CHAPTER ELEVEN

Design and Implementation of an Effective Decision Support System: A Case Study in Steel Hot Rolling Mill Scheduling

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11.1 THE PRODUCTION ENVIRONMENT

The work described here was largely performed at a medium-sized European steel mill, with an unusually diverse product portfolio, and hence a difficult scheduling problem to solve. The decision support system developed as a result has been successfully used, with minor modifications, at many steel mills worldwide. The work was carried out while the author was employed at A. I. Systems, Belgium, a software house building software for planning and scheduling decision support.

A steel hot rolling mill transforms steel slabs into steel coils. First, slabs must be moved from a storage area to the furnace area using manual or semi-automatic cranes. After heating, the slabs are subjected to very high pressures in a series of rolls to produce a steel coil of a few millimetres thickness. The rolls which are in contact with the hot steel band quickly become worn, so coils are milled in programmes of a few hours. Between programmes some or all rolls must be replaced. Several different types of programmes may be chosen, where the programme type chosen determines the types of coil which may be rolled in the programme and the preparation which must be carried out prior to executing the programme. The correct choice of programme type is an important planning decision. A rolling schedule is a sequence of 100 to 300 coils to be milled in a programme lasting several hours, which satisfies complex technical, commercial and logistical constraints. Producing such a rolling schedule is a difficult task, which is carried out by a small group of experienced schedulers. A schematic diagram of the production processes surrounding steel hot rolling is given in Figure 11.1.

![Fig. 11.1 Schematic of the hot rolling mill production processes.](image-url)
Technical and logistical constraints arise from the wide range of machinery involved in steel hot rolling. It is possible that each coil could be manufactured from one of a number of different slabs that are available, so that slabs may be assigned to coils in such a way as to facilitate the rest of the production process. The cranes, which transport steel slabs from the slab yard storage area, may present a production bottleneck, particularly when the rolling schedule calls for slabs which are not at the top of a stack and crane-intensive unpiling operations must be carried out. Short slabs should be present in consecutive pairs in the sequence, otherwise there will be energy-wasting gaps in the furnace. Steel with different mechanical and chemical properties will need to attain different temperatures before milling. It is important that the slabs in a furnace at any given time require similar temperatures. Since there may be several furnaces, each having different properties, the schedule for each furnace should group coils having similar milling temperatures. Furthermore, the flow of slabs leaving each furnace needs to be balanced since each slab will have a minimum and maximum heating time. Changes in the dimensions or hardness of consecutive coils in the sequence may require changes in the pressure exerted by each rolling stand. Making changes in the pressures exerted is likely to result in reduced coil quality. Large changes give the risk of machine failure, expensive downtime and unplanned maintenance. Each programme should have a particular form, starting with easy-to-roll narrow, thick, soft, high tolerance coils, moving through a series of smooth changes in dimensions and hardness to difficult-to-roll wide, thin, hard, low tolerance coils. From these difficult, wide coils we then finish with a long sequence of coils having gradually reducing width in order to stop grooves which are made in work rolls by the edges of each steel coil rolled from marking future coils. Hence the width profile of each programme has a ‘coffin’ shape. The status and type of the work rolls used determine the coffin types and hence the coils which can be rolled. The choice of coffin type, taking into account technical and commercial constraints, is an important medium term planning problem. In particular, the population of coils/slabs which remains after rolling the scheduled coffins, has to be sufficiently heterogeneous to allow future coffins to be rolled without large jumps in dimensions or hardness.

Commercial constraints arise since, in this make-to-order environment, each coil has a due date and selling price and is destined for a customer who has certain tolerances for non-adherence to due date and quality targets. These tolerances will usually be known for internal customers and must be guessed for external ones. In an environment where the order book is full then throughput of appropriate coils must be maximised, so that careful selection must be made of coils to be rolled, and hence the coffin types to be made. Throughput must be maximised by ensuring that each programme is as long as possible between downtimes caused by work roll changes. When the order book is not so full, emphasis can be placed on coil quality, or on rolling coils with unusual dimensions or physical properties that require highly specific coffin types.

Whilst hot rolling is one of the most reliable processes in a steel mill, rolling mill schedules must be able to react quickly to unforeseen events, including the failure of cranes or furnaces, non-availability of certain coffin types due to non-availability of work rolls, rush and cancelled customer orders and problems with manufacturing processes upstream and downstream. Schedule generation must be able to react to these unforeseen events.
Different performance measures exist to measure the effectiveness of the hot rolling mill. Production personnel often use measures associated with the throughput and quality of steel coils. Commercial staff have measures associated with sales volume and delivery performance. Senior managers have measures, that attempt to aggregate and measure overall customer satisfaction and production costs. Each of these groups may receive bonus payments in accordance with their performance measures. It is often the case that these measures will conflict with each other.

The information which is used to make schedules for the hot mill comes from several sources. Data concerning the slabs currently in the slabyard and client orders are usually held in the plant computer systems. Caster scheduling systems provide information as to which slabs will arrive in the slabyard in the immediate future. However, it is not always possible for caster schedules to be met and this information may be unreliable. Other rules and procedures governing the technical capabilities of the mill are usually known by a small group of engineers and schedulers. These rules change rapidly in response to conditions in the plant and external forces. Other inputs to the scheduling process come from sales and marketing divisions and from strategic directives emanating from higher management.

11.2 CAPTURING SCHEDULER EXPERTISE

Typically the manual planning of an eight hour shift would take the scheduler a couple of hours. This long planning time meant that it was difficult to react to unforeseen production events, particularly on night and weekend shifts when a scheduler might not be available. When several programme schedules had to be generated at the same time, sequential generation of the schedules in advance meant that the quality of the manually generated schedules deteriorates with time. Too much scheduler time was spent in the mundane activity of coil sequencing, when this time could be better spent investigating higher-level issues of mill scheduling. Both schedulers and production managers recognised that the manual scheduling procedures in place were incapable of dealing with all of the technical, commercial and logistical constraints of the production process. Moreover, the performance measures considered were simple ones concerned with steel throughput, coil quality and customer due dates, which lacked the ability to discriminate at a sufficiently high level of detail.

The procedure used by the hot rolling mill scheduler was to print off a large mainframe listing of the orders whose due dates fell in the current week, sorted by coil width and then cut and paste slabs from this list by hand until a sufficiently good sequence was found. The resulting sequence was then keyed into the mainframe systems for dissemination to production and commercial departments. The schedulers work office hours, but the production process is continuous. Hence some schedules would be rolled shortly after being entered into the mainframe, whereas others would use data of the forecast production over the next 24 hours. Forecast data are often unreliable due to failures to attain quality targets in the steel-making processes. The forecast data would usually be ignored in practice, with only steel slabs currently in the slab yard being scheduled, so that some schedules (rolled on Sunday evenings) used data which are up to 60 hours out of date. We have now seen the manual scheduling activity at several steel mills, and
the procedure appears to be similar at most of them. Some steel mills provide a simple computer tool for editing schedules. This does not greatly speed up schedule generation, but it does reduce problems due to errors of transcription. Whilst the scheduler generated schedules, he absorbed a good deal of information via telephonic and verbal communications from colleagues. This information concerned particularly errors in the data held, and commercial and production considerations. The programmes found by this manual method were of very variable quality, in terms of throughput, coil quality, technical characteristics and customer satisfaction. One systematic effect that was introduced by the manual scheduling system was that each scheduler did not wish to include difficult material in his schedules, since he received no extra reward for this material and this material may have resulted in reduced coil quality and throughput and increased production risk.

A model for the hot rolling mill scheduling problem was constructed by a team consisting of a specialist in Operational Research, a software engineer and a production engineer with many years’ experience in the steel industry. This small team had regular meetings with a group of schedulers, managers and engineers from a given steel plant. The steel plant contribution to the project was championed by a senior manager with a good knowledge of the the engineering process and the commercial requirements of the mill. His continued enthusiasm for the project was critical for success. Meetings with engineers and schedulers from other steel plants ensured general applicability of results.

One of the most important activities of the modelling process was to identify which features of schedule generation were mundane, where computer-generated information would be most useful, and which corresponded to the interesting tasks which required the skills, insight and experience of a human scheduler. Presentation of the project to schedulers, engineers and managers as removing some of the mundane part of their jobs aided the process of gathering data. Here again the input of experienced managers, themselves ex-schedulers, was of more direct use than information provided by schedulers. We found that schedulers were defensive in regarding all aspects of their work as requiring a high degree of creativity, unsuitable for computer assistance. The scheduling managers were more willing to listen to new ideas and propose those areas amenable to computerised decision support. Table 11.1 briefly summarises the results obtained.

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<tr>
<th>Tasks suitable for computerisation</th>
<th>Tasks requiring human flexibility</th>
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<td>1. Coil sequencing, applying ‘rules of thumb’ and engineering principles.</td>
<td>1. Deciding which programme types should be milled.</td>
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<td>2. Assigning slabs to coils.</td>
<td>2. Assigning priorities to customer orders.</td>
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<td>3. Assigning priorities to production goals.</td>
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<td>4. Rescheduling in response to production events.</td>
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<td>5. Revising ‘rules of thumb’in response to information received.</td>
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<td>6. Obtaining information concerning likely future events.</td>
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<td>7. Giving out information.</td>
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Most of the schedulers’ time was spent in sequencing the coils to be rolled in each shift. However the choice of sequence to be rolled was largely governed by well understood engineering principles. Even so, the task of assigning slabs to coils and sequencing the coils is a generalisation of the Asymmetric Travelling Salesman Problem (Lawler, et al., 1985) which is a member of the NP-hard class of difficult combinatorial optimisation problems (Garey and Johnson, 1979). The complexity of these principles had caused other attempts at creating a useful decision aid for hot rolling mill planning to fail. If the schedulers’ time were freed from the mundane task of sequencing coils then he would have more time for the interesting tasks associated with the generation of good schedules. These interesting tasks were concerned with dissemination of information and reflection upon planning practices and external information received. In particular he could better decide the priority of coils to be sequenced and the types of programme to be investigated and be more proactive in response to information received, for example concerning machine failure or rush orders. This would allow the scheduler to build schedules which better balanced the requirements of production staff, commercial staff and senior management, whilst the majority of the technical constraints could be handled by the computerised coil sequencing process. Information as to the tasks performed by schedulers and scheduling managers was obtained both through observing these personnel at work and through discussion. It was felt that the information obtained from the meetings and from middle-level scheduling managers was more useful than that obtained from meetings with, and observation of, schedulers. Most of the middle-level scheduling managers were themselves former schedulers and a view was formed as to what constituted ‘ideal’ practice rather than simply current practice. In the process of identifying the mundane and the interesting tasks that the scheduler carries out the managers in charge of the scheduling and production process were able to consider the impact of the personality and mood of human schedulers in schedule generation. Whilst it was felt by the scheduling managers that personality and mood could have a highly positive, or negative impact on how well the interesting tasks of the schedulers were performed, it was regarded as unlikely that personality and mood would have a particularly positive effect on the tasks of coil sequencing and the assignment of slabs to coils. We illustrate this later with the cases of ‘Risky Ron’ and ‘Safe Sam’.

It quickly became apparent that the constraints and objectives of the hot rolling mill schedule were not at all stable, so that any successful computerised scheduling aid would have to be easily configurable. In particular the coil sequencing problem, although mundane, required input from many other information sources, particularly the engineering and scheduling expertise of plant employees. Easy configuration would enable the system to react to a wide range of circumstances, in particular real-time events and changes in plant machinery or working practices. In addition methods were required to enable the scheduler to quickly assimilate, communicate and act upon a large amount of information, particularly on the population of slabs currently held in the slab yard and the production possibilities offered by that population.

In our long series of meetings and observations with schedulers and managers, it became evident that these two groups of people would have different expectations and require decision support in different ways. Engineers and managers needed to be able to change most aspects of the system, most notably
they needed to be able to change aspects of the model which arose due to changes in plant configuration or working practices. They would also need to be able to set the performance measures, which would determine the nature of the schedules produced. Whilst engineers/managers had faith in the technical abilities of their scheduling staff, they felt it was rather dangerous to give access to the performance measures to them. This might reintroduce behaviour which was perceived as undesirable, such as the tendency for schedulers not to include difficult coils in their schedules, in order to maintain popularity with those responsible for milling the sequence. The schedulers would need to select coffin types to be milled and those slabs that were available for milling, but this could be done whilst hiding much of the detailed information and parameter-setting possibilities. There was a feeling from the schedulers that they would benefit by having clearer goalposts, inasmuch as they would simply have to maximise their score, in order to satisfy the purely technical task of sequence generation. The engineers/managers perceived benefit, since they would be determining the weighting of factors, which went to make up the score, which would give them more control over the detailed scheduling process. The performance measures which this put in place could be more detailed and less prone to abuse than simple ones used previously. It is interesting to note that the measures, which were arrived at for the final system, varied a great deal from those that were already in place. The ‘maximise throughput while maintaining acceptable quality’ measure which was predominant was felt to be prone to abuse, for example since it discouraged the rolling of difficult coils. New measures would consider performance from both commercial and technical points of view, using a combination of five different measures considering the:

- commercial value of coils, including aspects such as timeliness and profitability
- coil quality
- work roll usage (throughput)
- slab yard management
- adherence to ideal programme shape.

Much of the work done to capture the knowledge of schedulers and managers was done ‘from first principles’, with the key being a very high level of user involvement in all stages of development of the model and decision support system. The schedulers and managers spent much of their time fire fighting and had little time to reflect on what their jobs actually involved, prior to the BetaPlanner project. There was no body of knowledge then available to the developers (who did not include any human factors specialists) as to how schedulers work in practice. (The current volume should be a valuable aid for future practitioners who attempt to implement scheduling decision support systems in areas where the scheduling process is currently manually intensive.)

11.3 TECHNIQUES FOR HOT ROLLING MILL SCHEDULING

There have been several papers written about decision support for hot rolling mill planning. The literature in this area may be divided into two groups. Jacobs, et al., (1988), Balas and Martin (1991), Sasidhar and Achary (1991), Petersen, et al., (1992) and Assaf, et al., (1997) all use mathematical programming techniques to solve simplified models of the hot rolling mill scheduling problem. Cowling
(1995), Stauffer and Liebling (1997) and Lopez, et al. (1998) propose more generally applicable models which are solved using heuristic optimisation techniques. Using a simple model produces nearly optimal solutions more often, which may, however, be harder to implement in practice. Using a more complex model, solved using heuristic approaches, presents no absolute guarantee of distance from optimality in the model, but gives results that are usually easier to apply in practice. Each of these approaches has its merits and deficiencies. None of these papers have addressed the issues of the capture of scheduler expertise or the effects of implementation upon the working practices of a steel mill. It was clear throughout our study of the problem, that only a complex model solved using fast heuristics would provide a mechanism for capturing scheduler expertise and production complexities for adequate decision support within the client steel plants.

11.4 THE BETAPLANNER DECISION SUPPORT SYSTEM

The decision support system for the hot rolling mill planning problem would be used by a range of users with different levels of expertise. Functionality must be hidden from lower-level users both to give rise to a system that is sufficiently easy to use and for reasons of security. In order to cope with the different levels of expertise, the scheduling decision support system was made configurable on three levels: OR analyst, engineer/expert and scheduler/mill foreman.

The OR analyst is needed only on initial set-up to tune parameters of the heuristic which were hidden from other users. Due to the wide variation between the specifications of different steel plants, the heuristics used to solve the problems modelled need tweaking for best possible performance. The users of the system so far have not been able to do this tuning themselves, and so this user level contains parameters that would not be changed following initial implementation. An early prototype of BetaPlanner did not hide these parameters sufficiently well and curious users induced undesirable behaviour by changing the parameters for the OR/analyst user level!

The engineer/expert is able to alter all technical aspects of the system. In particular he can reflect changes in operating procedures and machinery through an intuitive graphical user interface. He can define the categories of slabs and orders which the scheduler uses to define the population to be scheduled, model the commercial value of coils to reflect the desires of sales and marketing departments and define new coffin types to reflect changes in the technological and commercial environment. The system allows him to balance all of the technical, commercial and strategic performance goals to arrive at a best compromise for a given situation. He can save configuration data, using descriptive names, so historical data are built up over time, which captures some elements of the knowledge and expertise of the engineer/expert, and the system becomes easier to use over time. For example, configuration data might handle the two situations when the order book is full and throughput considerations dominate and the situation where the order book is nearly empty and quality considerations dominate. They could also handle a variety of strategic directives, for example concerning a marketing push for specific types of steel or customer.

The scheduler possesses the tools required to analyse the slabyard and generate and analyse a number of schedules to the engineers’ specification. He
can also analyse the impact of a particular schedule on the remaining slab population to ensure that the population remains sufficiently heterogeneous for future schedule generation. He can choose schedule types and has some control over coil priorities. The scheduler’s interface is sufficiently easy to use that it may be, and has been, used by the mill foreman to generate a schedule in response to unforeseen events when there is no scheduler present at the steel plant. This very simple operation is aided by the engineers’ interface described above. Typically the engineer will have defined programmes with names such as ‘Night shift emergency coffin – full slab yard’ and schedules for these coffins can be generated with a couple of mouse clicks. As maintained above, it is very important that certain tools and parameters are hidden from certain users. An early prototype of the system did not hide this information and the schedulers demonstrated considerable ingenuity in locating configuration files and trying new values, with the result that schedule generation slowed by a factor of several thousand times.

Initial attempts to solve the model by mimicking the schedulers’ approaches were unsuccessful, due to the difficulty of capturing the approaches in sufficient detail so as to make computer implementation possible. As we have noted above, managers/engineers within the steel plant wanted to introduce a new system of performance measurement. However, since a very detailed level of modelling, starting from basic engineering principles, had been carried out it was possible to approach the problem using heuristic techniques from Combinatorial Optimisation, particularly local and Tabu search. The results were highly satisfactory. For further details see Cowling (1995) and Baccus, et al., (1995).

A high-level view of the schedule generation procedure used is given in Figure 11.2. In the slab selection stage first the slabs which are released for sequencing are selected. Certain slabs may be unavailable, for example due to the breakdown of one of the slab yard cranes. Then commercial considerations are used to determine the priority of each coil. This step is usually carried out every few days by the engineer/expert in response to commercial considerations and strategic goals. The coffin selection is carried out, usually by the scheduler/mill foreman, to determine which programme types are to be rolled to produce coffin programmes containing slabs of the highest possible value. Slab and coffin selection are both supported by powerful and easy to use graphical user interfaces that allow the user great flexibility in doing ‘what-if’ analyses. The interfaces provide statistics concerning the value of rolled coils and the production possibilities of the remaining population, suitable for both the scheduler and the engineer/expert. The slab and coffin selections, together with the technical rules and weights for each performance measure are then used by the sequencer to heuristically generate a high quality schedule, within a time frame of a couple of minutes. Since the time frame to change the mill specification and reschedule is short, new schedules can be generated quickly in response to unexpected events such as machine breakdowns and rush orders. When more time is available the sequencer can use this time to generate schedules of slightly higher quality. Finally, the scheduler is able to use the programme editor to carry out detailed editing of the sequence, if necessary. Experience shows that this is almost never necessary in practice, but it is important that the scheduler has this final element of control. We will return to this point later. After this editing process the schedules are sent to mill mainframe systems for dissemination throughout the steel mill.
11.5 BENEFITS OF THE BETAPLANNER SYSTEM

The most obvious benefits of the BetaPlanner system over a manual planning system are the improved technical and commercial characteristics of the schedules generated, due to the system’s ability to consider a wider range of factors than could be considered by a human planner. Of course, the BetaPlanner system is not able to bring to bear reasoning and other faculties, unlike a human scheduler. Since the tasks which are undertaken by the computer system have been chosen as those where the human qualities of reasoning are less important, and since the computer system can make simple decisions many millions of times faster than a human planner, the result is far better schedules overall. Faster sequence generation allows a quick response to disturbances and frees up the schedulers so that they can spend more time on the more interesting tasks, such as data-gathering, which will also improve sequence quality, although the benefits from this are harder to quantify. The fast scheduling time also allows the decision support tool to be used to consider ‘what-if’ questions. For example, one BetaPlanner user has used the system to appraise the possibility of investment in a new type of furnace. Since BetaPlanner can plan several shifts within a reasonable time (a few minutes) and each shift has equal priority, the planning horizon can be increased to improve the characteristics of sequences in the medium term, without the decrease in quality over time which manual schedules demonstrate.

Personality, mood and opinion influence the schedulers’ work. Whilst this is critical to scheduling flexibility, scheduling managers may prefer that the mundane activity of sequencing is not influenced by these factors. An interesting example occurred at a particular steel plant where there were two schedulers, who we shall name ‘Risky Ron’ and ‘Safe Sam’. Ron believed that it was his duty to stretch the technical capacity of the mill to its limits. His programmes were very
long and often contained dangerously large changes in coil dimensions and
hardness. Sam’s sequences were often significantly shorter since he was unwilling
to approach the limits of the mill. Under normal conditions, the company would
prefer Sam’s conservative approach, leading to a higher quality of steel produced.
Under unusual conditions, for example when slab stocks were low, then Ron’s
approach was necessary to make commercially viable sequences. The hours
worked by Ron and Sam were governed by shift patterns and not mill conditions.
By building configurations corresponding to the best sequencing characteristics of
Ron and Sam, management have been able to have a greater influence on
schedule characteristics. These configurations contain information of the attitudes
of Ron and Sam concerning the ideal ‘shape’ of a schedule, and the penalties
associated with violations from this shape. Since both Ron and Sam had
significant input into the scheduling configuration to be used under normal
conditions, they were happy to use the standard configuration (corresponding
closely to Sam’s conservative style). However, when the number of slabs in the
slab yard was reduced, an appropriately titled configuration was used by both Ron
and Sam with similar results, corresponding more closely to Ron’s more vigorou
scheduling style. Acceptance of a computerised decision support system by the
schedulers was improved since the system was presented, truthfully, as a system
that would make their jobs more interesting and not replace them. There was also
some enthusiasm to learn computer skills, which was boosted by the introduction
of simple computer games into the workplace.

11.6 USER INGENUITY IN APPLYING BETAPLANNER

BetaPlanner is currently in use at several steel mills worldwide and possesses a
small club of ‘power users’. The open-ended nature of the planning tool has
allowed it to be used in several ingenious ways that its creators had not originally
foreseen.

A pickling line passes hot rolled steel coils through a bath of hot acid in order
to remove surface oxides before further processing or shipping. The coils must be
welded together in a continuous band prior to passing through the acid bath. As
may be imagined, the pickling line is governed by quite different constraints and
objectives than the hot rolling mill. One user noted particular similarities in that
there were significant set-up costs in passing from one coil to another, and overall
sequence shape was governed by complex rules. He designed a series of
configurations for BetaPlanner in order to address the pickling line scheduling
problem and has now used it successfully for pickling line scheduling for some
time.

Another user considered simultaneous implementation of BetaPlanner,
together with an advanced furnace. The ability of BetaPlanner to handle the
resulting complex furnace arrangement allowed the user to carry out extensive
‘what-if’ analysis to aid the decision whether to invest in new furnace technology.
In this particular case the steel manufacturer was at some considerable distance
from the BetaPlanner system developers and nearly all of the modelling and
‘what-if’ testing was done over the Internet. The result was that both the furnace
and the decision support system were purchased and used successfully.

Further users have used BetaPlanner extensively to carry out ‘hot charging’
where slabs pass directly from the caster to the hot rolling mill, with a large
consequent energy saving. Hot charged slabs have a relatively short time window
in which they must be placed in a hot rolling mill sequence, requiring detailed
timing information from schedule generation. In this case the existence of
accurate sequence data greatly facilitated the incorporation of timing information
and this feature was successfully incorporated into BetaPlanner with only a couple
of weeks of development effort.

The application of our decision support system in areas not originally
foreseen provides evidence that including a far greater amount of flexibility into
the model than is necessary for providing scheduling decision support in the
short-term, has two significant benefits. Not only does it provide a good deal of
‘future-proofing’, but it can also aid users in applying the decision support tool in
novel ways and in seeing new areas of application of other computerised decision
support tools. We believe that the extra effort required for this ‘over-modelling’
may be worthwhile for any decision support system that will be used over a long
period. Providing a mechanism whereby experienced users can continually
update, improve and extend their knowledge of the production process and the
decision support system using an open-ended model and interfaces which support
‘what-if?’ questions has increased acceptance of the decision support system at all
levels. It should be noted in this case that the cost of development of the system is
increased enormously by the incorporation of this flexible approach, which may,
therefore, be most appropriate for large systems, or those which have a potentially
very large user base.

11.7 LOOKING BACK AT THE APPROACHES TAKEN

The BetaPlanner system has now been installed and used successfully at a range
of steel mills throughout the world. In this section we reflect on the methods for
capturing the expertise of human schedulers and development and
implementation of the BetaPlanner decision support system.

We believe that there were two keys to the development of a successful
prototype of the decision support system. First, a champion within the main pilot
site at senior management level ensured a very high level of interest and that
resources were devoted to the project. Second, a wide range of personnel were
involved and felt involved in the project, so that ownership of the project was
clearly joint from the beginning. However, the great deal of information and a
great variety of opinions available made available gave rise to a good deal of
‘nervousness’ in the model. The model of the scheduling process included, at
some stage in the modelling process, many features that are either no longer
present in the current system, or present, but not used to the best of our
knowledge. Initially this nervousness resulted in frequent changes to models and
software prototypes. Once a reasonably stable model and prototype were in place,
a waiting time was instituted for all user requests that were felt to be transitory.
Essentially this meant that user requests would have to be made more than once
before they were implemented. Much time was saved using this technique, at only
a small loss in user satisfaction levels.

Spending a good deal of time talking to and observing schedulers at work
provided much information as to the overall nature of the scheduling task. It was
our experience that the schedulers themselves found it difficult to step back and
separate those parts of their work which could usefully receive computer support,
from those which could not. In particular most schedulers felt that the number and instability of the rules, which they had to deal with when sequencing coils, would be prohibitive to computer implementation. Talking with engineers and managers at a higher level and an analysis of the sequences actually produced, allowed us to capture some important aspects of the scheduling process using a mathematical model. This technique was alien to both the schedulers and the engineers/managers, who had to be kept on board through regular dissemination of the results produced. The steel engineer who was part of the development team was constantly appraised of the development of the model and heuristics for solving it. He was able to successfully communicate details of the system in a language which the engineers and managers could understand. The schedulers were kept on board through constant reassurance that a decision support system would make their jobs more interesting, rather than replace them. This constant explanation and reassurance was a time-consuming activity that was critical to overall project success.

Considerable development time was spent in developing a flexible and powerful sequence-editing capability for the system. This is a capability which is seldom used now. However, this capability was important in prototyping, since observation and automatic capture of the changes which scheduling staff made, allowed the models and heuristics to be improved. In the final system, it is almost never the case that a human operator can find changes to a schedule that would improve the overall score. However, being able to make these changes is important in the early stages of implementation since it both exposes situations where the performance measures should be changed, and once the performance measures are trusted, demonstrates that the solutions produced are not subject to easy improvement on a technical level. This encourages schedulers to spend far less time on the mundane task of coil sequencing and more time looking at wider opportunities for schedule improvement through better reaction to production events and exchange of information with personnel involved in scheduling or production at upstream and downstream processes.

11.8 CONCLUSIONS

We believe that BetaPlanner provides an example of a system for scheduling support that has enjoyed considerable success due mainly to the following factors:

- only those aspects which may genuinely be eased by computer support are tackled
- extensive configurability allows the user to express his preferences in a way which can influence detailed scheduling behaviour
- three different levels to suit the level of user expertise, and for security
- hiding information and features of the system to suit user level and requirements
- allowing users to maintain historical configuration information in a way which enables and encourages its reuse
- results are provided sufficiently quickly for experimentation to be possible
- an easy to use graphical user interface

We have described the approaches used to develop the scheduling decision support system and discussed the issues, that arise when the system is used in practice, particularly the impact upon performance measures and the effect of user
ingenuity in using the system. On reflection it is clear that in this case too much of the time spent in the analysis of the system requirements was spent with schedulers working at a low level. Whilst these schedulers were good sources of information concerning the details of the scheduling process, they found it very hard to think ‘outside the box’. More senior managers and engineers, particularly those who had formerly been schedulers, provided more useful insight as to ideal future practice, as opposed to the current practice.

The ability of the system to evolve naturally to capture the knowledge of the schedulers, engineers and managers is very important to acceptance of the system. Whilst the hardware platform upon which the decision support system runs is likely to date quickly, the ability of the system to ‘learn’ and ‘evolve’ through the capture of changing schedule specifications and performance measures, should greatly increase its practical lifespan.

Had there existed a structured framework of knowledge concerning the abilities and capacity for training of scheduling personnel, this would have provided a useful start to the process of systems requirements capture. In particular, it would have aided the division of the scheduling problem into aspects where computer automation is useful and those requiring human creativity, flexibility and communication skills. However, it is likely that the problems within the steel industry alone demand sufficiently different skills from schedulers that only general conclusions would be possible. For example, continuous caster planning, where liquid steel is turned to steel slabs, is a highly flexible production process requiring good skills of order aggregation, very different to those sequencing and assignment skills required by hot rolling mill planning. Scheduling problems across different industries might be categorised as to type of skill employed, so that information from other manufacturing and service sector applications may be used in requirements specification. This book will add useful insight for commercial software developers in specifying requirements for these future scheduling decision support systems.

11.9 REFERENCES


