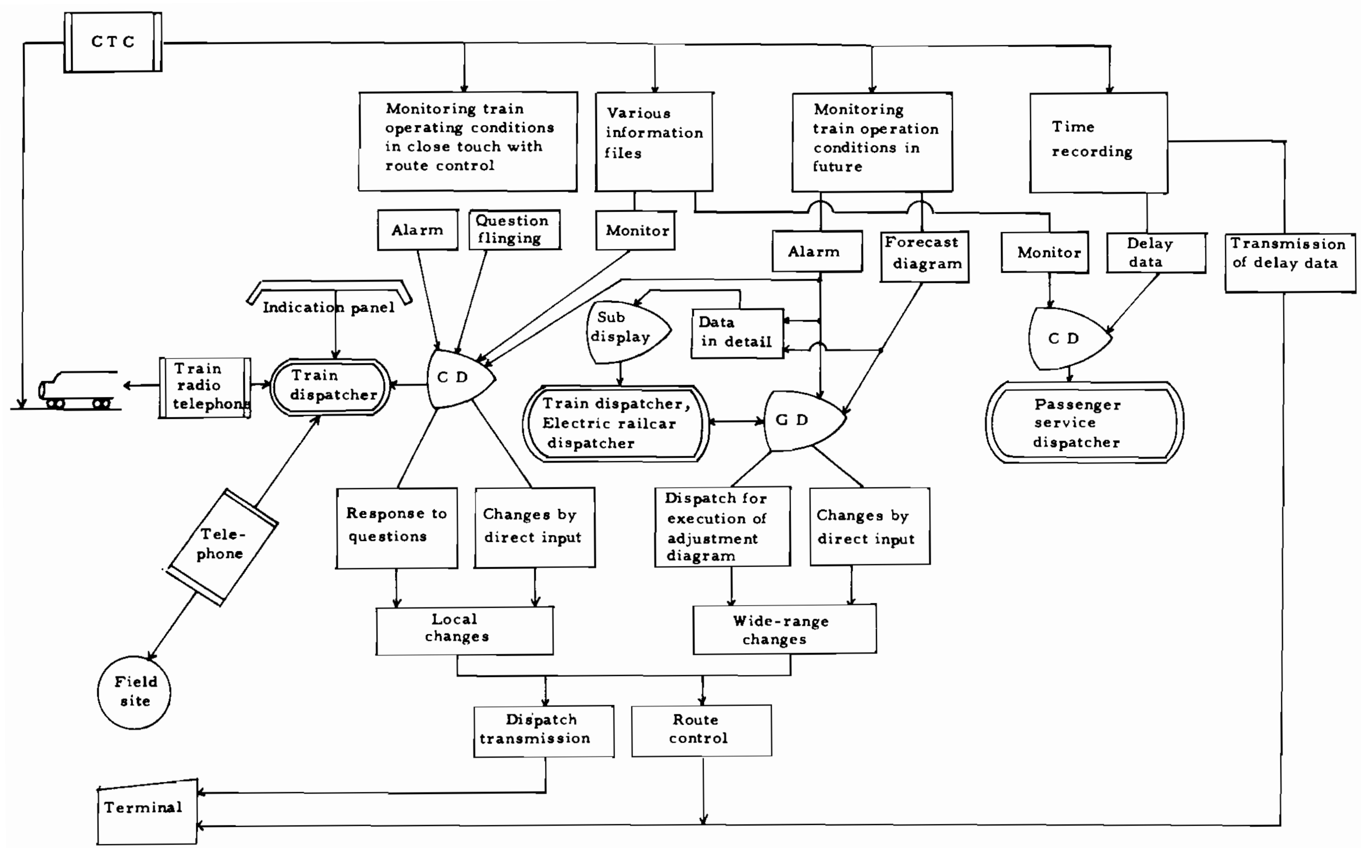


Fig. 34.7. Information flow in train operation adjustment.

Rolling-stock allotment

Out of numerous combinations of trainsets for rolling-stock rotation, the computer draws up an optimum plan in conformity with the train operation plan, rolling-stock running kilometerage, and the inspection plan. Keeping constant watch on the trainsets in use, it also checks up on their running kilometerage when changes take place in rolling-stock rotation and prepares the plans for changes in rotation for the following day and thereafter.

OTHER EQUIPMENT

CSC (Centralized Substation Control)

For train operation, Shinkansen substations are supplied with power at 3-phase 77,000 V to 275,000 V by power companies through the power transmission lines erected exclusively for that purpose. The power is transformed to single-phase 25,000 V at JNR substations. These substations and sectioning posts are all unmanned and remotely controlled from the center. The system consists of the panel for the connection diagram of power feeding and the control panel. The former indicates the power-feeding network and the latter the operation of all the equipment in the substations and sectioning posts, and their failures. For the connection between the center and substations and the sectioning posts, a coaxial carrier circuit is used. The information communication speed is about 7/100 second at a time.

Train Operation-Control System of the Future

COMTRAC SYSTEM AS ENVISIONED

The first-stage system of COMTRAC was introduced in 1972 and the second-stage system, now in use, in 1975. There have been continued improvements and the system is fulfilling its expectations. What is desired of it now is greater reliability and a wider range of performance. For the latter, the following are contemplated and studied: control of data on train crews (the number of crews needed, their trips, etc.) and on rolling-stock conditions, which the present system lacks; and print out of dispatches and information transmission on the terminals aboard trains through the COMTRAC circuit, which would replace the present system of wireless telephonic communication.

PRESENT STATE OF SHINKANSEN TRAIN CONTROL TECHNIQUE

In train operation, the only automated function is brake control by signals operated by ATC. For further automation, various methods of automatic control of power running have been studied, with the aim of operating trains at designated speeds in designated time and automatically bringing them to a stop at designated spots. The first apparatus using a mini-computer was mounted on the 951-type Shinkansen test car manufactured in 1969. After testing on commercial run cars and studying the performance of both hardware and software, the No. 2 apparatus, also capable of automatically monitoring the functioning of all the electric machines and instruments of the car and performing the necessary steps when the car is out of order, was produced and mounted on the 961-type Shinkansen prototype car brought out in 1973.

Its main functions are as follows:

On-time train operation control

After a train leaves a station, its time of arrival at the next station is calculated every second, taking the actual speed as the maximum speed. When the speed is the same as that given on the diagram, it is taken as the optimal maximum speed. In applying the brake by ATC signal before arriving at a station, the optimal speed within the allowed speed range in the ATC signal section is also calculated all the time the train is slowing down.

Train operation control at fixed speeds

The function of this system is to control the train speed so that it will conform with the target speed determined in the On-time Train Operation Control. Train speed varies according to track grades and voltage fluctuations of the power supply. To maintain the fixed rate of speed, the power running notch (the brake notch in some cases) will occasionally have to be adjusted. There are two ways to control the power running notch: one is to fix the notch in response to the target speed and the difference in speed, and the other is to fix the notch to be taken by judging from the difference in speed, acceleration, and the notch conditions 1 second before. Under this system, both ways are used for control, depending on the difference in speed, so that the frequency of notch changes can be minimized.

Train-stopping control at designated spot

This is a device to bring a train to a stop at a designated spot in the station. The stopping spot is detected from the wayside coil laid a certain distance away from the station to be entered. The system determines and controls the braking by calculating the speed, the distance up to the stopping point, and the deceleration rate.

Performance

On-time Train Operation Control ... Time of arrival at station: ± 15 sec.
Train Operation Control at Fixed Speeds: ± 2 km/h.
Train-stopping Control at Designated Speed: ± 50 cm.

Ideas for the Future

As a result of studies and tests, train-operation control has reached the stage where it can almost be put to practical use. Before driverless trains can be operated, however, there are still problems to be solved such as detecting and treating rolling stock breakdown and damage, linking CTC with stations, etc., and confirming that the way is clear on entering stations. Further automation is now under study.

35. *Maintenance System: Vehicles*

S. KUBO

Introduction

The Japanese National Railways have adopted a periodical inspection and repair system for the maintenance of vehicles. The details and frequency of inspection are determined according to the type of vehicle. All vehicles other than freight cars are controlled by the vehicle's running kilometerage and period of service, and the inspection and repairs are performed according to operating conditions.

Kinds and Frequency of Inspection

The kinds and frequency of inspection for the Shinkansen electric railcars are arranged, from experience of the conventional narrow-gauge line vehicles, so as to raise the turnaround coefficient to the highest possible point (for details see Table 35.1).

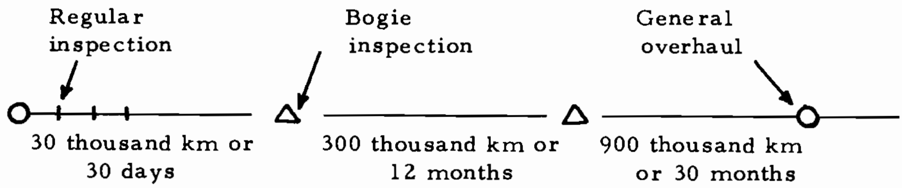
The daily inspection is performed during the night. Renewal of collector strips, inspection of ATC behavior, and minor repairs of passenger accommodation are conducted simultaneously with the cleaning of the car interior and draining of the toilet tank. One train unit is dealt with in this way in about 1 hour.

The regular inspection is conducted every 30,000 km. Here each train is inspected, as a set, on the behavior of its installations and instruments; flaws on its axles are detected by an ultrasonic detector, and brake blocks and carbon brushes are renewed in about 4 hours.

When the installations and instruments are out of order, or when flaws are detected upon inspection, minor parts are replaced at the time of the regular inspection; but the train set is temporarily removed to a repair shop for renewal of major spare parts.

The bogie inspection is conducted every 300,000 km, and the train is broken up for replacement of each bogie by a spare. This is done for a set of eight cars in about 8 hours. The bogies removed are disassembled for check-up of their main components, wheel grinding and lubricant renewal, and these components are used on the next train set coming up for inspection. The tread surface of wheels undergo another inspection every 70,000 km and are corrected, this time without the train consist being broken up. A flat tread, however, is corrected whenever it occurs.

TABLE 35.1. *Kinds and periods of inspection*



Kinds	Description	Periods
Daily inspection	Vital parts for safety operation inspected	Daily
Regular inspection	Major parts of the vehicles as a train set inspected	Every 30,000 km or 30 days
Bogie inspection	Bogie disassembled and replaced by spare bogie	Every 300,000 km or 12 months
General overhaul	All components overhauled	Every 900,000 km or 30 months
Wheel tread grinding	Tread surface of wheels and flat tread corrected	Every 70,000 km or when flat tread occurs

In the general overhaul conducted every 900,000 km, each vehicle is disassembled for overhaul. This general overhaul takes about 10 days. A detailed description of this overhaul is given later.

Distribution of Bases and Inspection Facilities

Main rolling-stock bases are located close to Tokyo, Shin-Osaka, and Hakata stations, where the first trains of the day depart from. Minor bases are located at intervening stations, varying in scale according to the number of first trains leaving for the day. It is economic to set up these rolling-stock bases close to the stations as this reduced the deadheading distance. However, as a base occupies a large area, they have been located, of necessity, where land could be easily acquired or where some railway facilities were already in use, and could be made available for conversion to rolling-stock bases. The location of these bases is shown in Table 35.2.

The general overhaul is conducted intensively at Hamamatsu and Hakata, and the bogie inspection at Osaka and Hakata. The Hamamatsu Workshop,

TABLE 35.2. *Location of rolling-stock maintenance bases*

Base	Accommoda-ting capacity	Daily inspection	Regular inspection	Bogie inspection	General overhaul
	(train sets)				
Tokyo (Shinagawa)	16	0	0		
Tokyo (Ohi)	25	0			
Mishima	14	0			
Shizuoka	2				
Hamamatsu Workshop					0
Nagoya	6	0			
Osaka	34	0	0	0	
Okayama	12	0			
Hiroshima	7	0			
Hakata	23	0	0	0	0

Note: In addition to these bases, the trains are kept at the platforms of the major stations during night.

located along the Tokaido Line, was originally set up for narrow-gauge line trains. When the Shinkansen was about to be opened, its facilities were updated and vastly improved so as to serve as a workshop that could also overhaul Shinkansen electric railcars, and it is now planned to use this workshop exclusively for them.

The bases where the daily and regular inspections are performed have pit tracks in the roofed buildings, each capable of accommodating a trainset of sixteen cars. Facilities are also provided for inspection and repair during the night.

The daily inspection track has a passageway for pantograph check-up and a platform (service deck) for cleaning the passenger-car interior. In the pit is a cart in which the inspectors move about. For the inspection of ATC installations, all sorts of simulation signals are transmitted from the test room to check the brake performance in combination with the testor that indicates the train speed.

In the bogie inspection and general overhaul, installations and instruments are taken apart and put together, and major parts are broken up for inspection and repair. In reassembling parts dismantled for inspection and repair, the "spare-part rotation" system is adopted, by which the vehicle is fitted with parts which have already been repaired, and this cuts down the vehicle's out-of-service period. In the inspection and repair of dismantled parts, a number of recently developed machines are used.

General Overhaul System

In the general overhaul and bogie inspection, the main components are dismounted and broken up for inspection in order to ensure safe performance and to maintain the high service level of the Shinkansen electric railcars. The systems have evolved after much study aimed at raising the rate of operation and reducing maintenance cost by cutting down the personnel and time required for inspection and repair.

DECREASING THE NUMBER OF DAYS FOR INSPECTION AND REPAIR

One of the most effective ways of raising the rate of vehicle operation is to reduce the number of days spent in inspection and repair. Today the general overhaul of a Shinkansen trainset takes 10 days, as shown in Fig. 35.1. It would be uneconomic to reduce the number of days allowed for inspection and repair of a complete trainset of sixteen cars as this would require the expansion of facilities and a greater number of men. Each trainset is divided into three blocks and the dismantling is performed over a period of 3 days, which enables the inspection and repair of a trainset to be carried out smoothly and satisfactorily.

The number of days required for inspection and repair depends on the time taken for carbody repair and painting. The painting is an assembly-line operation of washing, masking, painting, and drying. As it cannot be performed at the same time as other kinds of work, it is performed as a 10-hour continuous job, to shorten the work schedule.

Spare parts needing repair are put aside to be repaired later and to be fitted on vehicles coming up for inspection later. The parts are rotated, and this saves time in inspection and repair.

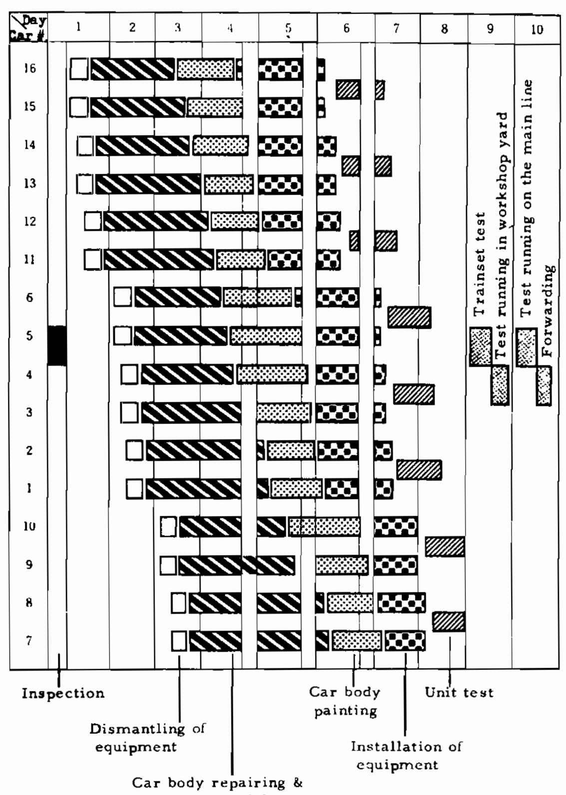


Fig. 35.1. Standard schedule for general overhaul of electric railcars of the Shinkansen.

The general overhaul, including test running on the main line, takes 10 days. The train to be inspected is deadheaded to the workshop at midnight before the first day of inspection. The inspectors report for work early in the morning of the first day and look for the points that need repair. After the test run, the train, with inspection and repairs completed, is deadheaded to the base by the evening of the same day. As the train is ready for use the following day, it is out of commission for very few days on account of inspection and repair, even when it is being overhauled.

Two or three shifts for rolling-stock repairs are not desirable, for three reasons. First, the cost of personnel goes up. Second, for reasons of safety, the handling of heavy material and parts and testing at high voltage or high revolution speed are not suitable for night work. Third, since the job descriptions are not uniform, mistakes and oversights are apt to occur when a job being performed by one shift is taken over by another.

It is very important that job performance does not lag behind schedule and that a job is performed without error. Automatic testors and other up-to-date devices are therefore used as much as possible.

STANDARDIZATION OF WORKLOAD

Repair work is not so simple as manufacturing (as is shown in Fig. 35.2) and workloads vary widely with the type of job. It is therefore necessary to standardize the workload in each department in order to minimize the

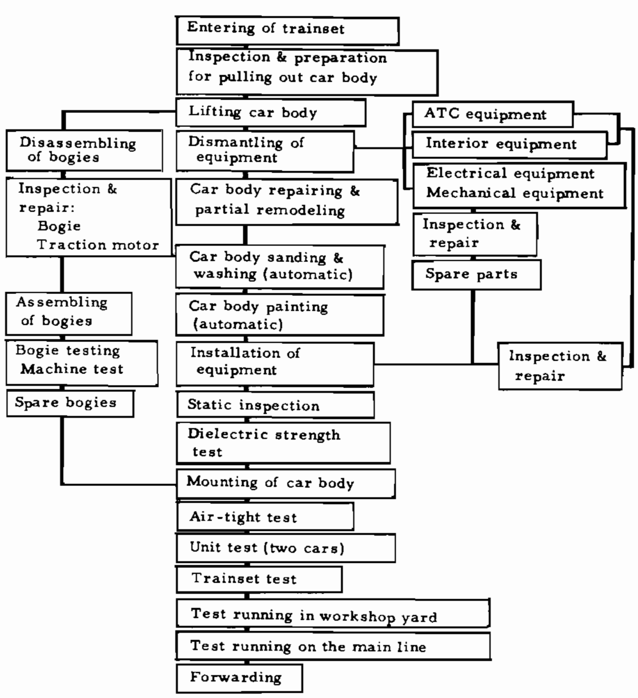


Fig. 35.2. Standard block diagram for general overhaul of electric railcars.

personnel and make sure that there is no idleness. For this there must be a detailed inspection and repair program. As it is desirable for vehicles to enter at regular intervals, the present arrangement is for them to enter every sixth day, which suits the capacity of the workshop.

For time to be saved by fitting spare parts on different vehicles (rotation), each of such parts must be identical. The same part may be supplied by various manufacturers, but they must all be freely interchangeable with those from other makers.

MECHANIZATION AND AUTOMATION OF TESTING OPERATIONS

The use of numerous standardized parts and the requirement for high-level precision have expanded the mechanization and automatization of the inspection and repair operations. In the initial period of the Shinkansen, many inspection phases were dealt with by human hand. During the first decade, however, various automatic inspection systems were developed and many kinds of automated testing machines have been set up in the Hakata Rolling Stock Maintenance Center, established when the Sanyo Shinkansen was extended down to Hakata. The kinds and number of these machines are so many (see Table 35.3) that no more than a few of the most important can be described here.

Automatic wheel-axle inspection line

In the maintenance of high-speed rolling stock, the greatest importance is given to the bogies, of which the wheels and axles must be especially well taken care of, as cracks occur due to the wear and metal fatigue caused by high-speed operation. The metal used for axles has its fatigue strength raised by high-frequency hardening. Since fine cracks, as small as 0.1 mm, have to be detected to ensure safe operation until the next inspection, ultrasonic and magnetic flaw-detection methods are employed.

Bearings are also strictly inspected for cracks, and when the accumulated running kilometerage reaches 2.5 million, they are, as a rule, taken out of use.

Wheels are designed to maintain circularity, and the difference in diameter of end wheels, the two pairs of wheels to each bogie, and those of the other

TABLE 35.3. *Machines installed at Hakata rolling stock maintenaince center*

Machines for:	Ordinary	Process-computer controlled	Mini-computer controlled	Numerical controlled	Other automatic controlled
Power	4				5
Processing	90	4		2	14
Painting and drying	51				8
Washing and dust collecting	124	1			64
Testing	75	10	1		35
Parts transferring	299	3	3		58
Total	643	18	4	2	184

bogies, are carefully checked. The flowchart of this inspection and repair line is shown in Fig. 35.3.

Apparatus for the testing of bogie running

Under the conventional rolling-stock inspection and repair system, the reassembled rolling stock undergoes test runs on the main line. For high-speed rolling stock, however, the reassembled bogie is instead placed on the bogie-running testing apparatus in case it should develop any trouble during the testing which would impede the operation of other regular trains in service. On this apparatus, the bogie is run at high speeds and the temperature and vibration of each component are closely checked. In this test two sets of bogies are placed on the test rail loop. The traction motor of one bogie rotates the wheels of the other bogie, which are linked directly to the rail loop, i.e. the traction motor is worked here as a generator in loadback fashion. The traction motor is thus checked at the same time.

The rotation direction, the number of rotations and the time are preset in the program for automatic control, and one testing cycle is completed in about 80 minutes.

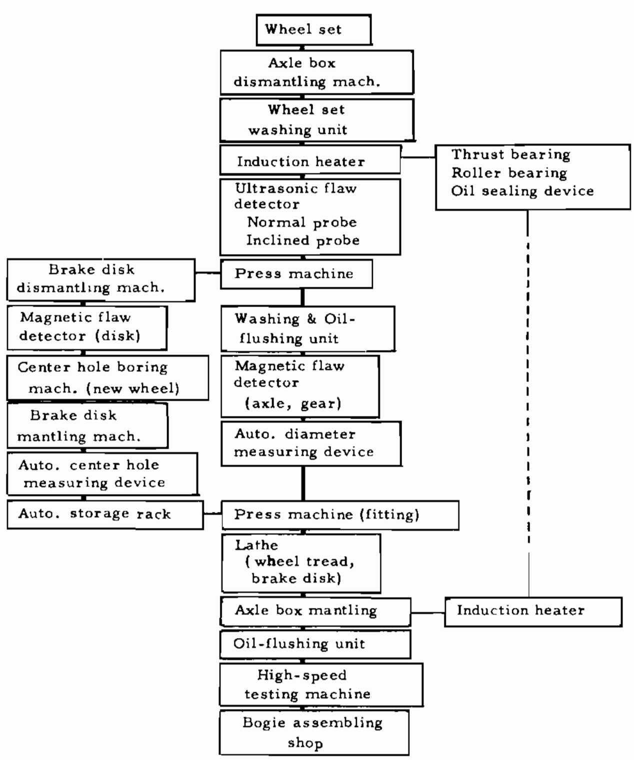


Fig. 35.3. Details of wheel-axle inspection line.

Apparatus for general circuit testing

The difficult and vital job of checking the control and main circuits of the reassembled Shinkansen electric railcars demands an extremely high technical level.

For maximum automatic control of circuit testing, test terminals are set on the rolling stock and a circuit testor with a control computer, main memory of 16 k-words, auxiliary memory of 96 k-words, is set up in the inspection shop for the circuit testing, and a two-car unit test and a sixteen-car trainset total test are performed. When the result is satisfactory, the data are printed out and the work goes on to the next step. When something is wrong, the NG indication appears and the test is suspended.

There are about 500 testing items in the case of electric circuits, and about 750 for braking circuits. Of this, 85% are automatically tested and the remaining 15% semi-automatically.

Rolling-Stock Maintenance Control by Computer

The cost control of job performance at JNR workshops is done by the workshop accounting system. The repairing cost per vehicle has the standard unit price set for each type of rolling stock.

The workshop must know the exact state of the vehicles in its charge for inspection and repair, assign its men properly and optimize its manpower, plan the use of its facilities, coordinate job performance and have supplies ready for use in the most efficient way. For this, JNR operates an information control system, Kojo (workshop) Information Control System (KICS) in conjunction with the Shinkansen Management Information System (SMIS). KICS is composed of the following six subsystems.

ROLLING-STOCK HISTORY SUBSYSTEM

Input in this subsystem are the manufacturing, remodeling, and repairing data of each vehicle, as well as the data of its fittings of machinery and instruments, since parts go from one vehicle to another under the spare-part rotation system. From the data of its running kilometerage, the inspection time is predetermined and the number of vehicles coming up for inspection supplied to other subsystems. This subsystem also predetermines the repairs to be performed and the materials needed and provides the data to the shop-in plan and work process subsystem and the supplies subsystem. These data help to improve the inspection system and to understand the degree of superannuation.

SHOP-IN PLAN AND WORK PROCESS SUBSYSTEM

Under this subsystem the turnaround and historical records of rolling stock are made known at any time, so that optimum plans well adapted to the fluctuations of requirement work can be drawn up. Work-process plans are now set up for each day instead of for each month or 10-day period, as before, to control the progress of daily work, to ensure delivery exactly as scheduled, and to optimize work assignments. The flow chart of mass information under the system is given in Fig. 35.4.

PERSONNEL SUBSYSTEM

Formerly, work schedules were made to suit the fixed allocation of personnel. Under the new system, men are assigned in a wider range according to their qualitative capabilities, and an optimum allocation can be made to suit the daily fluctuations of work now that the total man-power is known immediately the men report for the days work and they can be assigned individually according to their qualifications.

SUPPLIES SUBSYSTEM

Supplies are planned for each work unit based on the established standard list of required articles. As the history of inspection and repair and the exact

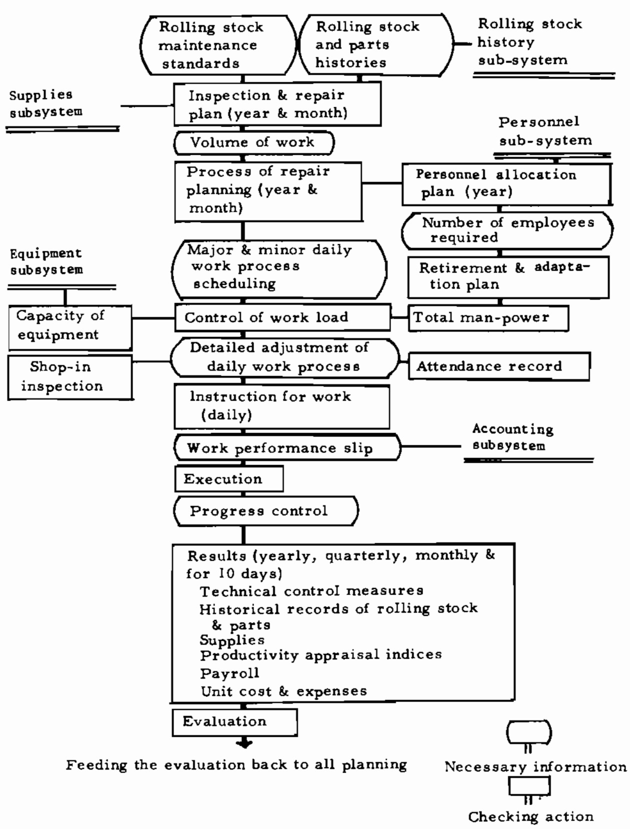


Fig. 35.4. Flow chart of mass of information in the shop-in and work process subsystem.

quantities of supplies needed are made known, idle stock, surplus, or shortage can be eliminated.

Supplies are now automatically distributed to each work unit from the storehouse at the time shop-in dismantling begins, as indicated by the data of shop-in inspection and the standard list of required articles. The planning and processing for supplies are simplified and greater efficiency is attained.

ACCOUNTING SUBSYSTEM

Optimum costing quickly determines the work costs, and accounting is now made more precisely, with expenses subtracted from the budget every day. Formerly, the results were summed up monthly for feedback to planning. Now that the day's plan becomes definite in the morning, the budget can be controlled in advance.

EQUIPMENT SUBSYSTEM

The factors of a long-term investment plan are more minutely divided and optimum planning is made possible by simulation. Taking into account the rolling stock inspection and repairing plans, preventive maintenance is planned in order to reduce the loss which would be incurred by the after-maintenance as practiced formerly.

Actual Number of Cases of Vehicle Trouble: System for Dealing with Vehicles in Trouble during Operation

Cars in trouble that delay the train over 10 minutes are classified as "Trouble A" and those delaying the train less than 10 minutes or cars that are replaced at the terminal station are designated "Trouble B". There has been no fatal accident on the Shinkansen since its opening, but since train delays cause traffic confusion, every effort is exerted to reduce the number of cases of car trouble.

The cases of car trouble have been few (see Table 35.4). The main reasons for this are the car inspection and repair system, and a series of general improvements to rolling stock. Another important reason is that the Shinkansen electric railcars are on a multiplicate system, so that even when equipment goes out of order, a train is kept running by cutting out the car for the rest of the way. 'Trouble B' is really part failure, and cases occur at the rate of once per car per year. "Trouble A" cases are negligible.

When trouble develops during operation, the protection device goes into action to close the circuit involved immediately, or the brake is applied. The indication lamp on the panel in the car then lights up. So do the trouble-indication lamp and the car-number indication lamp on the panel in the motorman's cab to warn the driver. The inspector checks the indication lamp in the car concerned and examines the trouble. He then takes action according to the instructions in the Manual, or confers with the electric railcar dispatcher

TABLE 35.4. *Cases of rolling stock trouble*

Year	Trouble A		Trouble B	
	No. of cases	No. of cases/ million car km	No. of cases	No. of cases/ million car km
1964	24	0.37		
1965	30	0.166		
1966	28	0.118		
1967	8	0.030	39	0.15
1968	12	0.038	62	0.20
1969	12	0.031	48	0.13
1970	6	0.012	62	0.13
1971	8	0.017	95	0.20
1972	16	0.028	81	0.14
1973	27	0.041	117	0.18
1974	47	0.072	106	0.16
1975	43	0.051	103	0.12
1976	63	0.072	118	0.13

of CTC via the train wireless. When the main circuit goes out of order, the unit affected is cut out, and in the case of the auxiliary circuit, the power supply is switched over to the other unit so that the train continues to run.

The train has to stop running only when ATC, the braking system, or the bogie goes out of order, but the number of cases of such magnitude is kept low by equipping such systems in multiplicity and by using highly reliable parts and components.

36. *Maintenance System: Fixed Facilities*

Y. MUTO

Object of the System

The maintenance system for fixed facilities was set up with the object of satisfying the following conditions:

Appropriate inspection, repair and renewal of facilities in order to maintain their functions.
Speedy recovery from abnormality of the facilities.
Ensuring the technical capacity to meet the above requirements.

Maintenance of Functions of Facilities

To enable inspection, repair, and renewal of the facilities so as to maintain their functions, special attention must be paid to the following requirements:

Establishment of standards of maintenance (cycles and methods of inspection, repair, and renewal) suitable for each kind of facility.
Provision of machinery, tools, and other equipment or installations necessary for inspection, repair, and renewal.
Securing the necessary time to make the inspection, repair, and renewal.
Establishment of an organization to assign appropriate staff to each division of the cycle — planning the inspection, repair and renewal; executing these plans; reviewing the results and reflecting them in subsequent plans (Planning, Doing, and Seeing) — and to define the responsibility of each division.

The system for maintenance of the functions of the Shinkansen is explained as follows for each of the four items.

MAINTENANCE STANDARDS OF FACILITIES

While the adoption of the latest techniques made the Shinkansen facilities highly maintenance-free and reliable (see Fig. 36.1), there was no advance knowledge of the deterioration through age of the facilities serving high-speed trains operating at 210 km/h.

In the early planning stage of the Shinkansen, it was intended that passenger

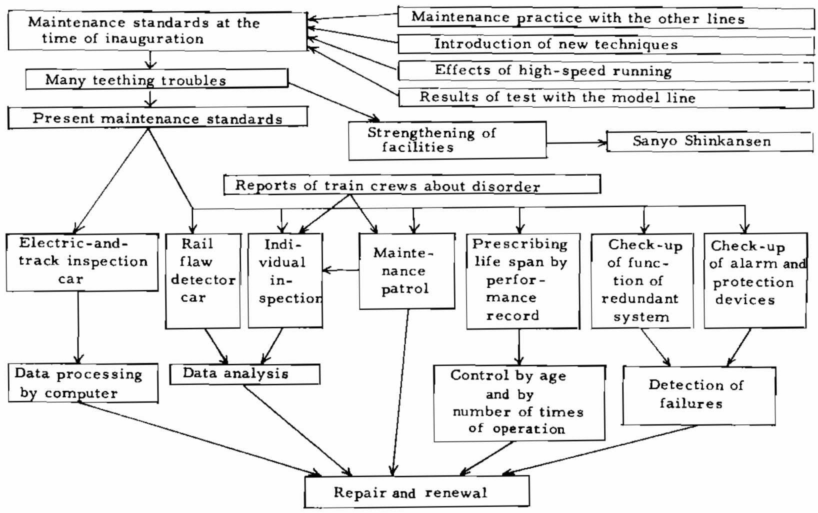


Fig. 36.1. Maintenance standards of facilities (block diagram).

trains would run during the day and freight trains at night. It was expected that sufficient time for maintenance of facilities would be provided by assigning Saturday night for this purpose, when freight trains would not be running. However, when the service began, it was found impossible to maintain the facilities with maintenance work performed only once a week.

The Shinkansen train actually began to run at 210 km/h about 2 years before the inauguration of the line, and this took place on the specially constructed test line, about 30 km long. Running tests were repeated, using two sets of experimental trains, one of two cars and the other of four. There was a great difference between the volume of maintenance work actually needed during commercial service and that expected from the experiments of maintenance of facilities performed during the test period. In the beginning of commercial operation, there were no more than thirty round trips a day, each train consisting of twelve cars, but this was much more frequent than the runs performed on the model line.

Maintenance of track and electric facilities of the Shinkansen began with standards based on the experience of the conventional lines, taking into account the new factors of high-speed operation. The effects of the unprecedented speed were severer than expected and, for the first few years, troubles with the way facilities occurred frequently. All of these problems were investigated and laid the foundations for the present standards of maintenance. The experiences on the Tokaido Shinkansen were utilized by the more advanced facilities of the Sanyo Shinkansen, which requires less maintenance and which enjoys more stable operation, almost completely free of trouble.

The most noteworthy item of the Shinkansen maintenance system is probably the operation of the track-and-electric inspection train, conducted at a standard cycle of 10 days for the purpose of inspecting the functions of the way facilities. The inspection trains runs at the same speed as the commercial train and automatically measures and records the dynamic characteristics of the track and electric facilities under high-speed operation. The data derived are processed by computer, compared with the allowable limits of maintenance, and the spots in need of repair are identified and notified to the field offices in charge of maintenance work. In addition to the inspection train, vibration accelerometers are mounted on a commercial train every day as a means of controlling the riding quality of the Shinkansen trains.

Facilities that cannot be measured by the inspection train or which cannot be dealt with by the inspection train are individually inspected at an appropriate cycle by field maintenance staff, and defects of rails are looked for at night by the rail flaw-detector car.

Pieces of equipment whose service life can be determined in terms of age or number of times of operation are excluded from the inspection and are renewed or overhauled according to a predetermined schedule.

Facilities provided with a dual system undergo a switch-over test to the standby unit at a specified cycle. This checks that the switch-over device and the standby equipment are working properly, so that system failure can be avoided. For systems that require especially high reliability, such as the ATC, a device is installed to constantly monitor the function of both the working and the standby unit, so that any trouble is immediately made known.

Equipment that is usually inactive, such as alarm and protective devices, also have their function checked periodically and any disorder found is remedied.

In addition to these individual inspections, an overall patrol inspection of the whole system is made during the daytime every day or every 2 or 3 days. This patrol concentrates on the detection of anomalies while observing the working of the facilities. Changes in ambient conditions are carefully noted.

Detection of an anomaly is not always the result of the patrol inspection by maintenance staff and the running inspection of the multiple-duty inspection train: in many cases it is discovered from the reports of train crews. For example, a geometric irregularity of the track is often discovered where the crew felt an unusual train vibration, and the deterioration of the ATC system or poor track circuit is indicated by an abnormal flicker in the ATC cab signal. The train crews play an important maintenance role as monitors.

The maintenance standards governing routine inspection and repair have been established in this way. Now, after more than 10 years of intense use since inauguration, the Tokaido Shinkansen needs renewal of its facilities. In carrying out this renewal, the facilities will be improved by the introduction of the technological advances made in the interim; particularly, the remarkable technical innovations in the field of electronic equipment.

The renewal work has to be done without interrupting commercial train services, so the work is divided into portions of 4 to 5 hours of night work, suspended in the morning to let the trains run as usual, the process being repeated throughout the renewal. This is more difficult and troublesome than constructing a new Shinkansen line.

Experience has already been gained in constructing three new Shinkansen lines. Renewal work, however, is something new; some of it has already been started and it must be carried out efficiently and safely, developing new work methods. The Shinkansen railway system can only be said to have been brought to completion when this renewal work has been carried out successfully and the Tokaido Shinkansen is reborn as a new Shinkansen.

MACHINERY AND EQUIPMENT FOR MAINTENANCE WORK

The maintenance work of the Shinkansen has been mechanized as far as practicable so as to attain the highest efficiency, safety of performance, and quality of work (see Fig. 36.2). Use of mechanical power has been pushed forward, for example, by the introduction of such heavy equipment as multiple tie-tamper and track liner in track maintenance, a work car to carry heavy materials (ballast, rails, etc.), the introduction of a catenary maintenance car, and a contact wire-replacing car.

Maintenance bases have been set up along the line for storing and servicing this equipment and for bringing in, stockpiling, and loading on the work train the materials for maintenance.

Other physical arrangements for maintenance include the pathway (1 m wide) laid along the whole line for track patrol use, and telephones installed along the pathway at intervals of about 500 m. Illuminators and train approach alarms have been installed in tunnels.

Where electric power for lighting and work is required for night work, an engine generator is generally used but, on account of its noise, a low-voltage power distribution line and outlets have been installed along some sections in residential areas.

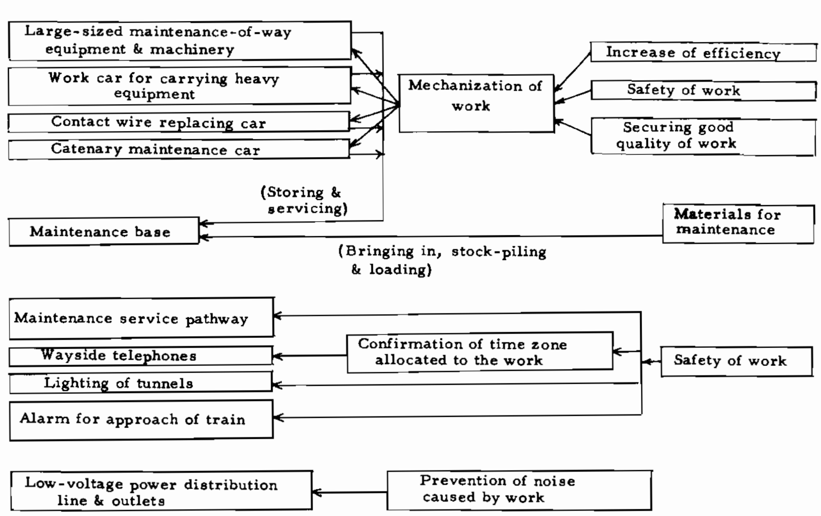


Fig. 36.2. Machinery and equipment for maintenance work (block diagram).

TIME FOR MAINTENANCE WORK

Because mechanical power is used to a maximum extent and trains are running at 210 km/h and frequently, the Shinkansen maintenance work, with the exception of track patrol, is performed during the night in order to prevent train accidents and to protect the workers. To make this possible, a time zone exclusively for maintenance is set aside, clearly separating maintenance from train operation time (see Fig. 36.3).

The maintenance work for the day has to be carried out efficiently and safely within this limited time, and therefore the following measures have been taken.

Establishment of regional dispatcher

To enable the maintenance work to be performed smoothly and to prevent accidents, a regional dispatcher is established in each region to exercise control over work (approval of planned work, control of the time zone assigned to maintenance work, approval of start of work and ascertainment of completion of work, permission for trespass into right-of-way, collection and transmission of information related to the work, etc.) and so coordinate the different kinds of work (adjustment of work section in cases of duplication of different work groups, control of use of maintenance cars and work cars, etc.). Keeping close contact with the central dispatcher, the regional dispatcher is aware of the movements of trains and exercises strict control over the start and end of the time zone for maintenance work.

Operation of safety confirmation car

On completion of maintenance or improvement work, a safety confirmation car (rail motor car) is operated prior to the operation of the first train to make

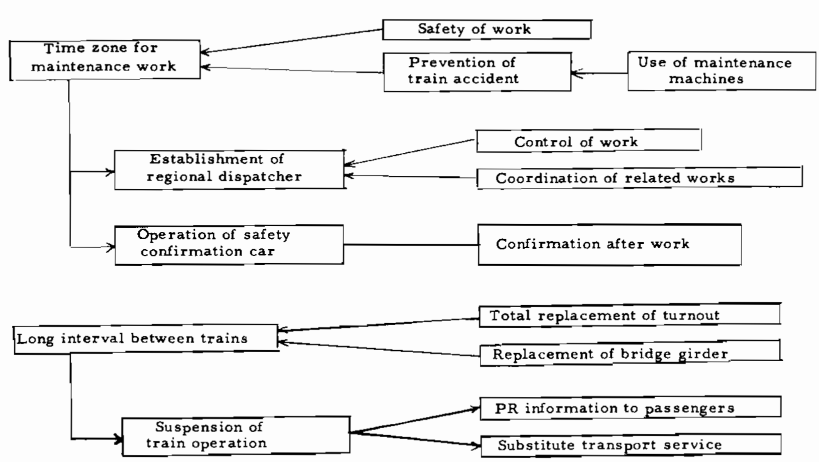


Fig. 36.3. Time for maintenance work (block diagram).

sure that materials, tools, etc., are not left on the track, and to confirm that the track is safe for train operation.

In renewing the facilities of the Tokaido Shinkansen, the original 50-kg/m rails are being replaced by 60-kg/m rails; in this connection, turnouts also have to be replaced.

Since the turnout, about 70 m long and weighing about 50 tons, must be replaced in one operation, and the normal maintenance work period is too short, all train operation is suspended for a whole morning for this purpose. When such a long interruption of train service is necessary, it is incorporated in the plan for the year and conducted during the light traffic season. It is made known to the public well in advance, and extra services are provided on that day on the narrow-gauge Tokaido line and on the Tokyo-Nagoya Expressway Bus route. This half-day suspension of trains for turnout replacement began in 1976, and, taking place about ten times a year, will end in 1981, according to the present plan.

For future replacement of bridge girders, more than half-a-day will be required, but studies are being made to reduce this time.

ORGANIZATION AND ASSIGNMENT OF DUTIES IN FACILITIES MAINTENANCE

As indicated in Fig. 36.4, the organization for maintenance of fixed facilities of the Shinkansen consists of the civil engineering side for maintenance of such electrical facilities as substations, overhead contact system, signalling and telecommunication facilities. Both are under the control and supervision of the Shinkansen Administration, the civil engineering side coming under its Track and Structures Department, and the electrical engineering side under its Electrical Engineering Department.

They have their respective centers and depots as subordinate organs. Each center draws up execution plans for maintenance, in accordance with the basic

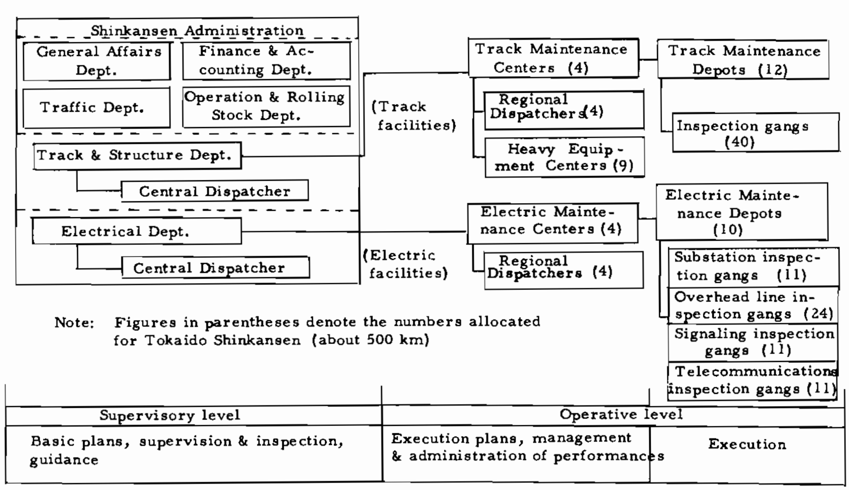


Fig. 36.4. Organization and assignment of duties in facilities maintenance (block diagram).

plans decided by the Department, and oversees the work. The depot is the organ that executes the maintenance according to the plan drawn up by the center, and it assigns inspection gangs to important places.

In addition, the Track Maintenance Center is assisted by the Heavy Machinery Center which is in charge of mechanized track maintenance as well as management of the use of large maintenance equipment, such as multiple tie-tamper and track liner, and work cars to carry heavy materials such as ballast and rails.

Daily maintenance work is controlled by the Regional Dispatcher, and is carried out with full coordination between the track-and-electric facilities maintenance organs.

Of all the work involved in facilities maintenance, that of knowing the condition of the facilities (e.g. management of historical data on age, number of operations, failures and repairs, and the time series management of inspection results), planning of maintenance and the execution of inspection are, in principle, undertaken directly by the railway, while the actual repair and renewal work is conducted under contract. Simple but voluminous inspections are done under contract, and repairs which can be readily performed upon inspection are performed by the railway.

Recovery from Failure of Facilities

The fundamental method of keeping the facilities functioning is to renew or repair them before failure occurs, either by prescribing a service life commensurate with their working condition, environmental conditions, and behavior traits correctly understood, or by forecasting the remaining life by judging the degradation by means of inspection at an appropriate cycle. It is impossible to completely eliminate failures, since maintenance standards are liable to be short of perfection and there can be an oversight in the inspection. The railway facilities are often damaged by natural elements and unexpected external causes, since they lie outdoors and extend over a long distance.

It is therefore an important element of the facilities maintenance system that arrangements be made for early recovery in the event of failure of facilities. The means adopted to this end are as follows (see Fig. 36.5).

ESTABLISHMENT OF DISPATCHER IN CHARGE OF FACILITIES

With the aim of recovering from failure of facilities as quickly as possible, a dispatcher in charge of facilities has been established. He constantly watches the state of facilities with centralized monitoring devices and, on becoming aware of a failure, ascertains its location and condition, and issues orders for recovery.

The duties of the Facilities Dispatcher are performed by five dispatchers who are in charge of track, power supply (substation and catenary), signalling, telecommunications, and COMTRAC, each divided into the Central

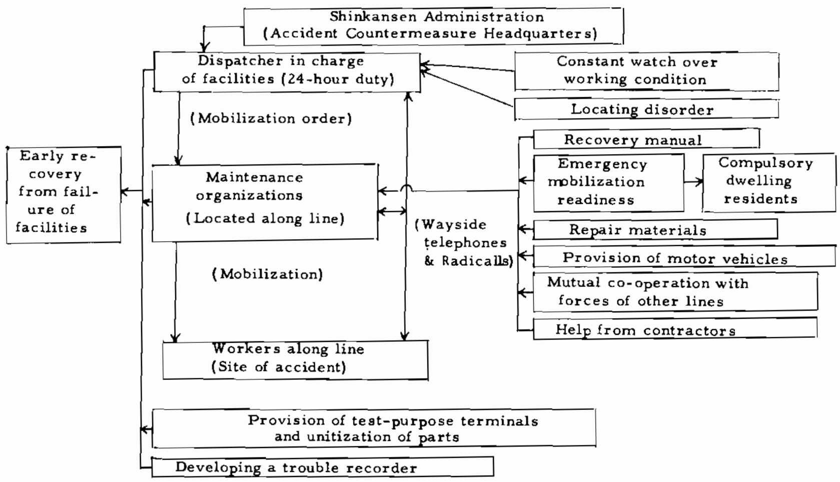


Fig. 36.5. Recovery from failure of facilities (block diagram).

Dispatcher (Tokyo) and Regional Dispatcher (seven places on the entire line between Tokyo and Hakata).

The Central Facilities Dispatcher is located on the same floor of the same building as the train dispatcher and the passenger service dispatcher, so that they can all keep in close contact. In case of failure, an accident counter-measure headquarters, composed of senior staff of the Shinkansen Administration, is set up in the General Control Center and adjusts the train operation plan and passenger traffic in accordance with the schedule for recovery.

The Regional Dispatcher is located in the regional organizations in charge of maintenance. Its normal function is to control and coordinate the maintenance works as described above, but in case of failure of facilities it becomes a regional Accident Counter-measure Headquarters.

CENTRALIZED MONITORING OF FACILITIES

In the Central Dispatcher in charge of facilities there is a centralized monitoring device that keeps watch over the state of the facilities of the whole line. As soon as an abnormality is found in the facilities, it issues an alarm to inform the dispatcher and indicates the troublespot.

The items indicated are the place (station, equipment house, substation, etc.) and the kind of facilities in trouble, e.g. "failure of turnout No. X of station P" or "stoppage of circuit Y of substation Q". For facilities extending over a long distance, such as rails and overhead line, the troublespot is given within a range of 2 or 3 km, differentiating between up- and down-tracks, so that the section in question can be reached by patrol and the trouble spotted. It is also the practice to call, by train radio, the driver of any train that happens to be running in the section in question, instructing him to slow down and report on the exact place and state of the trouble. Thus the general state of the trouble is often known by the dispatcher before the patrol arrives at the site.

PLACING OF MAINTENANCE ORGANIZATIONS ALONG THE LINE

The organizations for maintenance of facilities should be so placed and staffed that daily maintenance work can be carried out efficiently, and early recovery from failure should be possible.

The front-line groups directly undertaking the maintenance of fixed facilities of the Shinkansen are placed as follows:

The groups in charge of track facilities and power-supply facilities (substations and catenary) are each placed at an average interval of 20 km, staffed with ten and twenty persons, respectively.

The groups in charge of signalling and telecommunication facilities are assigned to each station where such equipment is concentrated (average interval 40 km), each staffed with about twenty persons.

Few maintenance workers are on duty during the day since daily maintenance operations take place at night. There are thus not enough available men to do the work of recovery from failures, although the initial job of detecting the fault and finding the facts can be adequately dealt with. To make up for this, workers off duty are called out in emergency mobilization, and it is compulsory for the workers designated for emergency mobilization to live in JNR official residences near the line.

Workers on patrol duty can be immediately called by radio in case of a failure, as they carry a Radicall. For emergency communication, the Regional Dispatcher sends out a radio calling signal, and the patrolman who receives it calls back using a nearby wayside telephone.

To expedite recovery in case of a failure, the maintenance organizations in the field have set up measures to be taken for various conceivable cases of failures, such as the order of performing recovery work, preparedness of materials for repair work, and the provision of motor vehicles for transport of men and materials. The Shinkansen maintenance organizations have arranged with maintenance organizations of other JNR lines nearby for mutual assistance, and have also arranged with contractors for emergency help and for the channel through which such help is to be requested.

TEST-PURPOSE TERMINALS AND UNITIZATION OF PARTS

Signalling and telecommunication facilities are made up of complicated circuits, and the prompt detection of a faulty part is essential. To this end, the process of measuring characteristic values (voltage, ohmage, etc.) in accordance with the failure symptoms is prescribed to facilitate fault-finding. Test-purpose terminals are provided where needed.

It is also the practice to unitize the parts so that a failure can be quickly remedied by simply replacing the faulty unit by a spare.

TROUBLE RECORDER

In cases of failure of such facilities as ATC, CTC, and signals at stations, which constantly change their state, it is important to know how each of the equipment composing the facilities was acting immediately before the disorder occurred. For this, a trouble recorder has been developed which, when a button is pushed, is capable of memorizing and storing all the data on the state of operation for a certain time retrospectively from the moment the disorder is discovered.

Securing and Improving Maintenance Techniques

The Shinkansen was planned and constructed to new specifications, independent of the existing railway, and utilizes the latest technology. Most of the engineers and technical staff engaged in construction were retrained as maintenance personnel for some time after inauguration of the line. Being familiar with the facilities, they were able to diagnose the cause of failure and remedy it quickly.

Many of the experienced technical staff who engaged in the construction and tackled the teething troubles are now reaching retirement age. In 10 years time, the Shinkansen will have to depend solely on younger people lacking construction experience or the trouble-shooting of the early days. It is therefore important to secure the technical ability for prevention of failures with complete knowledge of the important maintenance items, and the technical ability for speedy determination of the causes of failure and their remedies.

This requirement is common to all fields where technological innovation has produced more reliable equipment and has widened the scope of maintenance-free facilities dispensing with daily maintenance services, and, further, where the number of failures has decreased so much so that the opportunities for repair have diminished. The principal measures being taken by Shinkansen in this respect are as follows (see Fig. 36.6):

TRAINING AT RAILWAY SCHOOL

JNR has its own schools to provide general training for new employees, reassignment training on changing jobs, retraining for introduction of new techniques, and supervisory training for management staff. Included in the school curriculum are courses for technical training on the Shinkansen for new employees and transferees from other lines.

TRAINING AT THE PLACE OF EMPLOYMENT

Workers who having received technical training on the Shinkansen at the railway training school are instructed on the construction and functions of the facilities, with actual objects serving as teaching materials, and are then

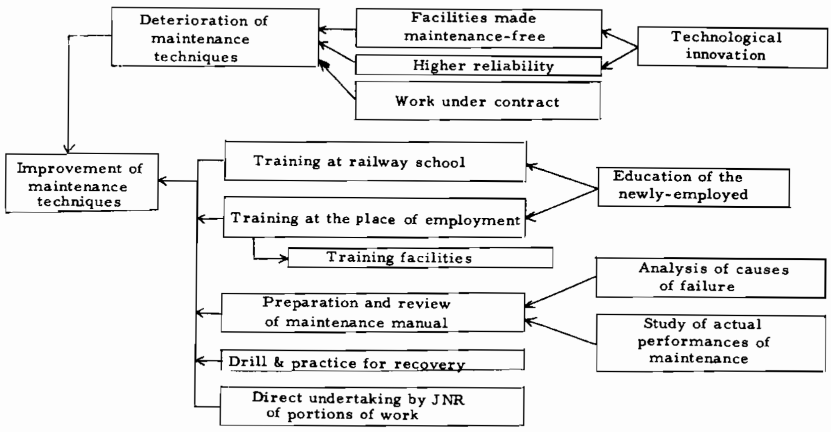


Fig. 36.6. Securing and improvement of maintenance techniques (block diagram).

trained in daily maintenance work. Training facilities for this are set up as required.

PREPARATION AND REVIEW OF MAINTENANCE MANUAL

A manual describing the structure, performance, and the concrete methods of maintenance, the troubles that have occurred in the past, and the methods of recovery from failure, has been prepared for each of the facilities and is distributed to maintenance personnel.

The manual is periodically reviewed by all concerned, on the basis of the analyses of causes of failures that have recently occurred, and on the performance of maintenance. Amendments are made to the manual as required. If reinforcement of facilities is considered imperative, the findings are fed back to those responsible.

By letting everyone concerned take part in revising the maintenance manual and the reinforcement of facilities, the technical ability of the front-line workers is improved.

RECOVERY DRILL FOR FACILITIES FAILURE

Drill for recovery from various conceivable failures is periodically conducted. For a highly mechanized and automated railway like Shinkansen, training is necessary on the substitute means to be taken by operating personnel in cases of failure of facilities until their recovery.

DIRECT UNDERTAKING OF WORK

Work for repair or renewal of facilities is, in principle, conducted under contract, but a part is undertaken directly by JNR. The coverage of the direct undertaking is selected according to its value in nurturing the technical ability for the maintenance of the facilities and recovery from failure.

The time has come for the renewal of the Tokaido Shinkansen facilities, and this renewal work requires even higher technical capacities than the initial construction. It may be expected that the technical ability of the workers engaged in the renewal will be greatly enhanced. That the cycle of renewal of facilities coincides with the cycle of refreshment of the technical capacity of the maintenance personnel is something to be welcomed.

37. *Seat Reservation System and Computer Application in JNR*

H. HARADA

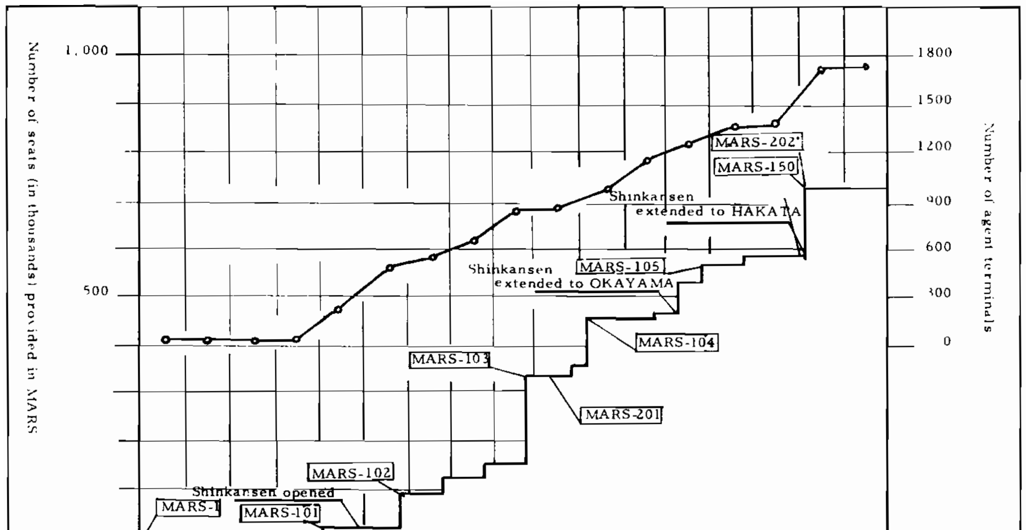
Introduction

Some readers of these proceedings might visit Japan and happen to see a ticket clerk working on a machine like a cash register at the open counter of a JNR station or a travel agency. This machine is an agent terminal of the Magneto-electronic Automatic Reservation System, called MARS, provided for reservation of seats and berths. They might also have an opportunity to go to the Computer Center located in the suburbs of Tokyo and see a group of 2-megabyte class Central Processing Units (CPU) used exclusively for seat and berth reservations. Approximately 30 billion yen have so far been invested in this system, which covers about 1900 agent terminals, nine sets of CPUs and special lines with the maximum of 2400 band. The system has in memory as much as 99.9% of the total seats and berths reservable, helping to earn 1.3 billion yen daily, or about 43% of the total passenger revenue in JNR.

Before the introduction of MARS I, the first type of this system, on an experimental basis in 1960, booking clerks at seat reservation centers received applications from each ticket window by headphone and recorded them in books held in special rotating cases. Experiments were conducted until 1964 when MARS 101 was put to practical use. The system had since been developed and capacity increased stage by stage from MARS 101 to 105. In 1969 MARS 201 and in 1975 MARS 202 were put into service for group reservations, and again in 1975 MARS 150 for telephone reservations. These developments are shown in Fig. 37.1. The system has thus become a large one with 1400 kilostep programs, making an average of a million transactions daily. At present, the system handles as many as 750,000 seats for 1700 trains a day, playing a basic role in passenger service sales. It covers trains not only on the Shinkansen but all other trunk lines where seats are reservable.

Functions of MARS

At present MARS consists of three subsystems: MARS 105, 202 and 150. MARS 105 enables a customer to make reservations for one to fourteen seats on the train he selects 1 week before boarding, specifying their locations or leaving the clerk to choose. When places on the desired train are all filled, the train immediately before or after can be checked for available space. The



Trains Covered	4	4	4	4	42	182	236	287	965	1,046	1,345	1,344	1,463	1,548	1,565	1,707	1,797	JNR ferries and buses included
Capacity *	2	2	2	2	18	95	126	157	332	354	463	473	562	585	582	738	692	
Terminals	12	12	12	12	173	467	560	642	892	892	892	1,021	1,168	1,277	1,417	1,773	1,855	
Fiscal Year 19-	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	

*In thousand seats

Fig. 37.1. Development of MARS.

system sells both reserved seats and fare tickets, calculating the basic fare and charges, prints them on the ticket and records them separately, for statistical data processing, thus saving much labor. The system is shown in Fig. 37.2. Communication Computers (CC) accept the inputs from terminals through Communication Control Multichannel (CCM), check their logical errors (30 February, etc.), transfer them to either of the File Computers, FC1 or FC2, according to the train requested. FC1 or FC2 checks the validity of the request (does the train really stop at the requested destination station?, etc.), searches the files (magnetic disks) for the seats, and informs the CC whether they are available. If they are available, it signals the terminal to print and issue the ticket. This done, files are amended and statistical data processing goes on. CCM relays the communications between terminals and CC.

To further computerize ticket selling, MARS 202 was developed for group reservations. This system enables an applicant for group travel to make reservations for 15 to 980 seats on the train desired, 5 months before boarding, specifying their locations or leaving the clerk to choose. When places on the desired train are not available, the train immediately before or after can be checked. These functions of MARS 202 are similar to those of MARS 105. The difference is that the MARS 202 enables the applicant to reserve seats on many different trains on many different routes, allowing him to alter the details of the application several times, all items being kept in the central memory until the final series of reservations is completed and the clerk in charge sends out a signal for the final issue of the ticket. The distance for group travel is usually long and the itinerary subject to change. The system is designed to meet this characteristic, and its composition is shown in Fig. 37.3.

MARS 150 is a unique system that enables a customer to make reservations without the aid of a ticket clerk, conversing with the central unit by telephone (see Fig. 37.4). An applicant may use any touch-tone telephone provided within the area (approximately 50 km radius of Tokyo) and call up the Audio Response Unit (ARU). In response to this call, the unit asks questions one by one, and the applicant answers them by pushing the buttons of the touch-tone telephone to input the necessary data directly into the central unit of MARS 150. Based on the input data, MARS 150 makes inquiries of MARS 105, and when places are available, records the results in the reservation file of MARS 150 while working the ARU, to transmit (in Japanese) the reservation number and the purchase date to the applicant. When places are not available it works on ARU to inform the applicant. When the applicant shows the reservation number to a clerk at the ticket window of the station, the clerk works the agent terminal of MARS 105 to read out the reservation file MARS 150 for confirmation of the details of the reservation requested, and he issues the ticket. At present, this reservation system is applicable only to the Shinkansen trains leaving and arriving at Tokyo. (Details of the three subsystems will be given later.)

Since 1965 rapidly growing national economy led to a demand not only for increased passenger transport capacity, but also for greater comfort. To meet this demand, JNR has continually put into service additional express trains for which seat reservations are required. Without these computer systems the

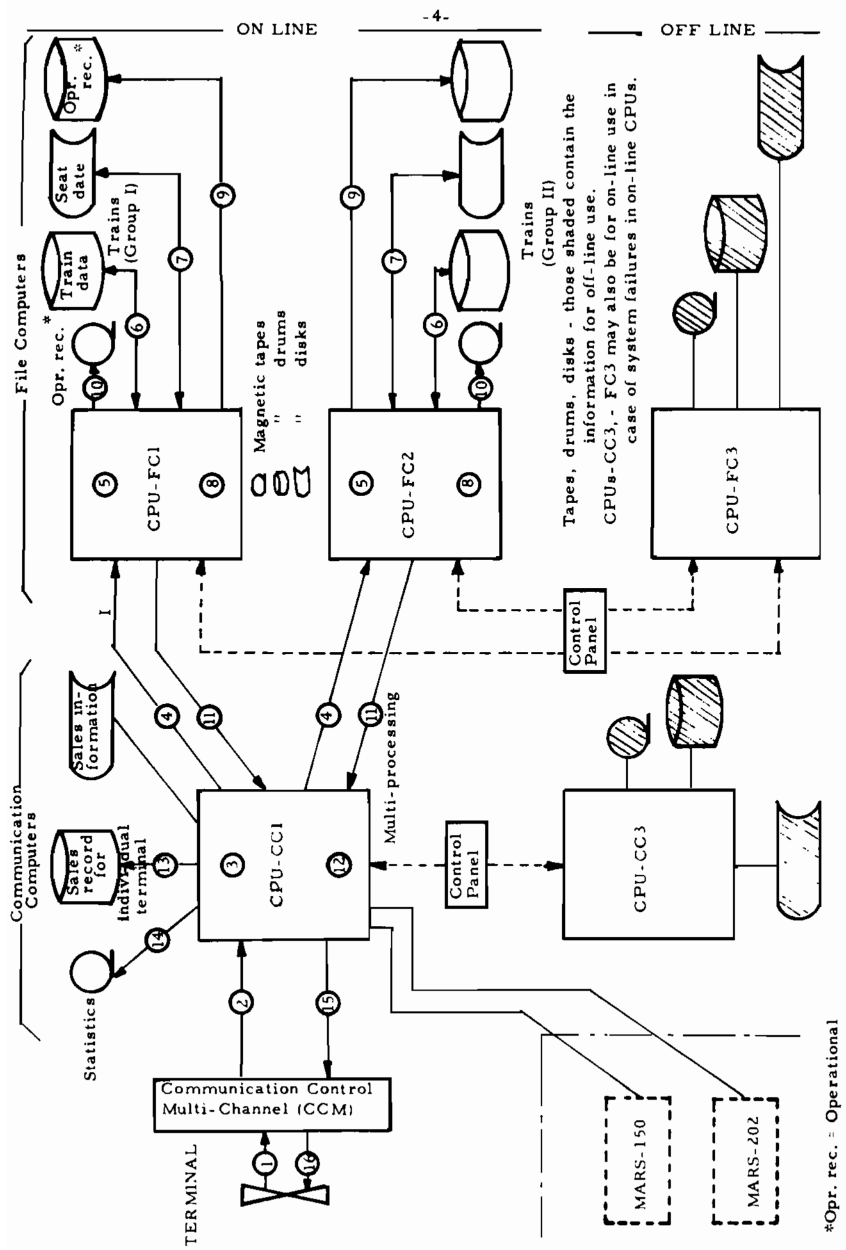


Fig. 37.2. Data-flow of MARS-105.

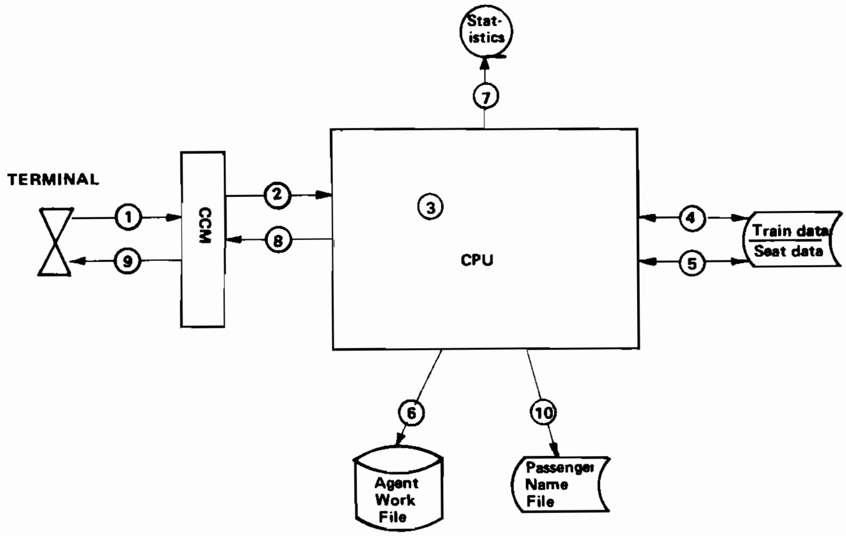


Fig. 37.3. Data-flow of MARS-202.

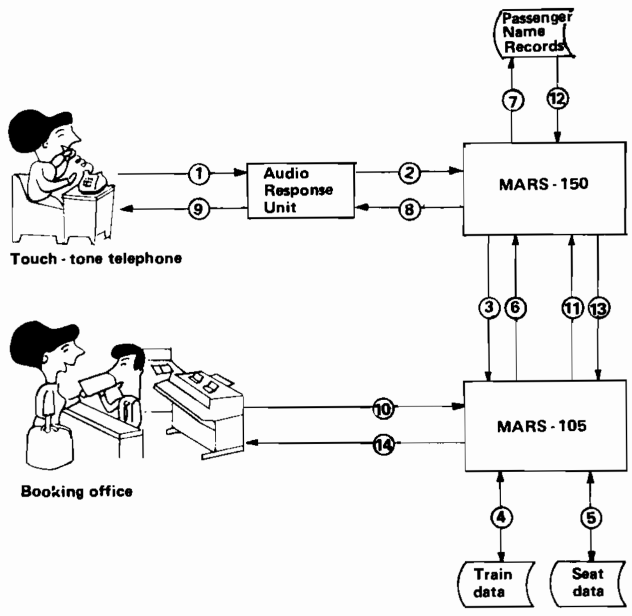


Fig. 37.4. Data-flow of MARS—150.

demand could never have been satisfied, even if the number of clerks at ticket windows had been increased several times. It is no exaggeration to say that the systems have contributed a great deal towards the modernization of passenger services in JNR.

Features of MARS

CC-FC SYSTEM — MARS 105

MARS 105 processes data in mass and at high speed; its central processing unit deals with 1,600,000 calls a day in the busiest season or an average of 75 calls a second. A response is made within 6 seconds, or more accurately 6 seconds with the probability of 90%, counting from the moment when a key on the agent terminal is touched to the moment the first letter is printed. As is seen in Fig. 37.1, the system has been continually developed and improved, especially MARS 103 and later models, with emphasis on the development of the special Operational Systems for MARS and on improvement of the agent terminals for processing the increasing data. The capacity that could meet the demand of a certain year might not be sufficient to satisfy that of the following year. On the other hand, if the system's capacity is enlarged, and a big change in the system has to be made later, a considerable loss could be incurred. To avoid this dilemma, the CC-FC system was devised, by which the central processing unit is composed of two parts: Communication Computer (CC) and File Computer (FC). CC gives and receives information to and from the agent terminals, while FC controls groups of files for data on seats. Thus, the FC part only can cope with an increase in the number of reservable seats, and the CC part only could deal with a very large change effected on the whole system (for instance, to connect MARS with other computer systems).

The Shinkansen network is scheduled to become larger in several years with the number of reserved seats considerably increased, and MARS 105 is the now being connected to the computer systems operated by the major travel agents. Trials will prove that the CC-FC system is the most effective method, needing the least modification.

MULTI-RESERVATION SYSTEM — MARS 202

Assume that there are trains *a*, a^1, *b*, and *c* on the section between stations X, Y, and Z, as is seen in Fig. 37.5. MARS 105 is designed for the reservation of a trip for which such essentials as date, destination, train, etc., are definitely given, fixed by the customer himself who has made his choice. Take, for example, individual customers intending to travel from station X to station Y. He will apply for reservation on train a^1 from among the trains *a*, a^1, and *c* (on the section between X and Y). All that is required of MARS 105 is to make it clear whether or not a place on train a^1 is available, and if not available, it will suggest a place on train *a* or *c*.

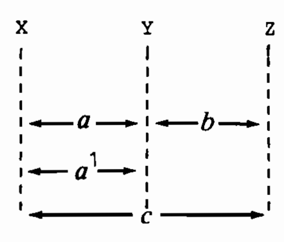


Fig. 37.5. Arrangement of trains for the explanation of multi-reservation system, MARS-202.

On the other hand, an itinerary for a group is usually uncertain at first and apt to change. Customers will make it definite in consultation with the ticket clerk. The multi-reservation system, MARS 202, has been developed with the object of preparing such an itinerary.

MARS 202 can make a tentative reservation on train *a* for an applicant who wishes to travel from X to Y, and can also suggest a lengthy trip down to Z in order to sell him train *b*. It can make a reservation with many courses up to 29 per application. The central unit processes four applications per second, the response time being approximately 8 seconds with 90% probability. Suppose reservations are made as follows:

C (customer representing a party of 20): We would like to make a trip from X to Y.

R (JNR clerk): How about taking the train *a?*

C: O.K. We will take it, but not definitely. (Tentative reservation (1) for train *a* is made.)

R: How about extending your trip down to the sightseeing area Z? If you take train *b,* there will be a 10% discount on the express charges.

C: Let me see. . . .

C^1 (another customer comes up): Excuse me, we would like to make a reservation on train *c*. (Reservation (1^1) for train *c* is made for customer C^1.)

C: Reserve the train *b* tentatively. We will come back tomorrow with the definite decision. (Tentative reservation (2) for train *b* is made for C.)

C (second day): Yes, we have decided to make a trip down to the sightseeing area Z as you suggested. But we would like to take train *c* on the section between Y and Z, not train *b.* And for the section XY, we would like to take train a^1 instead of train *a.* [Tentative reservation (3), $a^1 + c$ (for the section Y Z) is made.]

C (third day): We would like to add one more person to our party, but our budget is limited. On the section between Y and Z, instead of train *c,* we would like to take train *b,* as you originally suggested, with the discount. [Tentative reservation (4), $a^1 + b$ is made and one member added.]

C (fourth day): We would like to defer our departure for one day. [Definite reservation (5) for trains *a* (one day deferred) + *b* (one day deferred) for 21 members is made.]

MARS 105 could not make these four tentative reservations and one definite reservation. In making the tentative reservation (3) all the items, including the date of boarding, the number of people, etc., required for making the tentative reservations (1) and (2) must be input into the agent terminal again, to search for trains *a* and *b* in the seat file in order to cancel the reservations. New reservations must then be made for trains a^1 and *c* (on the section between Y and Z). All other changes must be made in the same way.

Take MARS 202 for making these reservations. First, input the data required for reserving trains *a* and *b* for the tentative reservations (1) and (2). Then keep these input data in the other memory, the Passenger Name Record (PNR). On changing them into the tentative reservation (3), it would suffice to take them out on the CRT-display, and just change the train *a* into a^1 and *b* into *c*. No other input is required, thus reducing input considerably.

Assumable in an actual situation is the reservation (1^1) for C^1 arising between the tentative reservations (1) and (2). Compare two cases: case (A), where two reservations are made separately, one for train *a* and the other for train *b*, as in the tentative reservations (1) and (2), and case (B), where one integrated reservation for trains *a* and *b* is made, as in the tentative reservation (3). The fares and charges for case (B) will be different from those for case (A) because of the tariff-tapering system now in use — the longer the distance, the lower the rate of fares and charges.

MARS 105 cannot calculate the fares and charges for one integrated reservation made for trains *a* and *b* as in case (B) when the reservation (1^1) for another customer arises between reservations (1) and (2). The clerk in charge will have to see whether or not the tapering fares and charges are applicable to the case, and, if applicable, then he must cancel the two reservations for trains *a* and *b*. Data must then be input afresh to complete an integrated reservation for trains $a + b$.

Use here MARS 202 in place of MARS 105. To minimize the handling of the *exégèse tarifaire,* cancellation and re-input, placed in front of the central unit is the Agent Work File (AWF), through which data will be input into the central unit. For the reservations exemplified, the reservation for train *a* is first made in the AWF. The result is transferred to the Passenger Name Record (PNR). Thus, clearing the AWF, the reservation for another customer is made. Then the result is transferred to the PNR for C^1, clearing the AWF again. After this, the input data for train *a* is taken back from the PNR for C to the AWF, and the data for train *b* is added. Automatically and accurately, the fares and charges for the tentative reservation (3) on trains *a* and *b* are processed in the AWF.

When MARS 105 is used to change the tentative reservation (4) into (5), two inputs must be made separately, one to change the date of boarding train *a* and the other to change that of train *b*. When MARS 202 is used instead, one input would suffice to make changes of this kind — parallel date transfer changes.

MARS 202 can print and issue tickets automatically as in MARS 105. It can also prepare a list of customers who have made reservations but have not picked up their tickets 10 days before their boarding dates. When the boarding dates approach and customers have not picked up their tickets, contact with them might be required in which case such a list is very useful.

ARU — MARS 150

The demand for reservations by telephone increases year by year. If JNR had set up as many manned telephone reservation centers as would be required to cope with the growing number of telephone applications for train reservations, the fares of JNR, which are much lower than airlines, would not have covered the cost operating these centers.

As is shown in Fig. 37.4, the JNR telephone reservation system has two parts: the Audio Response Unit (ARU) and the Passenger Name Record (PNR), the latter handled by MARS 150 computers.

A typical operation is shown in Table 37.1. A customer telephones the system and inputs the reservation data by means of a touch-tone telephone keyboard (about 300,000 were installed by Nihon Telephone & Telegraph Corporation in the Tokyo area as of March 1975).

ARU repeats each item for confirmation and sends it to MARS 150, which checks its validity and sends it to MARS 105. If the seat is available, MARS 150 assigns a reservation and records the information on PNR. The number and the time limit for ticketing are answered in recorded human language through ARU.

On giving this number, the customer obtains the ticket at a station or travel agent office where a MARS 105 agent terminal is installed.

The average time for making one reservation, as shown in Table 37.1, from Item 1 to Item 10, is estimated to be about 3 minutes. MARS 150 can deal with 20,000 reservations a day. The response time for booking (Item 9) is about 7 seconds, on the probability of 90%, measured from the moment when the last key is pushed for "order code" on the telephone keyboard to the moment the answer begins to be heard.

TABLE 37.1. *A typical touch-tone operation for seat reservation in MARS 150*

Input		Output
Item	Example of operation	Response (in Japanese) and Guide to Subsequent Input
Calling the booking center	9500	This is the JNR booking center Push your phone number, please
1 Your telephone number	2126311	Your telephone number is 2126311. Push your request code, please
2 Request code	1	Now, ready for booking. Push your departure date, please
3 Departure date	0510	10th of May. Push your train number, please
4 Train number	01025	Hikari No. 25. Push your departure station, please
5 Departure station	4000	From Tokyo Station. Push your arrival station, please
6 Arrival station	6100	To Shin-Osaka Station. Push the number of tickets, please
7 Number of tickets	2	2 tickets. Push your accommodation, please
8 Accommodation	2	Ordinary class. Push your order code, please
9 Order code	0	(booking the seats) Your reservation No. is 4312, repeat 4312. Push your reservation number, please
10 Reservation no.	4312	Now reserved. Please get your tickets at the ticket counter by 8 May. Thank you

Two methods of audio output were considered, one editing pre-recorded speech and the other simulating the human voice. For the latter, less memory capacity is required, but the cost of channel parts is high and the quality of audio output is not very satisfactory. The former method was therefore employed.

The voice element was set at a 1.1-second period in which most words, such as station names, months, and numerals, can be recorded (512 words are stored in one voice drum — 35 M-bits digital).

The word-editing part of the main control parts of the ARU picks up the necessary words from the drum according to the programmed order with the signals given.

Future MARS Problems

With a comparatively small modification, the current MARS would be capable of dealing with as many as 1,400,000 seats and berths to cope with the expanding network of Shinkansen lines. However, now that Japan has passed the period of high economic growth and entered a period of stability, it is necessary to improve MARS not only by increasing the numbers of reservable places but also by making "package reservations" and by further savings of manpower.

IMPROVEMENT OF AGENT TERMINALS AND EXPANSION OF TELEPHONE RESERVATIONS

To reduce the number of clerks engaged in the front sales service, efforts are being made to develop agent terminals operable by customers themselves as well as agent terminals designed exclusively to cancel reservations. The latter have been developed to deal with the considerable number of cancellations (as many as 10% of places reserved) and avoid double reservations that are liable to occur when cancellation is input by mistake. When a reservation ticket on which optical codes are printed, is inserted into the cancellation agent terminal specially installed at the fare adjustment office window, it will read into CPU and cancellation automatically made.

Telephone reservations are at present limited in areas and trains. Efforts are being made to expand these areas and to increase the trains for which the system can be applied so that reservations could be made with minimum help from clerks.

INTRODUCTION OF PACKAGE RESERVATION

Package reservation for train, rent-a-car, hotel, and airplane, if introduced, would offer greater convenience to customers and increase train reservation sales. The multireservation system of MARS 202 provides a technical basis for realization of package reservation.

Major travel agents in Japan operate a large network of hotel rooms and aircraft seats, using their own computer systems. JNR and Japan Travel Bureau (JTB) have jointly organized a project team which is now preparing to connect the MARS of JNR with the TRIPS of JTB. Should this connection be made, JNR and JTB could use their information and services jointly and offer improved services to customers.

Conclusion

Unlike other railways overseas, passenger services assume great importance in JNR. When further improved, MARS would become one of the strongest pillars supporting the operation of JNR. One might even say that a system like MARS, which deals with information required by the majority of the public, is destined to leave the hands of an individual enterprise, in this case JNR, and become part of the social assets of the nation.

We accept it as normal to endure certain inconveniences through lack of information, usually arising because the information is in the hands of many different specialists belonging to many different organizations. The joint use of a central unit, however, gives the users access to all the information required. Information is on the way to being "socialized" and a wider use of MARS is expected in this direction.

Computer Application: Introduction

OUTLINE

This section outlines the JNR computer systems as a whole. A conventional way to divide an industry's activities is into three parts: production, sales, and administration. Nearly a hundred JNR computer systems are now in service, and under this convention, they can be classified as shown in Table 37.2, which lists the fields already computerized and lead to the following questions:

Why were those fields computerized?
How do the JNR computer systems under development differ from those in other industries?
What problems are now being faced by JNR in further computerization?

Before these questions are discussed, some other major computer systems are briefly described.

ON-LINE REAL TIME SYSTEMS

Freight operational control system (FOCS)

JNR operates 24,600 freight cars daily, of which FOCS deals with about 4,600 cars used for interblock express freight trains. The features of this system are as follows:

TABLE 37.2. *Outline of JNR computer application* (Figures as of 1976)

Computers applied to: (see notes on systems)	Production (1) COMTRAC	(2) SMIS	(3) YACS	(4) KICS
[a] Sum total invested (Y billions):	-	1.0	7.0	1.8
[b] Manpower saved (persons):	30	150	120	980
[c] Computer personnel	30	50	50	270
Hardware				
CPUs installed at:	Shinkansen General Control Center	Shinkansen General Control Center	4 marsh-alling yards	9 work-shops
CPUs 500 KB or more (number of sets):	2	-	-	-
CPUs 65-500 KB (number of sets):	3	1	2	9
Less than 65 KB (number of sets):	-	-	10	-
Terminals (number of sets):	80	47	11	18
Software				
Program steps (thousands):	650	315	950	300
Numbers of trains a day (covered by the systems):	1300	-	400	-
Number of railway vehicles a day (covered by the systems):	-	2320EC	4400PC	[d] All railway vehicles
Other features (covered by the systems):	35 stations	1100 km of track	-	-
Input, in terms of calls per month (millions, unless otherwise shown):		30,000 OMR sheets		1.1
Rush-hour traffic, calls per hour (thousands):		0.4		

[a] Leased assets capitalized by aggregate rental (44 months).
[b] Actual decrease as well as prevented increase by computerization in the manpower of the application jobs.
[c] Excluding terminal operators.
[d] EL, DL 4,214
EC, DC, PC 28, 609
FC 144,537

Notes:

(1) COMTRAC
An on-line system applied to Shinkansen only, for:
(a) route-control throughout Shinkansen according to the given train diagrams;
(b) proposal by machine, of the optimum modification of the train diagrams in case of disturbance.

(2) SMIS
An on-line system, applied to Shinkansen only, for making up daily maintenance programs of tracks and of rolling stock, and for cost analysis of the jobs.

(3) YACS
An on-line system applied to major marshalling yards, for automatic classification of arrived freight-cars and for formation of train new destinations, by way of a computerized control of car-retarders, switching-points, etc.

(4) KICS
Batch systems applied to car-repairing workshops, for their resource control and for checking the maintenance record of individual cars and parts.

TABLE 37.2. continued

Sales		Administration			
(5) MARS	(6) FOCS-EPOCS	(7) RES/STAT	(8) DACS	Five minor systems	Total JNR
25.0	4.4	4.2	0.4	0.6	44.4
-	270	2800	300	540	5190
130	80	1050	200	80	1940
Kunitachi Computer Center (KCC)	Kunitachi Computer Center (KCC)	27 local divisions (ROD)	KCC & 6 local divisions	-	-
7	2	-	-	1	12
2	2	23	8	2	52
-	-	13	-	9	32
1950	361	-	900	-	-
1300	590	8360	1864	1100	15,429
1700	278	-	-	-	-
-	4300FC	-	-	-	-
900,000 seats	700 containers	430,000 employees' payment and other statistical processing for 6000 organs			-
21.0	0.5	10.9	1.3	-	-
370.0	4.4		4.7	-	-

E for electric
D for diesel
L for locomotive
C for car
P for passenger
F for freight

(5) MARS
An on-line system applied to entire sales network, for the reservation of seats and berths.

(6) FOCS-EPOCS
An on-line system applied to freight service, for:
(a) reservation of freight-cars to be coupled to the interblock freight express trains, or of containers to be loaded on the freightliner express trains;
(b) furnishing the consignees in advance with the arrival information on the cargo.

(7) RESOURCE CONTROL/STATISTIC
Batch systems covering the whole JNR, applied to local operating divisions, for personnel, accounting, stock control and for statistical review of the operations.

(8) DACS
An on-line system covering the whole JNR, used not for the particular application jobs but for message switching and computer-combination, by way of the JNR-owned telecommunication network.

The nationwide flow of freight is patterned and this patterned flow is incorporated into the diagram of freight trains, which is made public like that of passenger trains.

The freight consignor chooses a train and applies to the station for the number of freight cars required to be coupled to the train. When each car number has been determined the station applies to the central unit, through the agent terminal provided, to check whether they can be coupled to the train.

The central unit decides whether or not this is acceptable, based on the hauling capacity of the train. If it is acceptable, the unit informs the station of origin to that effect and informs the destination station in advance of the arrival.

The destination station conveys this arrival information to the consignee by telephone. Since the freight car numbers are known, it is easy to locate any of those cars in the yard, or anywhere else when necessary, especially in case of an accident. (Locating a freight car is extremely difficult without this system.)

This processing is performed and controlled between the central unit in Tokyo and the agent terminals at principal stations over the whole system and at major consignors' offices.

Effectual planning and operation of container system (EPOCS)

This system covers about 500 containers out of the 7500 handled daily. A container train is made up in almost the same way as a passenger train, with the number of cars in its composition and its schedule publicized in advance. When a reservation is made to load containers on the train, the advance arrival notice to the station of destination, the calculation of fares and charges, and the issue of a freight note is all done automatically through the agent terminals specially provided.

Yard automatic control system (YACS)

Using a computer, the system automatically breaks up a freight train arriving at the marshalling yard into several parts and couples each part to a train with a new destination. This system relieves the yardmen of the dangerous work of freight-car coupling and uncoupling. Since the complicated route setting in the central yard signal room has been fully automated, the number of freight cars handled per man has become four times what it was when manually operated.

Freight-terminal information system (FIS)

Computer-provided cranes automatically load and unload containers between trains and trucks and guide trucks in the container terminal yard.

Resource control systems and statistic systems

Twenty main systems and their sixty-five subsystems comprehensively cover the statistical processing of personnel, finance, and accounting, purchasing and stores, passengers and freight, and train operations.

The railway-operating division (ROD), an intermediate administrative organ, manually collects the regular reports from its field organs daily. These reports are input into the computer provided at each ROD, together with those reports prepared at the ROD itself. A small part of the output (e.g. that made under the wage subsystem of the personnel system) is used at the ROD and the rest is sent by train to the head office in the form of magnetic tapes. Part of the report collected at the head office is fed back to the ROD as required.

One or two computers, large or medium, are provided at each of the twenty-nine RODs and approximately 1000 men are engaged in maintaining these computer systems.

Control system of installations maintenance

The Shinkansen Management Information System (SMIS) controls the maintenance of installations on the Shinkansen. On other lines this system also controls materials such as rails and sleepers, the usable land, and track maintenance, including measuring track irregularities by auto-inspection car.

Kojo (Workshop) information control system (KICS)

Specially developed for the JNR workshops, this system files, car by car, all JNR vehicles, the data on troubles and repairs made, so that the workshop can find the car to be inspected, foresee what sort of repair it will undergo, and estimate the materials to be prepared for the repair. It also functions as part of the Resource Control and Statistic System for each shop.

Management information on railroad construction system (MIRCS)

This system enables the staff in charge of construction to find information on JNR installations designed in the past. It designs and draws automatically certain kinds of structure such as simplified bridges, and deals with the process control of the construction work. It also calculates the basic estimate for the cost of construction work, and enters acquirements and removals in the book of properties.

Reasons for Computerization in JNR

In 1965 the Japanese economy began its spectacular growth, and 10 years later, in 1975, it began to stabilize. During this first period (1955-1964) the computerization in JNR was prepared and some off-line batch systems firmly fixed. During the second period (1965-1975) urbanization progressed and the national standard of living rose. Passenger transport experienced a remarkable transformation, symbolized by the inauguration of the Shinkansen, all of whose seats require reservation. Such computer systems as MARS and COMTRAC were devised to meet the transport requirements of the decade.

Meanwhile, with the increasing social investments of the second period, many improvements were made on roads, ports and goods circulation systems. This called for transformation of freight services: faster through trains, punctual arrival of freight cars, containers, etc. To this end, computer systems such as FOCS, EPOCS, YACS, and FIS were developed and put to practical use.

During the second period, wages rose and job seekers had the advantage of employers in the labor market. The proposed upward revision of JNR fares and charges was not approved, with the result that the increased personnel expenses could not be covered by the revenues anticipated. Manpower saving became one of the most serious problems in every sphere of railway activity and, to solve the problem, computerization had to be promoted in haste.

Briefly, the tasks of computerization in JNR were two: modernization of services and saving of manpower.

Features of JNR Computer Systems

EXTENT

JNR ranks first or second in Japan as an intranational enterprise, not only by number of employees, assets, revenues, and expenditure, but also by geographical extent and JNR's computer systems extend nationwide. Of the 100 or so computers used in JNR, forty-two are operated on-line and cover the entire system.

Japanese telegram and telephone services are monopolized by law by a quasi-governmental organ, Nihon Telephone & Telegraph Corporation, whereas JNR is allowed to possess a nationwide network of transmission so far as it is used for its own purposes. JNR has, therefore, an advantage over other enterprises in a wider choice of data-transmitting lines and lower cost of transmission. JNR also has the Data Agent Control System (DACS), using the computer provided with the Operation System specially designed for transmitting general data, utilizing solely the JNR-owned transmission network.

INDEPENDENCE OF EACH SYSTEM

A large organization such as JNR must be divided into several suborganizations. The principle of this division is functional rather than regional, and computerization in JNR has therefore been effective only on this basis.

Computerization of one service inevitably affects that of others. In most cases, however, computerization was developed independently, division by division, each being completed without reference to the others, which prevented the rational integration of various systems into a data bank system. To counteract this deficiency, a Shinkansen Management Information System (SMIS) is envisaged, with the object of making the different systems work relatedly and comprehensively within the Shinkansen.

SAFETY CONSIDERATIONS

The services offered by JNR, especially train operation, must be carried out smoothly and without interruption. Stand-by machines and devices must therefore be duplicated or even tripled. Furthermore, a manual system is required in order to complement the automatic system in case it fails to function. The function of computers in train operation is not so much to cut costs as to perform what human brains, hands, and feet cannot do so well.

COMPUTERIZATION IN MANAGEMENT PLANNING

The IIASA Secretariat suggested that I report on the application of computers to planning and management in JNR. Application of computers to planning means using computers to enable the manager to make a higher category of decisions under what is called the Management Information System (MIS). But if this means, as in the "business games", that computers are used for proposing a production plan by commodities or a price policy for a specific market in order to make the largest possible profit, JNR would not be interested in it.

JNR, being a public corporation, is operated and managed on two incompatible principles: public and commercial. From the commercial point of view, there are comparatively well-fixed methods by which "profit" is measured, a key guide to business activities. There are no key criteria, however, by which JNR's public activities can be measured. To explain these two aspects of a public corporation, a socio-economic and juridical thesis could be necessary. Here, it may suffice to point out that the need has never yet been envisaged for computerizing even a yearly budget.

In revising fares and charges, several plans are usually drawn up and computers are used to prepare financial statements resulting from each of these plans. This is one of the few cases where computers are used in planning.

Leaving aside management, and thinking only of operational planning, two systems are of the greatest importance to JNR: COMTRAC, which is at present used to propose an optimum diagram when train operations are out of order, and SMIS which prepares a daily utilization plan for railway vehicles.

Future Problems of Information Systems

Since 1975, when the Japanese National economy ceased its spectacular growth and entered a period of stagnation likely to last a long time, JNR itself encountered financial difficulties, and is facing the following problems in information systems:

> The present system must be completed and improved. Computerization in JNR has been carried out starting from the "services easiest to computerize". In other words, commencing with the services where manpower saving was expected, computerization has been pushed forward in a conventional way, often compromising with refusals made by the labor unions. Consequently, the system thus computerized have some deficiences, which are, however, repairable. One of the biggest deficiencies is in the area between the field organs, where books/tables are originally filled in, and the railway operating divisions. Data are carried by train from the former to the latter. These off-line systems must be made on-line in order to get rid of those books and tables still used at the field organs. The saving of manpower here is long overdue.
>
> As mentioned above, nearly every JNR computer system was developed independently and departmentally, and sometimes the same input and output are duplicated and the same data filed in triplicate. The systems must be interconnected, taking into account the interrelationships, for example, between COMTRAC/MARS, EPOCS/FIS, and MIRCS/ Finance & Accounting (Assets) subsystem, in addition to the function and efficiency of each system. It must also be made possible to connect JNR information systems with those outside.

To meet these requirements, the data-processing section and some systems construction sections, each belonging to different departments, were merged in 1975 into the Information Systems Department, which is now working on a long-term plan to establish a comprehensive data-base system of two stages, central and local.

Finally, since the data related to JNR are processed by the computers of governmental agencies and industries, JNR intends to connect its own computer systems effectively with these computers, securing harmony between the public importance of information and the security of industrial secrecy, so that such information may be used more extensively and efficiently as Japanese social assets.

38. *Discussion*

The first part of the discussion centered on problems of maintenance and renewal of track and vehicle facilities.

It was suggested that the maintenance problem could perhaps be attributed to the distance between stations on the Shinkansen lines, 50-70 km, and the fact that there are no track connections outside the station areas. If one of the double tracks requires maintenance work, the entire track must be closed. In the Federal Republic of Germany, for example, siding tracks are placed approximately every 20 km between stations on the high-speed lines. In addition to the siding tracks, connections are also employed which give an average distance of unconnected rail of only 7 km. This allows necessary maintenance work to be undertaken over increments of the 7-km distance; and with the side tracks in both directions is possible. It was suggested that JNR might examine such a system for the Shinkansen lines.

In reply, it was explained that the basic maintenance policy of JNR on the Shinkansen lines is that maintenance work is undertaken only at night when the Shinkansen trains are not running. Part of the reason for this is worker safety. It was considered dangerous for workers to perform maintenance work on one track when a train is passing at 200 km/h on the other. Another reason for night-time maintenance work was the daily number of trains running on the Shinkansen lines — as many as 275 trains between 6 a.m. and midnight. It would be impossible to redirect the trains, even in a section as short as 7 km. It is, however, planned to introduce a night train in the Sanyo section, and in some parts of the Tokaido section, in which case, a siding system could be introduced since only six or seven trains would be operating. One-track operation would then become feasible.

It was mentioned that maintenance work on the conventional narrow-gauge lines of JNR is operated on the system described in the first part of the discussion.

The computer-activated control system was discussed.

Since the main reasons for introducing the Automatic Control System were safety and the high frequency of operation, it was asked whether the introduction of this system also contributed to a reduction in labor force for dispatching. Comments on the modification of timetables were also requested.

In reply to the first question, it was stated that the introduction of a computer system had been accompanied by an extensive cost/benefit analysis. Since research and implementation of a computer system represents great expenditure, a strict cost/benefit analysis would not show any comparative advantage. The important objective was not to reduce the number of employees involved in dispatching, but to ensure that additional employees would not be needed and thus avoid organizational problems.

It was emphasized that human beings are not infallible. With the increasing complexity of Shinkansen operations, a system was necessary which could continuously monitor all aspects of train operations and give sufficient warning to the dispatchers of any abnormality. For example, if a train is delayed for more than 4 minutes, the computer gives an alarm in the form of a character display. The dispatcher simply monitors the display and gives permission to proceed or hold. This particular alarm is not of great importance, and it occurs in about 50% of train operations. There are about forty different types of alarm, such as train delay, track maintenance, missed signals, etc. If the alarm is significant, i.e. if a train is significantly delayed, the computer will make suggestions to the dispatcher to change operations to another form. In this situation, the dispatcher gives an OK or WAIT. If the dispatcher gives the WAIT signal he changes from the character display to a graphic display and begins to simulate possible decisions. If the dispatcher finds the optimal solution with the aid of the computer, he give the OK signal, and operations proceed under the new plan. However, in rare cases there is a very significant train delay or problem. In such circumstances, the computer gives up the operational control and the dispatchers must give every instruction to the computer. That is why it is necessary to have a sufficient number of dispatchers on duty at all times of train operation. In a normal day, the dispatchers have very little to do, but in an emergency, they are very busy. It is therefore difficult to calculate the correct number of dispatchers after the introduction of the computer system. Although such a system is very useful to the dispatchers, computers cannot do everything.

There was a discussion on the maintenance and standards of fixed facilities.

To the question whether JNR had experienced corrugation of the rails, the reply was that a limited amount of corrugation was experienced, and that it must be eliminated not only for safety but also for noise control. The usual counter-measure was to use hand and machine grinders.

In reply to a question, it was stated that the life expectancy of 60-kg rails now being used was 10 to 15 years.

It was mentioned that in North America, the construction standards for vehicles provide that a vehicle must be able to withstand a buff load on the longitudinal members of approximately 400 tons, and in Europe the standard is 200 tons. The construction standard for Shinkansen vehicles was given as 100 tons.

Train-delay statistics were discussed. In 1970 there were only 2 days when a delay of more than 30 minutes occurred. In 1975 there were 16 days, and in 1976, 44 days with a delay of more than 30 minutes.

Some additional questions were asked about Automatic Train Control. JNR is currently testing the use of on-board minicomputers on new trains, but the cost effectiveness of such a system is questionable. JNR cannot reduce the numbers of drivers (two motormen), partly owing to the reaction of passengers. It has also been recommended by a human physics institute that if the driver is not given specific duties, he will not be able to function efficiently in an emergency.

It was asked how much of the approximately 19 million dollars cost of the

OR system in JNR was spent specifically on hardware. The reply was that hardware accounts for 35-40% of total investments. For the MARS system, however, the hardware accounted for the greatest share since so many terminals were necessary.

In reply to a question on the design of the computer systems in operation in JNR, it was stated that JNR had developed the systems now in operation. The MARS system, for example, was constructed by JNR personnel over a period of 13 or 14 years. Until the early 1970s, JNR had the most advanced technology in the field of computers in Japan, the result of JNR's efforts in the design and manufacture of systems. In the last 5 or 6 years, however, computer technology in Japanese private industries had made great advances and JNR was taking advantage of the technology becoming available from private sources.

A question of general interest was raised concerning an opinion from the JNR delegates on the contribution of the computing system to the success of the whole Shinkansen. The general answer was that JNR views computer operations as complementary to human abilities. The system should be able to function without computers. There are basically two types of activity that enable the Shinkansen lines to operate successfully: the train-operation control system, and the sale of tickets and other passenger services. For the first, computer systems are not essential — it is possible to run the Shinkansen without computers. It would, however, be almost impossible to operate the second without computers. The tickets could simply not be sold fast enough during the time the train was in the station. Before the introduction of the MARS system, long lines of ticket purchasers were formed. The Shinkansen could not handle the tremendous volume of traffic experienced today, and it would not be able to handle ticket purchases efficiently without computers.

An opinion was given that it would also be difficult to operate all of the present Shinkansen lines without the aid of computers. The Tokaido Shinkansen could be operated without computers, but the extension of the line and the extra tunnels have increased. The original Tokaido line employed only two types of train and two types of stopping station, but after the Sanyo section was opened, the stopping station was different for each train. Control of such a complicated system would now be extremely difficult without the aid of computers.

The proposed linkup of the JNR MARS system with the Japan Travel Bureau was enlarged upon. JNR plans to link the MARS system with the reservation system of three travel bureaus in Japan, the largest being the Japan Travel Bureau. JNR has organized a data committee to combine the files. When this link up has been completed, it will be possible for JNR to search the files of the travel agents for airline seats, hotel rooms, rental cars, etc., and the travel bureaus will be able to reserve train seats. For connection to the files a special relay computer must be used in front of MARS 105 for connection with JTB's TRIP system and vice versa. The two systems are quite different as they use different hardware. JTB uses IBM computers and JNR a different type, so the work is complex.

The remaining discussion covered a number of other major topics. It was asked whether JNR must apply to a special Federal agency for certification of systems used. The reply was that JNR is authorized to give certification. It has its own rules, construction criteria, and testing procedures. The private railways, however, are tightly controlled by the Ministry of Transport. In principle, JNR has no special division for certification, but has a team to test equipment, as well as an operational control division, attached to the buying department, which decides on the standards for inspection, tracks, materials, and electrical equipment.

Fire precautions on JNR trains were discussed. In 1972 a bad accident occurred in a tunnel 13 km long, and about thirty passengers were killed in a fire on the train. A special research group was then formed to study fires on trains in long tunnels. Through the efforts of this group, many parts with a tendency towards flammability have been eliminated, old cars have been phased out, and special fire-extinguishing systems have been installed in each car. The Ministry of Transport also requested a report from JNR on the measures taken to decrease the risks of fire. These measures were all accomplished in 1972.

The comment was made that speeds were reduced during high winds, during heavy snowfall, and sometimes after earthquakes. During poor visibility, however, there was no speed reduction. The trains take at least 3 km to stop so sight is not a factor in train security.

It was asked whether JNR was satisfied with the present system, or whether they planned to make any changes in the way of improvement. The reply was that JNR is continuously improving the Shinkansen system, and there are still many areas for improvement. JNR set a standard of reliability of design on the original Shinkansen, and the results obtained have been better than originally expected.

A question was raised concerning documentation: for example, if a man who designs a system or a program retires, a new man has to use a program he is not familiar with. It was asked what JNR was doing in this field of railroad documentation. The reply was that JNR needs documentation to make up for the increasing number of experienced people who are leaving. The JNR information system established in 1975 requires each system-constructing person to supply enough documentation on his way of thinking for a new employee to be able to follow and use the system. In spite of short experience in this field, JNR has accumulated voluminous papers on many subjects, such as the use of computers, maintenance, etc. JNR has found it extremely important to document the experience of seasoned engineers.

The final question concerned the development of automatic control in station yards. The reply was that JNR has four major yards either under construction or completed. Most of them are hump yards under a computer-control system called YAKS. Linear motors were introduced into one of the yards and gave some difficulty until the design of the motors was improved. In general, automation of yards is very expensive.

Final Remarks

39. *Final Remarks*

K. MIYASAWA

When the Japan Committee for IIASA accepted IIASA's proposal to hold the Shinkansen Conference, we felt that we ought to do our best to contribute to IIASA's efforts in international research. Professor Knop, the former leader of the Management and Technology Area, was instrumental in convincing us of the appropriateness of the Shinkansen project as an object of study for IIASA. Professor Straszak has also made a great contribution towards the realization of this Conference. During the preparations, we maintained close contact Professor Straszak. I would like to thank him for his very valuable and energetic support, and at the same time to express my sincere thanks to all the participants in the Conference for their kind cooperation and valuable comments.

A. STRASZAK

This Conference represents the first stage of our three-step research format. The first is, of course, the Conference; the second stage is a field study; and the third stage is the preparation and distribution of the formal study report by IIASA. We are therefore at the beginning of our research process.

I would like to add that my conclusions from the Conference are that transportation problems are still as crucial, if not more so, than they were 5 or 10 years ago. The Shinkansen is a good example of modern transportation considerations, and may prove beneficial to other countries in the near future, 10 or 20 years ahead.

This IIASA Shinkansen Conference has provided a unique opportunity for interaction between experts and scientists from both East and West, between systems analysts and economists involved in studying national and regional problems, and between railway and transportation experts of several countries and continents.

Transportation problems are very broad indeed and urgently need international applied systems analysis. These problems require analysis from many points of view — energy, environment, land use, population, human settlements, management, profitability, socio-economic impacts, optimization studies of different transportation modes, etc. What all this implies is that the international dimension of fundamental research on transportation systems represents an area of increasing importance in the study of modern transportation systems.

It has been mentioned several time that this Conference is unique. This uniqueness stems from the international mix of delegates and the wide variety of disciplines represented. We have discussed a new approach to rail transportation by examining all its aspects and effects. Altogether, the Conference has shown that transportation systems can be an object of future research here at IIASA. It has shown that transportation systems of the future will not only be regional, but also national and international; and Europe could be considered an example of where such a view could be applied. Highway systems in Europe are already reflecting this trend; they are becoming more international and within the next decade could well be serving the entire European continent.

Perhaps this Conference will lead to a future IIASA research task on integrated transport program development. The Shinkansen Conference has shown us an extreme case of transport utilization that may in the future be heavily copied by other nations. It is my opinion that such a possibility warrants research on an international basis, such as that being done here at IIASA.

I want to thank all of the delegates at this Conference for enabling us to examine the Shinkansen in the light of its systems — looking at the Shinkansen not simply as a railroad but as a total system of technological application and utilization — and for letting us see how the implementation of this system has influenced the regional and national development of Japan. Naturally, this Conference would not have been possible without the work of our Japanese colleagues. They deserve special thanks, not only for their excellent presentations, but also for the success of the Shinkansen system. In the name of IIASA and the Conference delegates, I congratulate them on their success, and thank all the delegates for their efforts on behalf of IIASA and the Management and Technology Area.

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THE SHINKANSEN HIGH-SPEED RAIL NETWORK OF JAPAN
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A. Straszak and R. Tuch, Editors

The Shinkansen is the peak of railway technology. Before it went into operation in 1964, the top speed of any train in the world was 160 km/hr, test trains running at higher speeds had melted the overhead high-tension wire. It was also generally believed that trains running at 200 km/hr would require too much maintenance and do too much damage to the roadbed to be feasible.

The Shinkansen now travels the 550 km between Tokyo and Osaka 275 times every day at a speed of 210 km/hr. Such a revolution in transportation technology requires very special organization and is bound to have unexpected socioeconomic effects. It will, of course, share organizational aspects of other ambitious projects. For these reasons, the Shinkansen, along with the Tennessee Valley Authority and the Bratsk-Ilimsk Territorial Production Complex, was chosen by the Management and Technology Area of the International Institute for Applied Systems Analysis to be studied as a fine example of a large-scale organization.

The IIASA study of the Shinkansen began with a conference in 1977. Officials from the Japanese National Railways were invited to describe the development of the Shinkansen, scientists who had studied its effects presented their findings, and members of the IIASA research team outlined the approach that they would use in their study of the Shinkansen. Their papers are collected in this volume.

The Shinkansen has had a large effect on migration patterns in Japan because it has so drastically reduced the time it takes to travel from city to city. It has also affected the lives of people who may not even use it. Stores in small communities can now offer produce that was too hard for them to obtain before the Shinkansen was built. But travel at such high speed creates a great deal of noise, and special care must be taken to keep the tracks clear; at 210 km/hr, a train needs 3 km to stop in an emergency.

Thus, after an introductory section describing the history and outlining the plans for the Shinkansen, Sections 2 and 3 deal with the socioeconomic and environmental effects of the Shinkansen. Section 4 describes the influence the Shinkansen has had on national development. The last two sections deal with the organization of the Shinkansen itself. Section 5 describes the planning and administration of the Shinkansen by the Japanese National Railways, and Section 6 covers the physical requirements of high-speed train operation: the maintenance network and maintenance schedule, vehicle design, accident prevention, the seat reservation system, and other aspects of running a high-speed railroad from day to day.

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