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PLANNING FOR PLANNING--COAL: ISSUES FOR THE EIGHTIES

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PREFACE

This collaborative paper is based on a meeting held at IIASA in November 1980. The meeting was part of a sequence of discussions arranged by IIASA in conjunction with the Polish Academy of Sciences and the Polish Mining Industry. A previous meeting had been held at Szczyrk, Poland in November 1979, and the proceedings are available as IIASA Working/Collaborative Papers, WP-80-140, CP-80-23, and CP-80-24. These coal industry meetings were part of a research program at IIASA under the generic title "Issues for the Eighties" in which systems analysts and managers from a given industry met to exchange ideas and information, as well as to explore and develop a strategy of using systems analysis, rather than using it merely as a tool to be brought in for certain well-defined problems.

The subject 'Planning for Planning' was used as a shorthand to explore the use of systems analysis in the planning of new capacity for deep mining in hard coal. The discussions were attended by 17 representatives for 7 countries, and 13 papers were presented or tabled at the meeting. These are reproduced separately as IIASA Collaborative Paper CP-82-80.

This paper, which summarizes the discussion, structures the planning process and discusses the place of systems analysis within it. It also presents a state-of-the-art account of the uses of systems analysis for major investment planning in the coal industry, and indicates areas for future research. The summaries have been prepared in conjunction with Bill Hancock and Mike Sadnicki of the Operational Research Executive, National Coal Board, UK.

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Management and Technology Area
(1977-1980)

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<u>NB</u>: References without a preceding letter, e.g., [2] refer to a paper given at the Task Force Meeting and are listed at the end of the paper. References with preceding letters, e.g., (B3, D5, etc.) are given at the end of that respective chapter.

CHAPTER I--INTRODUCTION

This is a paper about planning in the coal industry. Planning is a word which may be given a variety of interpretations--even within a single culture. It may refer to the detailed analysis of an investment proposal, an operating plan for a colliery, a financial plan or budget for a group of collieries, or a grand strategy for the determination of overall policy. Planning is both a routine activity--undertaken according to predetermined rules and time schedules--and a discretionary activity, relying on the intuition and acquired skill of the expert. All but the most elementary organizational activities have to be planned--for the coordination of individual effort, the making available of necessary resources, the identification of a common aim--all of them necessary for a successful and economic outcome--have to be thought of ahead, assumptions analyzed, schedules prepared, checks on progress set down, experts coordinated. In fact, the planning of any major project or enterprise is itself an extremely complex progress which, by definition, requires planning, i.e., the planning must itself be planned. Hence our title.

More particularly still, this is a paper about the use of systems analysis in planning. Systems analysis is a way of studying complex situations, which is interdisciplinary, applied and integrative. It sets out to define aims, evaluate alternatives, explore relationships. It is thus hardly surprising that it appears as a adjunct to planning more often than almost any other human activity. Indeed, in the coal industry, systems analysis is used in almost every aspect of planning--as this paper will reveal. But the main thesis of this paper, based on experience, is that the relationship between systems analysis and planning must go deeper than this. If planning must be planned, then systems analysis has a major part to play in that planning. Furthermore the use of systems analysis--a complex human activity--needs to be planned as part of the planning for planning. These statements are not, of course, true only for the coal industry they apply to all industries which engage in extensive planning. Indeed IIASA has already done work to show the value of the concept in the forest and forest products industry, and others could be cited. The lessons set out here are widely applicable.

The particular aspect of coal industry planning that we cover in this paper is the planning of new deep mine capacity for coal production. The paper is, in part, a statement of the state of the art so far as the use of systems analysis and operational research in the deep coal mining industry is concerned. As importantly, however, it structures the overall problem and points the way ahead as a guide for the future.

The concept of forward planning is not one that has recently been imposed on the industry--it has long been deeply embedded in the thinking of the coal mining industry. For this, there is one over-riding reason--that it is an extractive industry. It is not possible to continue producing the same product from the same place with the same machines, year in--year out. Once coal is extracted, it is gone. Every successive day one is mining a different piece of coal with slightly different characteristics from what went before. In three months time, the coal face may have hit a fault or the thickness of the seam halved and all continuity lost. Because of geological problems, the future is always uncertain, and one must lay plans accordingly. Every colliery has both operating plans and its development plans; every group of collieries has long term plans based on estimates of the market, finance and resource availability, technological development. The industry is full of planners, and has great need of them. And *their* work needs to be planned.

Operational Research and Applied Systems Analysis are perhaps more widely used in the coal industry than any other industry. 'OR Comes of Age' which traces the history of OR in the early days of the UK National Coal Board, shows how early and extensively these approaches were applied in the industry. Other national industries did not lag far behind in their use of these modern aids. And yet their use has not been, in general, the result of planning. We believe that this is wrong--for a number of reasons.

In the first place, there is the question of time. Effective systems analysis takes time--as any analytical and investigatory process does. If the study requires the development of a computer system for routine application even more time is required. The secret of successful applied systems analysis certainly includes the art of anticipation.

Secondly, one must set priorities. There are a great number of possible applications of systems analysis to mine planning--and even the considerable body of systems analysts represented at the meeting on which this paper is based have not solved them all. Priorities have to be allocated. It is not simply that some applications are more important than others, but that there is a natural sequence in which the applications can be incorporated into the overall planning process.

Above all, there is the fundamental need to examine the planning process itself in the light of systems analysis. Planning is a lengthy, expensive, complex system which should be analyzed as a whole. By definition that must be the subject for systems analysis. But it has to be done at the outset.

These statements should not, of course, be taken to imply that the process of planning has not been the subject of systematic thought. It clearly has--particularly in countries such as Poland, where the industry has been steadily expanding for many years and new colliery design has been a continuing activity, so that a continuous learning process has taken place. Nevertheless, there does not exist in the literature an adequate overview of the planning process as a whole, from the systems point of view. There is little doubt that when this is done, it will be possible to improve our planning design and understand better the part that systems analysis can play. In view of the major part already being played by several hundred operational research workers and systems analysts dedicated to the industry, there is little doubt that the skill, knowledge and experience is available to make this further step forward.

It is this belief and concern that led to the organization of the meeting whose discussion is summarized in this paper. It was, first and foremost, primarily a meeting of industry experts and of people who would directly benefit from any improved understanding and information that resulted from the discussion. They were concerned with finding out what other experts had done in tackling the same problems as themselves, and in particular whether they had successfully worked in problem areas which they had not attempted. There has not been heretofore a meeting place for these experts to meet and discuss their work in depth. The existing literature in the field is limited, in many languages, and seldom discusses the issues of real importance. In particular, it is often hard to identify whether a method described in a paper is really in regular use and--if so--what are the difficulties that have been overcome and how. Even in face to face discussion between people with different cultures and linguistic backgrounds, the underlying facts are hard to determine. Given the will it *is* possible in a concentrated session of this kind. All the analysts concerned agreed that their time was well spent.

Having achieved this primary aim--whose success can be asserted by those who attended, but can seldom be set out in financial terms--the meeting had a second task. It was to try and describe the state of the art so as to assist both planners and systems analysts to determine more comprehensively how systems analysis can assist the planner in his work, and the methods that may be used. That is what the paper attempts to do.

The first step has been to structure the problem as a whole, and in this report largely follows the structure of the meeting itself, described in Appendix A. The next three chapters, therefore, deal in turn with reserves assessment, the evaluation of mining layouts, the comparison of alternative technologies. In each case we have taken the discussion at the meeting as the basis for describing the state of the art, and indicating possible future directions. We have not attempted to summarize, e.g., all the computer programs available to tackle certain problems. There may be room for such a publication, but we have not attempted it here. Most of those at the meeting have already developed, or will certainly do so, their own standard computer programs to meet their specific requirements. The problems are in specification and in use, not in programming.

The purpose of these sessions, as of this report, was to identify the methods used to approach these problems, and reasons for their differences and similarities, and the factors affecting genuine achievement. Perhaps, more importantly still, the meeting served to identify new areas of research in fresh fields where the systems analyst has yet to make a full contribution but where we believe the potential is there to do so.

Reference should be made here, as an aside, to the question of manpower, supply and requirements. A sessions was devoted to this at the meeting, but there were no formal presentations and it became clear that relatively little analysis was being undertaken with manpower as the prime focus. What discussion there was has therefore been inserted as appropriate in the other chapters. Nevertheless, the problem is crucial. Although the dream of manless-mining persists--we are still very far from its achievement. For the time being, successful mining will depend on the availability of enough men with the right skills. We need to be able to forecast both, and analytical work here will become increasingly necessary.

After our first three sections, dealing with separate aspects of the whole problems, we come to the question of integrating the separate elements. We consider this in two parts. The first continues to concentrate on the mining activity as such, but pulls together the various parts so as to start answering such questions as: What is the best way to work the deposit? What is the optimal productive rate? Where do we locate the shafts? We need to think about the interrelationships of elements in the planning process but we also have to take account of uncertainty. The besetting sin of planners is to assume that the future is fixed. In coal mining terms, that implies that we know the future demand for coal (in terms of quantity, quality and price), as well as the geological conditions to be encountered in its extraction. The simple fact is that these things are not known with certainty. Even in national economies where demand runs ahead of supply, certain aspects of the market--particularly the future quality requirements of new utilization technologies--are unknown. Certainly geological difficulties do not respect cultural or political boundaries. The integration of systems work in this field remains a major challenge. This discussion is dealt with in Chapter V.

Moreover, we cannot simply talk in terms of economic mining solutions. Chapter VI deals with environmental factors, which now make a major impact in all countries, although the way in which an impact occurs depends on local administrative structures. No industry can ignore these factors, and the integrating power of systems analysis is being increasingly recognized in this field. Work of this kind relates the coal industry studies more broadly to studies by other specialists, e.g., socio-economic regional studies. So the systems analyst within the coal industry cannot be too narrow a specialist.

The chapter on environmental factors concludes the report on the discussions undertaken at the IIASA meeting. We conclude in Chapter VII with a coda, which draws together the conclusions from the individual chapters. Finally, Appendix A sets out the Agenda for the meeting, Appendix B the names of those attending; and the References and List of Papers Presented are reproduced separately as IIASA Collaborative Paper CP-82-80.

A number of references are made to the proceedings of the 17th International Conference on the Applications of Computers and Operational Research in Mining (APCOM 17). This meeting was cancelled at the last moment but we have had access to the pre-prints of papers prepared for that meeting.

This Introduction must end with a disclaimer and a warning. This paper represents to the best of our ability the present and prospective use of systems analysis as an aid to the planning of new capacity in deep coal mines. It is based on a knowledge of the literature, on presentations at the meeting, and on discussions. However, it has not been possible to examine every case referred to in detail, nor to confirm the degree of implementation actually achieved in any particular case. Moreover, it must necessarily be a partial picture, since many of those undertaking such work in different countries were neither present nor represented. In particular, when views are summarized in terms of 'In the USA...' it should be realized that this only expresses the understanding of those present at the meeting. It was a meeting of experts conducting a scientific exchange of ideas, not a meeting of official delegations. However, although this limitation will inevitably lead to some partial truths, we do not think that there is serious distortion in the general picture.

CHAPTER II--RESERVES ASSESSMENT

1. INTRODUCTION

The quantity, quality, disposition and geological characteristics of coal reserves are the first factors to be considered in evaluating a new mine or major mining extension. Exploration practice for deep mine coal reserves does not differ markedly from country to country and typically follows the following sequence:

(a) A few widely-spaced boreholes are sunk merely to identify the presence or absence of coal.

(b) If encouraging, more boreholes are sunk enabling tentative estimates to be made of the size and quality of reserves.

(c) Later, seismic methods may be used, supplemented by a still greater intensity of boreholes to establish whether the coal seams are sufficiently undisturbed for the required levels of productivity.

The information provided, together with information from neighboring collieries (if any) is all that can be used in assessing the feasibility of a new mine or major colliery extension: it provides the foundation for all that follows in new capacity planning. Nevertheless, as exploration is expensive the manager, planner, geologist, and systems analyst have to work with information that is far from complete.

This chapter describes the contribution that has been made by the systems analyst and outlines those areas where systems analysis has yet to make a full, or at least consistent, contribution. It is comprised of three sections, namely:

(i) the estimation from given exploration,

(ii) the design of exploration strategies, and

(iii) the calculation of reserves.

It should be emphasized that the chapter refers only to work done for deep mine coal reserves. Much valuable research has been undertaken in this field for opencast mining, but this is not directly transferable largely because of the huge differences in borehole density, which follows to some extent because of the relatively high costs of the deep boreholes.

2. THE ESTIMATION FROM GIVEN EXPLORATION

The use of systems analysis to help estimate the characteristics of the coal seam from the results of exploration is universal and uncontroversial. These achievements are, however, more marked in the case of the continuous properties of coal (such as thickness, depth, ash, sulfur, and chlorine) than with the discontinuous properties (primarily geological hazards such as faulting or washouts). This may be because the methodology required is lagging behind that developed for examining continuous properties, but more importantly because the sparsity of the information available before a mine is developed is more disadvantageous to an examination of discontinuities.

Several examples of the contribution made by systems analysis in estimating the continuous properties of coal were described at the meeting. While precise methods varied from country to country, it was evident that a good database of reserves information should be established so that speedy assessments can be made not only of the reserves themselves but of the impact of any mining plan. Two examples, from Poland and the UK, illustrate this approach.

In Poland, computer programs [5] have been developed which enable estimates to be made of coal reserves at optional depth intervals. The model itself contains details of depth, seam thickness and up to ten further parameters of interest (such as ash, sulfur, or calorific value). The programs are used to provide the initial link between reserves assessment and mining plan by dividing the reserves into coal mining areas, calculating the depth of mine horizons and indicating the preferred location of shafts. These programs have been successfully used several times, including for the major development in the Lublin Coal Basin.

Similarly, the UK have developed a computer system, GEOPLAN [8] which uses borehole information to produce summaries of the geological distribution of reserves on a square grid basis. The database of borehole information contains such details as coal section, dirt section and average percentage ash, sulfur and Chlorine and GEOPLAN system can be used to examine any of these, under different constraints. An example might be to examine the geographic distribution of reserves subject to a limit of 15% ash in the worked section. A feature of the system is the use of dummy boreholes when a geologist may correct the database to his own interpretation when borehole interpolation is thought misleading.

Like the Polish programs, GEOPLAN not only summarizes the reserves distribution, but also assesses the broad consequences of a mining strategy given this reserves distribution.

In constructing any database of reserves information the practitioners of the countries present at the meeting all tend to use methods of interpolation that are simple in concept. These include assessing linear change between boreholes (USSR, Poland), polygon methods (US, though occasionally geostatistical methods) and averaging from the three nearest boreholes using weights inversely related to their squared distance (UK). The evidence as to the value more sophisticated models of seam behavior in the assessment of deep mine coal reserves appears to be conflicting. For example, nobody present at the task force meeting had achieved success in the application of geostatistics, although several had tried. In particular, doubts were cast on the validity of the semi-variograms, given the paucity of data available. Nevertheless, there are some technical papers in the literature which support the use of geostatistics for deep coal assessment (A1, A2), so doubtless the matter will remain a subject for debate for some time to come. Fundamentally, however, the meeting concluded that the choice of methods of interpolation, in the context of new deep-mine planning, may not be crucial; what is important is to establish a convenient, acceptable and sufficiently reliable database of reserves information which is easily updated as more information becomes available and which relates reserves to subsequent mining activity.

It was mentioned earlier that although systems analysis has been widely involved in the field of estimating continuous properties of coal, the same cannot be said when it comes to dealing with discontinuous properties. One example of how systems analysis might contribute was provided at the task force meeting by the Federal Republic of Germany [1], (A3). For the Ruhr coalfield, a method has been devised for expressing in quantitative terms the likely reserves that will ultimately be extracted after relaxations have been made to insitu reserves according to various historically derived relationships. Amongst other things, these relationships allow for the degree of uncertainty about the geological structure of the area in questions, the anticipated fault intensity and the planned worked section of the seam in question. The method has been widely used in Ruhrkohle for long term planning, to advise on the relative attractiveness of different areas of coal, including advice on which areas of take to leave untouched.

3. DESIGN OF EXPLORATION

There are two major problems to be overcome by the systems analyst seeking to advise on the design of exploration, whether concerned with the continuous or the discontinuous properties of coal reserves. The first of these is to estimate (a) the increase in knowledge about these properties that is made possible by further exploration, and (b) to estimate the value of such increased knowledge. It appears that systems analysis has some way to go in this field and there is little evidence of a major contribution from systems analysis to exploration design.

This is particularly true of continuous properties. Little work was in evidence on such problems as borehole spacing, which appeared to vary from country to country because of historic custom and practice rather than for good scientific or statistical reasons. The lack of influence of systems analysis is probably explained by the absence of satisfactory methods of the required statistical sophistication for the necessary evaluation of risks and probabilities. The simple methods more generally used for reserves assessment are insufficient in this field. Geostatistics is certainly sophisticated enough but, as mentioned previously, its validity is not universally accepted.

With discontinuities, there is a little more evidence of a contribution from systems analysis--if not an exploration design, at least in advising on the value of exploration. One example [8], (A4) concerns the use of operational gaming to assess the benefits of surface seismic exploration. In simple terms, the approach is to test the consequences on a mining plan of the likely knowledge of the position of major faults that would be provided by seismic exploration, and to see whether the differences are significant enough to make expenditure on seismic exploration worthwhile. Decision analysis has been used to assess the benefits of in-seam seismology, based on a probability tree which describes outcomes with and without the survey.

4. THE CALCULATION OF RESERVES

Section 2 of this chapter outlines the substantial role played by systems analysis in estimating properties of the reserves from a given exploration. Much of this work, of course, applies directly to the final calculation of reserves when the surface exploration program is complete. It would, however, be wrong to assess reserves purely in the geological sense without relating them to other factors. In order to fully assess reserves it is necessary to take account of such factors as:

(a) economic assumptions (on the value of coal and its alternatives),

(b) mining technology (what extraction techniques are or will be possible?),

(c) quality (will constraints change?), and

(d) environmental issues (subsidence effects, pillars, necessary, changes to attitude or legislation).

There is wide literature (e.g., A5) describing assessments of this type on a national or international level, but for an individual mine more specific knowledge of the coal deposit is required to evaluate the effects of these four factors.

Clearly, this indicates the close connection with other topics discussed at the task force meeting, but it also demonstrates the true worth of the work described earlier. For the strength of the computer, as outlined in Section 3, is that once data banks are established, they can be updated as economic, technical, or marketing assumptions change. While it would be wrong to suggest that further research is not needed, systems analysts are developing models which demonstrate how estimates of reserves change with a continuously changing economic and technical climate.

5. SUMMARY AND CONCLUSIONS

1. Systems analysis has contributed significantly in the field of reserves assessment, largely through the development of computer systems which assess reserves linked to mining plans and relevant marketing and economic assumptions.

2. Work is not so advanced on the examination of the discontinuous properties of reserves as on the continuous properties.

3. A greater understanding of the knowledge provided by exploration and the value of such knowledge is necessary before systems analysis can contribute significantly in the field of exploration design.

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CHAPTER III--MINING METHODS: EVALUATION

1. INTRODUCTION

This chapter deals with the contribution of systems analysis in the analysis of the detailed planning sub-problems of mining method evaluation. These sub-problems arise whether or not location and size of mine(s) have been determined.

A wider range of OR systems applications has been reported in this field than in any other. Section 2 below lists some of these sub-problem areas and applications. Section 3 discusses the systems analysis techniques which have been used in such applications. Section 4 goes on to discuss the difficulties that have been encountered once attempts are made to link problem areas together.

2. PROBLEM AREAS

A large number of problem areas have been tackled. This emerged both from discussion and is also apparent from published literature such as the Summary of Papers of the 17th APCOM. The following list, which is not intended to be exhaustive, shows the range of problem areas where systems analysis techniques have been applied:

Face design--dimensions and/or equipment

Face design--working methods

Productivity forecasting--advance rates

Productivity forecasting--manpower requirements

Layout evaluation--the sequencing of faces in space and time

Coal clearance

Materials transport

Transport of men

Ventilation

Control of gas emission

Temperature control

Rock mechanics

Subsidence

Coal breaking characteristics

Accident prevention

Shaft design

Coal preparation.

It is in this sort of work where greatest and most consistent implementation success has been achieved. In some problem areas, e.g., coal clearance, ventilation, and coal preparation, it is almost standard throughout the world that mine planners and engineers use the models of the systems analyst, often now without his assistance. In other areas, e.g., face design, productivity forecasting, and layout evaluation, the systems analysis contribution is potentially as strong, although in the nature of things implementation cannot be so routine.

Two obvious, but nevertheless important, points were emphasized as being vital for implementation success. Firstly, from the earliest stages there must be close involvement of the potential user, the mine planner or engineer. Secondly, the amount of development effort necessary to achieve consistent implementation must not be underestimated.

The systems analysis techniques used are discussed in the next section. The discussion concentrates on one particular problem area, that of layout evaluation and the planning of the sequencing of faces in space and time. However, the discussion is relevant to all problem areas, and examples from others are used as appropriate.

3. SYSTEMS ANALYSIS TECHNIQUES USED

3.1 Descriptive Models

In these models (which are usually based on simple functional relationships) the emphasis is usually placed on communicability and the facility for easy and rapid evaluations with changing assumptions, so that the mine planner can explore the consequences of uncertainty. Examples relevant here are models of the production process aimed at improving the efficiency of longwall mining by increasing machine utilization coefficients (FRG--B1); models which allow the analysis of variation of production quantity (ash, chlorine, etc) for a given mine layout for up to 70 years future workings (UK Geoplan--[8]); and a model of subsidence arising from given mining layouts (Poland, B2).

3.2 Simulation Models

This is the most important technique by which the problem areas listed in Section 2 are investigated. A general survey of such applications in the USSR is given in [11, 12], while [5] gives a particularly detailed account of Polish experience. As more specific examples: simulation of longwall production, productivity and quality is described in for example, (B2, USSR); simulation of multiple seam mining for planning appropriate face sequences and mining geometry is described in (B4, Japan); simulation of coal clearance systems for planning underground bunker and belt capacities were described during Section 2 by Poland, the UK (Simbunk and Simbelt), and USSR; simulation of surface coal flows to determine required capacities of ROM bunkerage, coal preparation plant and rapid loading bunkerage is described in (B5, UK).

3.3 Operational Gaming--Hand Simulation

One method by which the purpose and implications of a simulation can be made particularly clear to the planner and engineer is by hand simulation, or operational gaming. There are very few examples of this technique in practice; perhaps the time taken to perform such simulations militates against them. The UK have developed one hand simulation methods, Geosimplan [8] which has been used repeatedly at existing collieries to analyze the robustness of layouts/mining strategies in the face of geological uncertainty, and also to analyze the value of information problem of the benefits of surface seismology.

3.4 Optimization

Of the main deep-mine coal producers, only USSR and Poland report substantial interest in optimization techniques (USSR [11, 12]; Poland [5, 7]. More detailed examples of approaches analyzing various aspects of mine layout planning in the USSR can be found for example in (B5, B7, B8). A detailed Polish study of optimum face and supply roadway configurations is shown in [4]. The FRG, USA and UK did not report use of optimization techniques in this field with the exception of regional production/market allocation models.

4. COMBINING PROBLEM AREAS

4.1 The Necessity to Combine

If two problem areas, or two segments, of a mine layout are modeled separately and decisions taken accordingly, there is no guarantee of total system optimality or even that the total solution is amongst the most robust. Poland noted that practical difficulties ensue through attempts to solve all problems separately: for example, the mechanization of developments and the automation of coal and man transport systems has lagged far behind face mechanization. There is full agreement that it is necessary to attempt to model combinations of problem areas.

4.2 Achievements of Systems Analysis

Simulation, so successful in investigating individual problem areas, has had mixed results once attempts are made to link sub-problem simulations. The Polish experience is that although simulation programs are used on quite a scale, it has not proved possible to develop a simulation program good enough for an entire layout. The USSR claims some success with simulation models combining more than one production process, e.g., coal mining and coal transport (e.g., B10, B11). The FRG reported some impressive papers covering some aspects of layout planning (references not given) at their last national meeting; however, overall attempts to obtain a total systems model have been a complete failure. The USA report technical success (B9); the Penn State University Simulation System can be used for total simulation of theoretically any underground mining system, although the model reflects the current USA bias towards room and pillar working. However, increased complexity has led to (a) problems with input data, and (b) problems of implementation--at the moment practical applications outside Universities are extremely rare.

Some of the optimization models of the USSR and Poland referenced in 3.4 above clearly imply a degree of total system modeling. However, it is also apparent from the Session discussion that this is at the expense of (a) the detail possible with models of individual problem areas; and (b) the communicability to mine planner and engineer which is the strong-point of descriptive and simulation modeling.

5. SUMMARY AND CONCLUSIONS

The relative failure of systems analysis to develop total system models does not imply that systems analysis should not be used to analze the total system. In fact the converse is the case, as is explored in Chapter 5.

1. Systems analysis has established a major contribution to many problem areas in mining method evaluation--from coal face design through all production processes to coal preparation. There have been a very wide number of applications, although of course the degree of implementation success in each particular problem area varies from country to country.

2. The techniques used vary by problem area, but descriptive modeling and simulation models have achieved most significant success, especially where emphasis is placed on simplicity and communicability.

3. The major research area for systems analysis now is in how to combine the models of individual sub-problems while maintaining the advantages of communicability.

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CHAPTER IV--COMPARISON OF ALTERNATIVE TECHNOLOGIES

(In particular NEW TECHNOLOGIES)

1. INTRODUCTION

All countries provided evidence of a strong role for systems analysis in technological assessment.

USSR : manless mining

Poland: new processes of technology and organization of longwall mining [4]

FRG : a new mining technology for steeply dipping faces; LHD equipment (C1)

UK : automated monitoring and control; underground gasification; face-end design; in-seam seismology [8]

CSSR : a new mining technology 'PEEM' (no reference)

USA : high speed tunneling; hish speed shaft sinking; hydraulic transport.

All of the studies fell into one of the following broad types, with some studies covering more than type:

(a) Assessing the new technology from an engineering/technological viewpoint

(b) Assessing how the new technology affects the existing mine operations

(c) Assessing the likely competitiveness of the new technology (if a substitute) or its benefits (if an augmentary technology)

(d) Given or assuming successful indications in 1.1, 1.2 and 1.3, assessing possible rates of introduction of the new technology.

How systems analysis can contribute in these four areas is reviewed in Sections 2-5 below.

2. ENGINEERING/TECHNOLOGICAL ASSESSMENT

At least three roles for systems analysis can be identified:

(a) Design of experiments

(b) Statistical assessment of test data

(c) Computer simulation of the proposed working system, to ensure that the logistics of performance are as intended.

Almost no examples of work in this sort of area were discussed. (Hopefully this could be because systems analysis is now so well established here that such contribution is no longer worthy of comment.) The FRG described one simulation of a possible new mining technology, composed of elements from existing technologies, for steeply dipping faces; the study had concentrated initially on whether the design was logistically sound.

3. SYSTEM COMPATIBILITY ASSESSMENT

This area is concerned with the compatibility of the new technology with the other mine operations with which the new process must be integrated. In this area, simulation is obviously an effective technique (although the problems of linking simulation sub-models, discussed in Chapter 3, must be borne in mind). Some of the simulation models of Poland and the USSR [5, 11, and 12] can clearly be used in this context, as could the US total mine simulation model of (C2). The UK described PREFECS, a detailed simulation model of cutting, loading and gate-end operations, which enables the mine engineer to select the best combination of available face and gate-end equipment for a given longwall face. Similarly the simulation of surface coal flows (C3, UK) has been used to assess the likely impact of new R.O.M. homogenization equipment on the capacities planned for the rest of the surface facilities.

Poland stressed strongly that in evaluating total system effects systems analysis should not be confined to the technological subsystem. The social and organizational subsystems must also be taken into account. Increasingly in the 80s, the effects of new technologies on these subsystems might be equally as important as the effects that can be studied by simulation. This field will be more closely analyzed at the next task force meeting in Katowice (1981). Preliminary work was reported, introducing a taxonomic method of classifying collieries into groups of similar economic, organizational and social characteristics [3].

4. ECONOMIC ASSESSMENT

4.1 Simulation

The FRG appeared to have most experience of attempts to use simulation for full economic assessment of a new technology. In addition to the model of the new mining technology for steeply dipping faces cited in Section 2 above, a model for analyzing the likely benefits of LHD equipment was described (C1). The investigation of the technology for steeply dipping faces had eventually proved that theoretically the new technology was at least equal to longwall mining in terms of economics. However, no practical application had ensued. One reason for this was that the simulation model had been inexorably drawn into increasingly minute technical questions, to the extent that the overall aim had become obscured. The FRG was of the opinion that for this and other reasons simulation is a very good tool to identify which technological lines *not* to follow, but less useful in quantifying the superiority of new technologies which should be taken up.

4.2 General Economic Appraisal

The US strongly believed that the systems analysis role is in total economic appraisal without detailed simulation. The UK supported this assessment role, citing for example a recent study of underground gasification (C4). The study involved economic comparison of extraction, conversion and utilization processes of the alternative technology with those of conventional technology, and concluded that the new technology would not be economically viable for some considerable time. Again, there was a feeling during the session discussion that it is easier to demonstrate objective and logical assessment when rejecting a possible new technology than when recommending it.

It emerged that there is a stronger role in economic assessment when the new technology is evolutionary rather than revolutionary, and when the problem area is relatively well defined. An example here is the UK study of the benefits of in-seam seismology in collieries with different operating conditions [8]; one of the objectives of the study is to define the operational characteristics that would be necessary for the new technology to show a benefit. A similar philosophy is shown by an FRG study (reference not given) of different tunneling methods in different rocks and the evaluation of the relative benefits of different possible marginal improvements to drilling technology.

4.3 The Problems of Uncertainty

A major reason for the relative failure of systems analysis observed in 4.1 and to some extent 4.2 is the problem of estimation of performance and other economic data. While one of the purposes of simulation may well be to attempt to reduce such uncertainty, the best source of key data is to consult experts, and to hope that a consensus view emerges. This is a hazardous process. If the experts differ too widely, then scenario analysis is possible; however, it becomes clearer why the formal techniques are more often trusted when rejecting new technologies.

5. GROWTH RATE ASSESSMENT

Looking 10-20 years ahead, revolutionary new processes will be necessary in the next phase of development of the mining industry. Whether engineering assessment, system compatibility assessment, and economic assessment is proved favorable or simply assumed to be favorable, there remains the separate problem of determining the likely rate of introduction of the new technology. Czechsolovakia is developing a dynamic simulation model of new technology introduction; the technology itself, PEEM is *assumed* to be technologically feasible and economically viable. At an even more general level, the approaches utilizing S-shaped development curves, popularized by Marchetti at IIASA, may be applicable. Such models apply simple commercial market-penetration models to systems where the 'market' is a less obviously defined consumer group, for example 'national primary fuel usage', or 'powered support usage'. The most urgent question here is whether it is possible to identify the potential winner while it is beginning to happen, so that further resources can be pushed into it. The session discussion was generally pessimistic that systems analysis can currently offer anything over and above the judgment of mining engineers. The Marchetti phenomenological approach is extremely useful in predicting the growth rate of a new technology once, say, 10% of the 'market' is achieved; however the growth curve is undefined at very low market shares, and the problem under discussion is exactly that of identifying which technologies are likely to cross the 10% point.

6. SUMMARY AND CONCLUSIONS

1. A strong well-established role for systems analysis in evaluating evolutionary changes to technological processes is identified. This contribution applies at all levels from engineering assessment, to system compatibility assessment through to economic assessment. A range of techniques are applicable, with simulation models being particularly appropriate.

2. For revolutionary technologies, the systems analysis contribution to date has been less clear cut. All techniques suffer because of the problems of uncertainty, and the amount of detail required for simulation models may obscure objectives. Because of these reasons, systems analysis is often more useful in rejecting new technological paths, rather than recommending them.

3. Systems analysis has not yet solved the problem of identifying potentially successful technologies at early stages. Consequently growth rate predictions are hazardous.

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CHAPTER V--FINDING THE BEST MINING SOLUTION

(Taking Uncertainty Into Account)

1. INTRODUCTION

This chapter pulls together the threads laid down in Chapters II, III, and IV. We have established how systems analysis can assist in: design of exploration and quantification of reserves; analysis of each problem area connected with designing a mine plan; analyzing the effects of new technologies. There still remains the overall problem: given a block of deep coal

-- What is the best way to mine it?

-- What is the optimal annual rate of production?

-- What is the best location of shafts/drifts(s) from the mining point of view?

Several countries have tackled this overall problem in depth: the approaches of four is documented in Section 2, together with implementation success. Difficulties encountered, and similarities and differences between the various approaches, are discussed in Section 3 under the headings Interrelationships; Uncertainty; and Decision Criteria and Elimination of Alternatives.

2. NATIONAL APPROACHES

2.1 FRG

The method for long term planning of production and utilization of production capacity has been developed at Ruhrkohle AG for 27 coal mines (D1). The comparison of mining alternatives is achieved using a standard method which takes into account: degree of exploration, tectonic conditions in the working seams; determination of face production capacities on the basis of regression analysis of data from current working panels; balancing production capacities from new panels with capacities of other sections of the production process; the determination of criteria for fixing appropriate face replacement; coal quality constraints; cost estimates.

The method has provided a sound basis for the analysis of the production activity of Ruhrkohle AG.

2.2 Poland

Poland have developed a large optimization system, MOBAR [7], which links together the best mining solution for a given block of reserves within the new prospect, through to optimization of the regional and the national mining plan. The MOBAR system places more emphasis on regional and national aspects than on the individual mine unit. To balance this, Poland has also developed an extremely detailed simulation model, SPP.1, which analyzes the costs and timing of any given new mine development alternative [6]. SPP.1 has been applied in the analysis of alternatives at 22 mines. The system is more frequently used to detect and overcome potential bottlenecks in the production process, or to analyze the possibilities of shortening the leadtimes in reaching target production. Economic comparison of alternatives is regarded as a secondary objective. The system has been compared with traditional planning methods by performing parallel planning exercises; use of SPP.1 achieved significant reductions in planned capital and operating costs.

2.3 UK

The UK approach to finding the best mining solution concentrates on sub-problem areas. Following close involvement with new mine planning, models specific to new mines have been developed in several areas: reserves assessment, underground layout assessment, manpower requirements, manpower availability, surface coal flow simulation, financial assessment models [9], (D2). In addition, models for existing collieries are adapted and used where relevant, e.g., underground coal flow simulation, ventilation assessment. Taken together, the set of models represent an almost complete new mine planning package; however no attempt is ever made to link them together automatically. The emphasis is placed on rapid evaluation of individual problems, with close collaboration of the systems analysts with the mine planners and engineers at all stages of planning. Several of the models are, however, very much concerned with bringing together the work of different specialists; for example the reserves assessment computer system, Geoplan, is designed so that it is of equal use to both the geologist and the mining engineer.

Most of the models specific to new mines were developed and used during the planning of one particular prospect from 1976 onwards, and they have since been used at other later prospects as appropriate.

2.4 USSR

The USSR are developing an optimizing mine planning system, SAPR-COAL [12], which covers all technical spects of new mine planning. The objectives are to improve the technical and economic level of planned enterprises, the productivity of planners, and the quality of project documents. The system is designed to mesh into the national and regional planning optimization systems, as described in the general paper on the USSR Systems Approach to Coal Industry Development [11]. Problem areas of mine planning covered included coal mining, coal transport, coal bunkerage, ventilation, auxiliary transport, gas emission, etc. A suite of planning models is being developed for each problem area: for example, (D3) describes a set of elements of SAPR-COAL covering classification and modeling of mining and geological conditions; spatial descriptions of geometric and physical properties of the rock massive; and forecasts of geomechanical processes and mining conditions during operations.

SAPR-COAL has also been compared with traditional planning methods by performing parallel planning exercises. The system achieved reductions in planned capital and operating costs of up to 15%, and the mining solutions recommended by SAPR-COAL were adopted. As the USSR noted during the session discussion, true validation can only be performed once production has begun.

3. DIFFICULTIES ENCOUNTERED

3.1 Interrelationships

Two of the main difficulties with new mine planning at this level are (a) to identify the interrelationships between different subproblem areas accurately, and (b) to identify the direction of information flow between subproblem areas. These two difficulties are related but distinct: not only must the planning system ensure that the consequences of analyses in one area are fully reflected in all other subproblem areas; it should also ensure that the correct subproblem areas are 'driving' the analysis, that is the system must identify those constraints which are most critically affecting the choice of mining solution.

The systems analysis contribution to this Planning for Planning difficulty can come in two ways. We can aim for either a structured solution or a more pragmatic approach. The approaches described in Section 2 from the FRG, Poland, and the USSR are all structured approaches. They assume that the interrelationships, and the direction of influence, can be identified and set down in advance. The advantages of such an approach are clear; from the beginning the mining engineer, mine planned and systems analyst are working to a common structure, and planning activities can be planned and scheduled accordingly. The UK favor the non-structured approach. Reference [9] discusses how the direction of information flow might vary even in one particular prospect at various times as new data becomes available, and shows how it will certainly vary between Prospects. Therefore, the total structure linking all subproblem areas is difficult in concept and possibly dangerous in use. The advantages of this approach are flexibility, and an ability to respond rapidly to new information or assumptions; the disadvantages are that scheduling of planning activities is more difficult, and possibly that a high emphasis is placed on continuous discussion between mining engineer and analyst.

3.2 Uncertainty

Another major difficulty is uncertainty. Whether the overall approach is structured or unstructured, one of the major roles of the systems analyst is to ensure that the planner is made aware of the implications of uncertainty, and that the decisions he takes are robust in the face of uncertainty. Two distinct types of uncertainty emerge:

(a) The uncertainty on future cost and productivity that is naturally associated with an expanding industry constantly introducing and utilizing new technologies. In this respect the coal mining industry is no different from any other industry and forecasting techniques, and methods used to reduce uncertainty, would be paralleled in any other industry discussion. For example, Poland give a particularly detailed account of regression analysis of current performance and cost data in [6]. The importance of continually improving the collection and organization of current actual data, taking advantage of improving computer technology, is stressed by all countries.

(b) The uncertainty as to geological structure which is unique to the coal mining industry. Only the mining industry plays such a game against nature, and perhaps only the deep-mine coal industry with such limited information. The form of this uncertainty means that the unifying of risk measurements in quantifiable units such as tonnes or money is uniquely difficult. Various attempts to quantify the qualitative are described in the report of Session 1 on Reserves Assessment.

In some senses the 'unstructured' approach of the UK allows more scope and flexibility for analyzing the implications of uncertainty. Reference [9] gives several examples of how such implications can be highlighted for specific subproblems, and how the directions of a planning study might change given such information.

3.3 Decision Criteria: Elimination of Alternatives (Variants)

A major contribution of systems analysis is that it allows the identification and analysis of many more alternatives than is possible by traditional planning methods. As commented in [6] from Poland "a quite essential obstacle in widening the scope of variants...was the high laboriousness...the traditional methods of variants appraisal".

Immediately a new difficulty arises. All alternatives cannot be fully evaluated. Given the capacity to consider the almost infinite set of possible alternatives, how should this set be reduced in successive stages, (where in each stage the alternatives left are defined in increasing detail), so as to emerge with the final recommended solution? This problem holds both for the 'structured' and the 'unstructured' approaches. In the structured approach the order in which decision criteria are to be applied must be laid down in advanced, in the unstructured approach the correct criterion must be identified at each stage as it is reached.

The difficulty is exacerbated once 'uncertainty' as to decision criteria is introduced. That several criteria are possible at any one level of management is reflected in, for example, the use of five possible objective functions in the Polish SPP.1 system [6]. In addition, (a) weights given to criteria will differ with the position of the decision-maker in the decision-making hierarchy, (b) they will change with time. The USSR presents a particularly thorough discussion of this problem in [13]--"under the condition of information indeterminacy...in major cases it is impossible to formulate the criterion system in advance...the criterion system could be revealed under favorable conditions only after the planning process". The paper goes on to recommend a theoretical system of planner-computer dialogue whereby the problem can be ameliorated--in theory, a tailor-made computer model for every separate decision-maker is necessary.

On one matter all countries agree. Whatever approach is used, whatever resolution of the above difficulties is mad at any one time, the importance of continuous dialogue at all decision stages between mine planner, computer, (and systems analyst) is paramount. Even the most structured approach no longer looks for a completely automatic solution.

4. SUMMARY AND CONCLUSIONS

1. In at least four of the major coal producing nations, systems analysis is making a major practical contribution to decisions as to optimum size and location of mine(s) for new deep mine prospects. This contribution exists over and above the contribution that is made in individual subproblem areas.

2. The contribution can assist the mine planner in many ways, e.g., in:

   (a) identifying interrelationships between subproblem areas,

   (b) identifying direction of information flow between subproblem areas,

   (c) highlighting the implications of uncertainty,

   (d) allowing the consideration of many more alternatives than is possible by traditional methods, and

   (e) assisting in the rational choice and application of different decision criteria at successive stages.

3. There exist many unsolved difficulties connected with such assistance. The treatment of these difficulties does and will differ with national custom and practice. Further theoretical research, and more importantly further international exchange of practical experience in new mine planning as this experience accumulates, will assist systems analysts in improving the resolution of these difficulties within their national milieu.

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CHAPTER VI--ENVIRONMENTAL FACTORS AND THEIR RELATIONSHIP TO THE BEST MINING SOLUTION

1. INTRODUCTION

Environmental considerations are of increasing importance in the planning of any major industrial activity and the coal industry is certainly no exception. The precise way in which these considerations affect the planning process may vary from country to country but the consequences are substantially the same--fuller and more detailed planning is necessary and constraints may be so fierce that coal industries may have to adopt a plan which is suboptimal from a mining point of view. Before discussion the role of systems analysis, therefore, a brief description of the effect of the environment on the planning process itself is relevant.

The system of planning inquiries used in the UK provides for the opportunity for local councils, pressure groups, or even individuals to raise objectives to any part, major or minor, of the planning submission. Industry has to prepare its case most thoroughly and carefully. In Poland, there are statutory limitations as to where structures may be built (for instance, not on certain land categories) and plans for coalfield development have to pass through many Institutions, perhaps 20 in all, involving around 50 separate approvals. In addition, the Polish mining industry has additional burdens to shoulder. As it is the leading industry in Poland, the coal industry is given responsibility not only for planning its mining development but also for planning the whole economic and social infrastructure. Thus, the mining industry has to demonstrate how provisions for housing, services, education and ancillary industries can be made--tasks which elsewhere may be within the responsibility of local government. Year-by-year more regulations and restrictions are being introduced which are affecting mining economics. The position in this respect is not dissimilar in the USSR where it is estimated the 10-20% of the construction costs of a new mine are devoted specially to environmental protection (the figure is as high as 35% for open-cast sites). In the FRG, plans have to pass through the Local Planning Committee, but having done os may be objected to by any group or any person. The National Environmental Protection Act provides for a formalized structure in the USA--even so, after getting the necessary approval in the form of a mining permit, any opposition can still resort to Court action adding to the expense and delay.

The environment, therefore, is an important influence on new capacity planning. The remainder of this chapter describes the contribution of systems analysis on individual environmental issues and on environmental issues as a whole. Although there is a wide and highly-specialized literature on environmental issues, this chapter is based solely on the direct experience of those present at the task force meeting.

2. INDIVIDUAL ENVIRONMENTAL ISSUES

When examining individual environmental issues two problems are encountered: (a) predicting the size of any impact, and (b) assessing the importance of this. The techniques of systems analysis are directly applicable when examining the first of these. Thus, it is recognized that there is a clear need for a suite of technical models on such issues as air pollution, transport and traffic flows, dirt production, manpower requirements and subsidence. Many of these have already been developed and successfully applied and no methodological problems appear to have been encountered. This contrasts with the second problem--the important of the impact--where far less work is in evidence.

One example described at the meeting itself related to IIASA's own research on long term energy studies. This work indicates an important role for synfuels derived from coal in the future, although environmental considerations may act as a major constraint. This was because it was anticipated that coal will be converted to various synfuels on the mine site, adding to the environmental impact of the mine the impact of a coal conversion plant. There was a major role for systems analysis in developing models to predict the pollutants produced and also to forecast the manning needs of the colliery and the plant itself.

Other models were also discussed and many have been full described in papers (for instance: E1, E2). All are aimed at demonstrating the consequences of planned mining activity. Their use is both internal, in the industry's own planning process, the external, when dealing with outside bodies. Their need is particularly important when such a range of possible detailed objections exist--detailed, carefully constructed models are necessary to cater for this. It is useful to be in a position to demonstrate quickly the consequences, including the financial ones, of, for instance changing a planned shaft location or stowing some proportion of the dirt produced or restricting the population inflow to an area. This is a field of growing importance for the systems analyst and one in which the models produced have readily proved their worth.

3. THE IMPACT ON THE ENVIRONMENT AS A WHOLE AND ITS RELATIONSHIP TO ECONOMIC BENEFITS

The value of the type of model described above can hardly be disputed but what is far less clear is how systems analysts should approach the problem of relating environmental impacts to economic benefits. Certainly, the systems analyst can help to ensure that environmental impacts are correctly identified and logically analyzed, partly through a sensible classification of those impacts [10]. But progress beyond this point seems to be very limited by the methodology so far developed, and the level of skills possessed by systems analysts in this highly specialized field.

Regional socio-economic models and input-output analysis are used widely in the USA and the USSR (E3) but spasmodically elsewhere. Poland, though, have started such work and are solving the problems of expertise by recruiting suitably trained personnel from the Ministry of Administration. These approaches are potentially very useful in summarizing the total environmental impacts of a planned mining activity but stop short of any trade-off with the economic benefits such activity brings.

Two approaches were briefly discussed on how this might be done. Cost Benefit Analysis (CBA) purports to describe and quantify the economic and social advantages and disadvantages of a policy in terms of a common monetary unit. Since its first application (E4) its history has been somewhat controversial with critics either doubting the logical possibility of valuing outcomes, the morality of so doing (particularly on human life) or the concept of a value for society when the members of that society differ so widely. Advocates of CBA do not dispute the difficulties but argue that if valuations are not attempted on a scientific basis they will be made anyway but subjectively and perhaps irrationally. Decision analysis is related to CBA but relies on a trade-off between intangeables rather than a firm valuation. There are rather more examples of using a trade-off approach in coal mining than there are of CBA, perhaps because of this (for instance, E5, E6). The sieve analysis, used in the UK and described in the meeting [10], where areas of land on a grid square basis are evaluated and scored according to a host of environmental factors to give a clear indication of which areas are most and least satisfactory from an environmental point of view, is an example of a very simple use of decision analysis. This, however, makes no attempt to relate environmental attractiveness to mining attractiveness.

Apart from the daunting question of measuring economic and environmental impacts, there seems a clear role for systems analysis in simply constructing models to provide a framework for intelligent and informed debate. These models could demonstrate the consequences, implied valuations and perhaps the inconsistencies of any line of argument. These need not be mathematically sophisticated but must be rationally and scientifically constructed.

4. SUMMARY AND CONCLUSIONS

1. Environmental factors are increasingly affecting the planning process in the mining industry, increasing the time and detail involved in planning for new capacity and affecting the economics of extraction.

2. To date, the contribution of systems analysis in this field is valuable but restricted. Most effort has concentrated on the development of models which predict the environmental consequences of mining activity.

3. Further work is necessary on measuring the importance of any environmental impact and on relating environmental impacts as a whole to the economic benefits of the planned mining activity. Some of this will be coal-specific but much can be learnt from research undertaken for other industrial activities.

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CHAPTER VII--SUMMARY AND CONCLUSIONS

It would be very satisfactory to conclude this paper with a summary statement of how planning should be undertaken within the deep coal mining industry, and the precise role of systems analysis within it. We are, however, in no position to do this and it is probably not desirable. It is certainly infeasible. The cultural and organizational differences between countries are such that procedures can hardly be common. In some industries the analytical teams are embedded with the industry's management structure, in some it is largely undertaken in research units, and elsewhere the Universities may play a major role. It is perhaps remarkable that, despite these differences, there was a great deal of common experience and awareness of common problems. No country was clearly in the lead across the board. This concensus therefore provides an alternative--to set out the general conclusions in each chapter as statement of where we are, and an indication for the future.

RESERVES ASSESSMENT

1. Systems analysis has contributed significantly in the field of reserves assessment, largely through the development of computer systems which assess reserves linked to mining plans and relevant marketing and economic assumptions.

2. Work is not so advanced on the examination of the discontinuous properties of reserves as on the continuous properties.

3. A greater understanding of the knowledge provided by exploration and the value of such knowledge is necessary before systems analysis can contribute significantly in the field of exploration design.

MINING METHODS: EVALUATION

1. Systems analysis has established a major contribution to many problem areas in mining method evaluation--from coal face design through all production processes to coal preparation. There have been a very wide number of applications, although of course the degree of implementation success in each particular problem area varies from country to country.

2. The techniques used vary by problem area, but descriptive modeling and simulation models have achieved most significant success, especially where emphasis is placed on simplicity and communicability.

3. The major research area for systems analysis now is in how to combine the models of individual subproblems while maintaining the advantages of communicability.

COMPARISON OF ALTERNATIVE TECHNOLOGIES

1. A strong well-established role for systems analysis in evaluating evolutionary changes to technological processes is identified. This contribution applies to all levels from engineering assessment, to system compatibility assessment through to economic assessment. A range of techniques are applicable, with simulation models being particularly appropriate.

2. For revolutionary technologies, the systems analysis contribution to date has been less clear cut. All techniques suffer because of the problems of uncertainty, and the amount of detail required for simulation models may obscure objectives. Because of these reasons, systems analysis is often more useful in rejecting new technological paths, rather than recommending them.

3. Systems analysis has not yet solved the problem of identifying potentially successful technologies at early stages. Consequently growth rate predictions are hazardous.

FINDING THE BEST MINING SOLUTION

1. In at least four of the major coal producing nations, systems analysis is making a major practical contribution to decisions as to optimum size and location of mine(s) for new deep-mine prospects. This contribution exists over and above the contribution that is made in individual subproblem areas.

2. The contribution can assist the mine planner in many ways: e.g.,

   (a) identifying interrelationships between subproblem areas,

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(d) allowing the consideration of many more alternatives than is possible by traditional methods,

(e) assisting in the rational choice and application of different decision criteria at successive stages.

3. There exist many unsolved difficulties connected with such assistance. The treatment of these difficulties does and will differ with national custom and practice. Further theoretical research, and more importantly further international exchange of practical experience in new mine planning as this experience accumulates, will assist systems analysts in improving the resolution of these difficulties within their national milieu.

ENVIRONMENTAL FACTORS AND THEIR RELATIONSHIP TO THE BEST MINING SOLUTION

1. Environmental factors are increasingly affecting the planning process in the mining industry, increasing the time and detail involved in planning for new capacity and affecting the economics of extraction.

2. To date, the contribution of systems analysis in this field is valuable but restricted. Most effort has concentrated on the development of models which predict the environmental consequences of mining activity.

3. Further work is necessary on measuring the importance of any environmental impact and on relating environmental impacts as a whole to the economic benefits of the planned mining activity. Some of this will be coal-specific but much can be learnt from research undertaken for other industrial activities.

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APPENDIX A

TENTATIVE AGENDA

COAL--PLANNING FOR PLANNING TASK FORCE MEETING

Seminar Room, IIASA, Laxenburg, Austria, 24-27 November 1980

This tentative agenda is for a Task Force Meeting on the Use of Operational Research and Systems Analysis in New Capacity Planning for the Deep Mining of Hard Coal.

MONDAY, NOVEMBER 24

08.30 Registration

09.00 Introduction and Welcome--Alec Lee, Area Chairman, Management and Technology Area

09.30 Reserves Assessment

Topics include:
- i) The design of exploration strategies
- ii) Estimation from given exploration
- iii) The calculation of reserves

(10.30 Coffee Break)

12.30 LUNCH

14.00 Mining Methods--Evaluation/Layout Assessment

Topics include:
- i) Selection of mining strategies
- ii) Optimization of a given strategy

(15.30 Tea Break)

17.30 Depart to Heuriger

TUESDAY, NOVEMBER 25

09.00 Manpower Requirements

Topics include:
- i) Productivity forecasting
- ii) Numbers and skills of men required
- iii) Recruitment and training programs

(10.30 Coffee Break)

12.30 LUNCH

14.00 Comparison of Alternative Technologies (with particular reference to new technologies)

Topics include:
- i) Technology assessment of alternative equipments or mining systems
- ii) Effect on whole operation of mine (system effects)
- iii) Problems of introduction and innovation

(15.30 Tea Break)

17.30 Return to Hotels

WEDNESDAY, NOVEMBER 26

09.00 Finding the Best Mining Solution, Taking Uncertainty Into Account

Topics include:
- i) The inter-relation of factors already considered
- ii) Establishing the uncertainties associated with these factors
- iii) Determining methods for reducing uncertainty
- iv) Planning to allow for unavoidable uncertainty

(10.30 Coffee Break)

12.30 LUNCH

14.00 No fixed program.

This time has been left free for further discussion on topics of particular interest, and for individual discussions with the rapporteurs. It is hoped that participants will leave themselves free for possible meetings to be arranged that morning.

(15.30 Tea Break)

17.30 Return to Hotels

THURSDAY, NOVEMBER 27

09.00 Environment Factors, and Their Relationship to the Best Mining Solution

Topics include:
- i) Impact of mining on the national environment
- ii) Impact of mining on the local economic infrastructure
- iii) Reconciliation of internal and external factors for site selection

(10.30 Coffee Break)

12.30 LUNCH

14.00 Concluding Discussion

16.00 Close of Meeting

LIST OF PARTICIPANTS

APPENDIX B

COAL--PLANNING FOR PLANNING TASK FORCE MEETING

Seminar Room, IIASA, Laxenburg, Austria, 24-27 November 1980

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