Understanding planning for effective decision support

Mietus, Dirkje Magrieta

CHAPTER 8

CONCLUSIONS

8.1 INTRODUCTION

The principal notion underlying this thesis is the application of the skills, knowledge and rules acquired by the scheduler in the design of a computerized planning system for more effective decision support. This was investigated by answering the research questions:

1 Which skills, knowledge and rules underly the task performance of a planning task in nurse scheduling?

2 What role do skills, knowledge and rules play in the task performance of nurse scheduling with and without decision support?

3 What is the operational relevance of the skills, knowledge and rules for designing decision support for this planning task?

In the following a summary is given of the results and conclusions related to the research questions.

8.2 CONCLUSIONS

8.2.1 Understanding planning

Let us now turn to the first research question concerning the skills, knowledge and rules underlying the making of a schedule. The making of a schedule is organized into three aggregate tasks, viz. administration, problem solving, and evaluation. The performance of the administrative part is evident, whereas the problem-solving part is more demanding from a cognitive point of view; therefore, the problem-solving results need to be controlled, which is the main activity within the evaluation. In this study the emphasis was on the problem-solving aspects.

The first aspect of problem solving-based behaviour notable in the task performance is the acquisition of domain knowledge. Various types of domain knowledge are distinguished in nurse scheduling and discussed in chapter four, namely: knowledge of the schedule, knowledge of shifts, knowledge of personnel, knowledge of constraints and knowledge of goals. The acquisition of domain knowledge partially took place in the making of a schedule. The results revealed differences between the experts and the novices in the amount and the content of domain knowledge. In contrast with the experts, the novices lack the knowledge pertaining to the effective making of the schedule, such as knowledge of goals and knowledge of constraints. The novices possess knowledge of the schedule and some knowledge of the personnel such as can directly be acquired either from the framework of the schedule itself or from the personnel. Their knowledge is oriented to surface features within the nurse scheduling. The experts thus possess greater domain knowledge content than the novices.

The second aspect of problem solving-based behaviour emerging in the task performance is the scheduling strategy, discussed in chapter five. Performing the scheduling strategy consists of determining different tasks combined with the ordering of the tasks. The three groups of subjects revealed the same decomposition of the nurse scheduling task into the three aggregate tasks, namely, the administration, the problem solving and the evaluation. However, the task decomposition of the problem solving revealed a less homogeneous picture. Differences as well as similarities showed up in the problem-solving part between the experts and novices and even within the experts' group and the novices' groups. Similarities in the task decompositions among the experts are the task schedule a shift, the task schedule the head nurse and the assistant head nurse and the task schedule the deputizing. Within the expert group they differ in decomposing the task schedule personnel and the task schedule the planning period. Thus, even schedulers who perform at the expert level revealed a variety among themselves in decomposing the problem-solving part of the nurse scheduling task. The two novice groups revealed a comparable task decomposition within the problem solving that is even similar to that of the experts. The results for the experts and the novices agree with regard to the tasks schedule a shift and schedule the head nurse and assistant head nurse. However, only the novices performed the task schedule one staff member and schedule one day, implying that the novices decompose the tasks more than the experts with regard to the tasks schedule personnel and schedule the planning period. Experience with the nurse scheduling task is important for acquiring an efficient task decomposition.

Table 8.1 OVERVIEW OF TASKS PERFORMED MANUALLY BY THE EXPERTS AND THE NOVICES

	manual		
	experts	novices-p	novices-np
administration			
process personal data	+	+	+
determine fixed data	+	+	+
determine historical data	+	+/-	+/-
determine wishes	+	+	+
problem solving			
schedule the night shift	+	+	+
schedule the evening shift	+	+	+
schedule the day shift	+	+	+
schedule the off-duty shifts	+	+/-	+/-
schedule the head and ass. head nurse	+	+/-	+/-
schedule the deputizing	+	-	-
schedule the responsible qualified nurse	+/-	+/-	-
schedule the trainees	+/-	-	+/-
schedule the part-timers	+/-	-	-
schedule one staff member	-	+/-	+/-
schedule a weekend	+/-	+/-	+/-
schedule a week	+/-	+/-	+/-
schedule one day	-	+/-	+/-

legend: + = performed by the schedulers
- = not performed by the schedulers
+/- = performed by some of the schedulers within a group (= variety within one level of expertise)

An overview of the tasks resulting from the task decomposition is given in table 8.1

Another aspect of the scheduling strategy is the arrangement of the tasks in order to perform all the several tasks effectively. Performing tasks in a controlled sequence was rather demanding for the novices, especially for the novices-np (no practical training experience in hospitals) compared with the experts. Even the two

novice groups differ with regard to arranging the administrative tasks. The novices-np were not able to execute these tasks before they started with the problem solving, while the novices-p (practical training experience in hospitals) and the experts both performed very well on this part. A comparable result was found for the scheduling of a shift. While the experts and the novices-p schedule a strict sequence, namely, night-evening-day, the novices-np followed an opportunistic sequence. Thus, along with the task decomposition, the novices-p resemble the experts concerning the arrangement of the tasks belonging to the task schedule a shift. These similarities refer to the invariable part of a scheduling strategy. However, the novices-p have more problems executing each of these tasks all the way through. They skip to the next task before finishing it, while the experts perform these tasks consistently. Moreover, in scheduling the personnel or the planning period the novices soon fall back into the tasks schedule one person or one day, as the case may be. Even within the expert group variety was seen in arranging the tasks related to scheduling personnel or planning period with the exception of the scheduling of the head nurse and the assistant head nurse and the deputizing.

The experts' scheduling strategy can be characterized as script-based planning. When scheduling they make use of a mental scheme each time guiding the cognitive processes required in making a schedule. By consulting such a script a reduction on the working memory load is achieved, since it is easy to see where one is in the problem solving and which tasks are already done and which one is to be performed next. The experts performed the nurse scheduling task in a structured way. The novices' scheduling strategy is regarded as opportunistic planning. This means that the task performance depends on decisions which just come about -- they performed the nurse scheduling task in an unstructured way. The novices could not consult a comparable script as the experts had done.

In conclusion, the scheduling strategy attributed to the task decomposition and task arrangement plays a significant role in the nurse scheduling task. As well as having knowledge about the domain, it is also beneficial to perform a particular strategy for solving a complex task. Comparable findings that the performance of a complex task involves not only specific domain knowledge but also knowledge on strategies were also found by Schraagen (1994) who investigated an experimental design task for setting up research by comparing experts and novices. In addition one of his findings was that the use of strategies will lead to higher quality outcomes. In general, the quality of problem solving and decision making can thus be improved by making the performance of a task explicit, implying that the focus should be not only on the quality of the final results of the problem-solving process, but also on the way the task was dealt with.

The scheduling strategy consists thus of manageable tasks. In the execution of

these tasks the assignment of the personnel to a shift takes place. This refers to the third aspect of problem solving-based behaviour notable in the task performance and is discussed in chapter five. Four activities were distinguished in the scheduling in which personnel are assigned to shifts: selecting personnel, ranking personnel, assigning personnel, and lastly, building a pattern. Each of these activities is executed by the processing of rules that are inferences applied to domain knowledge. The experts performed the four activities successively, though it is possible to jump to one of the foregoing activities. By performing the selection and ranking of personnel first, the scheduler focuses on the vertical dimension of the schedule. The horizontal dimension, i.e., the course of time within the planning period of the schedule, emerges, then, when a pattern is built around the assigned shift. The novices performed a less elaborate scheduling procedure compared with the experts. They often skipped the activities rank and assign and strongly focused on building a pattern. The novices immediately jumped from select a person to building a pattern.

A major aspect of scheduling is maintaining the goals. The weighing of the nurse scheduling goals addressing personnel is done within selecting and ranking personnel, whereas the weighing of the nurse scheduling goals aimed at guaranteeing a high standard of care for the patients is done within the assignment of a shift and the building of a pattern. The novices did not perform the elaborate scheduling procedure, implying that they had acquired relatively simple rules and consequently, no attention was paid to the weighing of the several nurse scheduling goals. Characteristic of expert scheduling is the interaction between domain knowledge and the activities within the scheduling procedure.

Counting the quantity of staffing and the number of assigned shifts per staff member is needed to justify decisions made during scheduling, which must be performed according to labour regulations. In table 8.2 the different scheduling activities are summarized for the experts and the novices.

In conclusion, problem solving-based behaviour with respect to the manual performance of the nurse scheduling task is thus characterized by a well-acquired declarative domain-knowledge base processed in the execution of the tasks by inference rules, together with scheduling strategies consisting of a number of ordered tasks in order to deal with the ill-structured nurse scheduling task.

Table 8.2 OVERVIEW OF THE SCHEDULING ACTIVITIES BY THE EXPERTS AND THE NOVICES

scheduling	experts	novices
select personnel	+	-
rank selected personnel	+	-
assign shift	+	+
build a pattern around shift	+	+
maintaining the goals	+	+
counting	+	+

legend: + = performed by the schedulers
- = not performed by the schedulers

Another interesting aspect related to knowledge, rules and skills underlying the task performance was the result of the task performance, that is, the outcomes of the nurse schedule. This is discussed in chapter six. Not surprisingly, differences in outcomes were found between the experts and the two novice groups. Such differences are due to differences in the acquisition of domain knowledge. Domain knowledge of the quality of staffing for the night, evening and day shifts was less developed among the novices. The same was found for the nurse scheduling goals. Differences in outcomes can be attributed to a badly performed task, such as counting, in which a mistake can easily be made. This was revealed in the outcomes of the quantity of staffing, especially for the day shift. A more interesting finding is that the subjects within a group differ among one another in their outcomes. Even experts differ in their final solution of the outcome. Such a variety in schedule outcomes can be attributed to differences in the weighing of the several nurse scheduling goals. Another aspect that may explain the variety is the order in which tasks are performed. It is thus hardly possible to specify one generally accepted outcome for the (nurse) schedule. Accordingly, the issue of optimizing can be questioned for nurse scheduling. Moreover, the knowledge and experience that a scheduler has with making schedules play a prominent role in deciding which outcomes are acceptable for the schedule. Use of declarative domain knowledge, script-based planning and goal maintenance results in 'better' schedules. An objective criterion for 'good' schedules has not been established.

8.2.2 Comparison of the nurse scheduling task with and without decision support

The second research question invites a comparison between the nurse scheduling task performed with and without decision support. This is discussed in this paragraph in order to understand the altered demand of the task performance as the consequence of a computerized system. An overview of tasks and the role of the scheduler and of the ZKR system in the performance of the nurse scheduling task is depicted in table 8.3 under the manual and the decision-supported situation. Below an explanation of the table results is given.

Administration

The scheduler still performs the tasks related to the administration except for determining the historical data; that is now automatically done by the system. In practice, the scheduler needs to insert data that may change among planning periods, such as the wishes and courses. In this regard the demand of the performance of the administrative tasks would not change very much. The benefits of decision support lie in the fact that the system enables the scheduler to process the administrative data in a more structured way and moreover, these data are more accessible if asked for, since they can be accessed conveniently via the user interface. The availability of the historical data on the worked shifts in particular can be more closely examined in the problem solving by the scheduler compared with the manual situation. Decision support improves the performance of the administrative tasks by offering structure.

Problem solving

The differences between working with and without decision support are more remarkable within the problem-solving part. A scheduler has at his or her disposal the tasks provided by decision support, which in the case of the ZKR system are the three tasks belonging to the scheduling of a shift. When activating these tasks the ZKR system fulfils the role of a knowledge-based system. Moreover, these three tasks are sufficient to make a complete schedule. In addition, a number of tasks that are performed in the manual situation are now performed implicitly by the ZKR system, namely, the tasks *schedule the responsible qualified*

Table 8.3 THE COMPARISON BETWEEN THE NURSE SCHEDULING TASK PERFORMED MANUALLY AND THE NURSE SCHEDULING TASK AIDED BY DECISION SUPPORT FOR THE EXPERTS AND THE NOVICES

	manual			decision support	
	scheduler expert	scheduler novice	scheduler novice-np	scheduler epb	ZKR system
administration					
process personal data	+	+	+	+	-
determine fixed data	+	+	+	+	-
determine historical data	+	+/-	+/-	-	+
determine wishes	+	+	+	+	-
problem solving					
schedule the night shift	+	+	+	+	+
schedule the evening shift	+	+	+	+	+
schedule the day shift	+	+	+	+	+
schedule the off-duty shifts	+	+/-	+/-	+	-
schedule the head and assistant head nurse	+	+/-	+/-	+	-
schedule the deputizing	+	-	-	+	-
schedule the trainees	+/-	-	-	+	-
schedule the responsible qualified nurse	+/-	-	+/-	+	+
schedule the part-timers	+/-	-	-	+	+
schedule one staff member	-	+/-	+/-	+	-
schedule a weekend	+/-	+/-	+/-	+	-
schedule a week	+/-	+/-	+/-	+	+
schedule one day	-	+/-	+/-	+	-

legend: + = performed by actor
- = not performed by actor

epb = electronic plan board

nurse and *schedule the part-timers*. The results of the task *schedule a shift* enhanced these two aspects. When the scheduler wants to schedule as in the manual situation, then these tasks can still be performed manually. The ZKR system fulfils than the role of an electronic planning-board. Most of the tasks need not be performed any more by the scheduler when cooperating with the computerized system. The several tasks performed in the manual situation are in fact reduced to a limited number of tasks under decision support. This means that the schedulers are no longer burdened with the demand of decomposing the nurse scheduling task into smaller tasks. Moreover, the ZKR system supports a part of the manual task decomposition referring to the invariant part, implying that the scheduling task becomes clearly recognizable. However, the arrangement of the tasks is still required. The scheduler imposes the sequence of the tasks to be performed by the ZKR system. The planning aspect of the nurse scheduling task with regard to determining the tasks becomes of lesser importance in the task performance, since the scheduler has to deal with a restricted number of the same tasks in contrast to the manual situation. In conclusion: decision support reduces the number of tasks, fills in gaps and omissions of the scheduler and maintains flexibility for task distribution between scheduler and system.

Scheduling

If under decision support a number of tasks are taken over by a computerized system then it is obvious that this will also include consequences for the scheduling itself. In table 8.4 the tasks referring to the scheduling itself are compared for the two situations.

The greatest transformation from the manual task to decision support is revealed for the scheduling itself. Performance of the complicated scheduling procedure and searching for solutions are no longer necessary, while the use of domain knowledge, in particular maintaining the goals, is demanded in both situations. The experts and the novices did carry out these tasks in their task performance. In this sense it can be said that there is an active cooperation between the scheduler and the system. This can also be observed in a new aspect of the scheduling task under decision support, namely, judging and choosing among alternative solutions. The scheduler still has to use his or her domain knowledge, namely, in the judgment of the solutions; this is a new aspect of the nurse scheduling task. While the scheduler converges to one solution in the manual task performance, he/she judges alternative solutions when aided by the system. The scheduler has now thus a variety of solutions at his or her disposal.

The last task to be mentioned is counting, which is performed so many times in the manual task performance. The experts and the novices did not need

Table 8.4 OVERVIEW OF THE SCHEDULING ACTIVITIES PERFORMED BY THE SCHEDULER AND THE ZKR SYSTEM

scheduling	manual		decision support		
	scheduler expert	scheduler novice-p/np	scheduler expert epb	scheduler novice epb	ZKR system
select personnel	+	-	-	-	+
rank selected personnel	+	-	-	-	+
assign shift	+	+	-	-	+
build a pattern around shift	+	+	-	-	+
maintaining the goals	+	+	+	+	+
judging alternative solutions	-	-	+	+	-
counting	+	+	-	-	+

legend: + = performed by actor
- = not performed by actor

epb = electronic plan board

to perform the counting themselves. Moreover, the scheduler has at his/her disposal more precise and ‘up to date’ data under decision support.

In conclusion: some aspects of the manual task are partly incorporated in the computerized system --enhancing a restricted number of tasks offered, the scheduling process itself, the counting-- whereas other aspects which are still important, such as maintaining the goals, remain the responsibility of the scheduler. New aspects also emerged under decision support: the number of solutions offered and consequently, the judgment of solutions, by which the application of knowledge is broadened. The manual task differs thus from the decision-supported task; this would be reflected in some way or other in the role of skills, knowledge and rules underlying the task performance, which leads us to the other part of the second research question.

8.2.3 The task performance under decision support

Making a schedule aided by decision support, discussed in chapter seven, puts a particular demand on the nurse scheduler. The task performance of the scheduler is partly moulded by the computerized system. The first change is the role of domain knowledge. The scheduler shifted to emphasizing the knowledge of goals in the judgment of the solutions since searching for a solution is taken over by the system. This means that performing the rules/inferences is becoming less intensive for the scheduler. The problem-solving capabilities are improved by decision support since the solutions can be considered more thoroughly.

There is also a shift in using strategic knowledge. The scheduling strategy depends on the tasks offered by the system. This implies that the task decomposition is already determined. The scheduler's role is then to arrange the tasks, which they can freely choose. Some of the experts did not stick to the normal scheduling strategy they use in the manual situation. They experiment with it by tuning the task arrangement to their preference for a specific sequence, which is possible because of the flexibility in task arrangement provided for by the ZKR system. For instance, one of the experts performed the sequence day, evening and night shift instead of their usual strategy of the night, evening and day shift. They are guided by domain knowledge of the shifts in knowing that the day shift, in fact, needs to be scheduled first. The novices were able to deal adequately with the tasks offered despite lacking in-depth domain knowledge of the shifts, though they were not bound by a particular strategy. Moreover, it was possible to have the system perform each arrangement in tasks. The scheduler is more able to adapt the scheduling strategy to personal preference, resulting in a greater measure of flexibility. Tentatively speaking, the

ZKR system increases the variety in performing the scheduling strategy, among the experts in particular, since they were less restricted by their problem-solving capabilities. The schedulers are thus less hindered by cognitive limitations, which also results in performing the nurse scheduling task in a structured way. Related to this, the quality of the making of a schedule or, as the case may be, the problem solving, is improved.

The change in the scheduling itself is due to its partly being taken over by the system. Each task scheduling the day, evening and night shift was separately executed. Consequently, the scheduling by the scheduler enhances the judgment of the (five) solutions presented by the system. Each solution referring to a scheduled shift represents then a part of the schedule's outcome. The scheduler applies domain knowledge in judging the different solutions. The experts developed a preference while working with the ZKR system for considering one solution, while the novices checked all five solutions. The experts might have learned more quickly than the novices that the first solution offered was the best solution. They checked whether their domain knowledge, especially their knowledge of the nurse scheduling goals, was displayed in the presented solution and soon came to the conclusion that the first solution came closest. The novices did not make a clear distinction in hierarchy among the solutions. In conclusion: the most significant change between making a schedule with and without decision support is that attention is shifted to other activities in the task performance. In scheduling with the system some of the types of domain knowledge such as the knowledge of the nurse scheduling goals are more explicitly used, while, for instance, knowledge of shifts becomes less important since the quantity of staffing is automatically performed and counted as well. The processing of domain knowledge in the judging of solutions becomes a core activity. Besides, the scheduler is manually busy dealing with the several tasks, while under decision support this becomes less demanding. The task performance under decision support enhances for the most part the task arrangement with regard to the scheduling strategy, and regarding the scheduling, the judgment and choice of solutions.

When comparing the experts and the novices in table 8.3 and 8.4, the differences between them are greater for the manual situation than for the decision-supported situation. The nurse scheduling task is accessible to them in a structured way, which benefits the novices especially. This means that decision support makes not only the experts more competent in making a schedule, since they did make greater use of their strategic knowledge in the task arrangement and of their domain knowledge in judging the solutions, but also the novices. If in the manual situation the scheduler is dependent on his or her scheduling knowledge, in the decision-support situation the experts and the novices both have access to the same scheduling

knowledge processed in the scheduling. In this regard, the novice may have greater domain knowledge at his or her disposal compared with the manual situation.

The changes in the task performance lead to a different demand on the scheduler, or to put it in other words, a different allocation of the cognitive resources. So the demand on the working memory capacity decreases because of the fact that the scheduling itself is supported. The scheduler will therefore pay more attention to other aspects in the making of a schedule. The cognitive limitations play a less influential role since the number of tasks is reduced and the tasks are more efficiently performed. In this sense decision support leads to an improvement of the nurse scheduling task for the scheduler. The cognitive effort required is limited and less time is needed for making a schedule.

In conclusion: decision support still requires an elaborate use of domain knowledge. The role of task and strategic knowledge, however, becomes less demanding from a cognitive point of view under decision support. The same is also true for the rules applied in the scheduling; the stereotyped rules especially can be incorporated under decision support. Thus attention on understanding the knowledge and skills of the scheduler will lead to more effective decision support.

8.2.4 Effective decision support

From the comparison between the nurse scheduling task with and without decision support and the related task performance the operational relevance of insight in knowledge, rules and skills evolves for designing decision support. This sets up the answer to the third research question.

In the making of the schedule the scheduling strategy performed and the domain knowledge acquired characterize the task performance (chapter 4 and 5). Both aspects reveal the ill-structuredness of the task, and related to this, the complexity of the nurse scheduling task along with the role of the cognitive limitations. Decision support should help to deal with the complexity of problems and, related to this, the cognitive effort needed for solving such problems (Timmermans, 1991). This means for the design of decision support that: *decision support should be adapted to characteristics of the human task performance.* This guideline implies that the manual scheduling should be taken seriously. When the support is based on the manual task decomposition, the computerized system is then compatible with the actual task performance (Visser, 1992). Supporting the strategic aspects of the nurse scheduling task comprehends the organization of the tasks, which refers to the division into the administration, the problem solving and the evaluation

(chapter 5). De Jong (1992) made a comparable conclusion for the trip planning domain that a DSS should offer integrated support, though typical of DSSs is the support of tasks at a more generic level, implying that the planning task is supported to a lesser degree. Therefore *decision support should support the tasks up to the more detailed level of the scheduling (problem-solving) strategy*. However, schedulers differ from one to another in their scheduling strategy, implying that there is not just one way of making a schedule. *Decision support then needs to offer the possibility of adapting to different scheduling strategies.* Hoc (1988) also pointed out that a planning aid should take the individual differences into account.

When following the structure of the task, the requirement for a computerized system that can be deduced is the modularity of the system. In the ZKR system it was realised by not only supporting the administration separately from the problem solving, but also offering the scheduling of the shifts separately (chapter 7). The modularity of the ZKR system means that the nurse scheduling task is more structured and that a solution of the schedule is not computed in one step, but rather per task, whereby a partial solution of the schedule is offered. The scheduler will judge these separate solutions implying that domain knowledge can be added per partial outcome of the schedule. This results in the guideline: *decision support should offer an elaborate and thorough use of domain knowledge.* Insofar as it is hardly possible to capture all aspects of domain knowledge acquired by an expert, part of the knowledge will be kept implicit. Therefore, the ZKR system emphasized the judgment of the scheduler in the cooperation. Falzon and Visser (1989) referred to a comparable implication for decision support that the problem solver him/herself will be the best judge, especially when there is no one right solution. This leads to the following guideline for designing decision support: *decision support should facilitate manipulation of the proposed solutions*. The ZKR system did not offer ready-made solutions of the schedule but offered the possibility of manipulating the solutions by manual adaptations. The scheduler may adapt his/her goal functions during the judgment of the solutions (chapter 7). A computerized system should therefore support the user by being highly interactive and offer a sufficient degree of freedom (Hofstede, 1992).

The division of tasks between the user and the system supports the generic view that a computerized system should not replace but support. It is therefore useful that *an interactive system ought to be based on considerations about human and computer strengths and weaknesses* (Wickens, 1984). Waern (1989), among others, mentioned that people are good at creative tasks, intuitive problem solving (heuristics), and tasks with a low need for precision; on the other hand computers are good at repetitive tasks, algorithmic problem-solving, tasks with a high need for precision and can perform a routine check (p. 128). An example is the counting

within scheduling. Counting is a repetitive task that burdens the working memory leading to errors in the outcomes of the schedule. However, it is not the main task in scheduling and it ought not to cause errors. Decision support can take over such a task, resulting in a minimal load on the working memory (Hoc, 1988). On the one hand much computing work can more quickly and easily be performed by the computerized system. On the other hand the computer can function as an extension of the short-term memory by keeping partial solutions or by offering several solutions. By searching for solutions the scheduler is relieved of complex reasoning which took up a great part of the working-memory capacity. *The responsibility for the final schedule which is operational on a ward, however, remains with the scheduler.*

When these guidelines are taken into account into the design of a computerized system, then, effective decision support will be achieved. Effective decision support stimulates a structured way of performance and improves the problem-solving capabilities. It should include procedures that compensate for the shortcomings of a problem solver. Then it is better adapted to the scheduler, and the system and the scheduler cooperate in solving complex tasks. However, these guidelines can only meaningfully be incorporated into the design when the problem is elaborately analyzed by a cognitive task analysis, because then decisions can be made based on the right grounds. It would be useless to design decision support when one does not know what needs to be supported. Therefore an important guideline is that *a cognitive task analysis should be the basis for designing effective decision support.* Moreover, if *the knowledge and skills are not taken into account then the design lacks cognitive validity.* This is important since then the user understands the performance of the system because it is comparable to the daily practice of making a schedule. Besides, one also knows what the system needs to do. The system is better grounded in the daily practice of solving the complex task. Then it is expected that decision support will improve the quality of decision making. The improvements resulting from the use of the ZKR system compared with the manual nurse scheduling task performance are that the scheduler considers more solutions, more attention can be given to the maintenance of the goals, difficult tasks are performed by the system and the scheduling strategy can be performed flexibly. Moreover, the making of a schedule is less time-consuming. It should, however, be noted that the nurse scheduling task under decision support differs in a qualitative nature from that of the manual situation. This means that unforeseen situations may happen. In the following section the question whether the findings and conclu-sions can be generalized is discussed.

8.3 GENERALITY OF THE RESULTS

The question to be considered when ending any research study is the generality of the results. What can others learn from this research? Results related to the domain of nurse scheduling can be used in other (manpower) planning domains in which comparable issues play a role. One such issue is that schedulers used vaguely defined goals in the making of a schedule making it hard to indicate what is understood by an optimal solution.

Findings related to the task performance as a consequence of the ill-structuredness of the nurse scheduling task can be generalized to other complex domains such as a diagnostic domain or a design domain. Dealing with complex tasks consists of the acquisition of domain knowledge along with the acquisition of a specific strategy. It is expected that performing a specific sequence of tasks, such as schedule the night shift and so on, will also be seen in the task performance in other manpower planning domains. Although, one needs to be prepared for the fact that even experts can differ one another in solving problems.

The guidelines for effective decision support can be generalized to designing more advanced computerized systems; since they are generic in nature and found in other research as well, they can therefore be considered as more general guidelines.

8.4 FUTURE RESEARCH

It would be interesting to investigate further the hypotheses that are tentatively tested in this research in an experimental setting in order to understand planning and scheduling knowledge better. Hypotheses referring to differences between schedulers at the same level of expertise need to be further investigated. A more thorough testing of hypotheses concerning a comparison between the experts and the novice schedulers will offer insight into the learning of the nurse scheduling task. The planning skills, especially insight into activities performed automatically, need to be paid further attention in nurse scheduling. It would also be interesting to perform comparable research in other manpower planning domains in order to further generalize the results.

Other interesting research would be a further investigation of the influence of decision support on problem solving and decision making, since solving a problem under decision support is quite a new task that may bring along unexpected changes in the organization. Schedulers might use the system to back up their argument why a person is assigned to a specific shift. Experiences with the ZKR system can shed

light on this. It is expected that the nurse scheduling policy may also be influenced by decision support: 'new' data is accessible to which the policy is tuned and adapted (chapter 2).

Also future research that aims at understanding ill-structured problems should standardize a cognitive task analysis. It is a useful method of investigating in a systematic way the knowledge and skills underlying the task performance without and with decision support (chapter 3). Although it is time-intensive, a cognitive task analysis stimulates the schedulers to make a schedule as they are used to in their practical setting by which it is made clear what kind of difficulties can be met in practice. Hereby an understanding of the problem in context overrules the problem moulded into some theoretical model. A cognitive task analysis attempts first to understand the richness of the real world which is benefiting since complex organization problems do not have a strictly technical nature. Moreover, the role of the problem solver is more prominent in such problems. The knowledge acquisition lays open the knowledge and experience gained in dealing with the organization's problem. When a better understanding of the problem is gained then the organization is more able to decide what kind of solution to a problem is appropriate. In addition, the insights from the cognitive task analysis can then be processed in shaping the solution. This was, in fact, the course taken for the development of the ZKR system.

Cognitive task analysis' importance is enhanced when organizations are viewed as knowledge-intensive entities. The organization is becoming more and more dependent on the knowledge carriers whether they are humans or machines. An important catalyst to such organizational change is knowledge technology (Simons, 1992). A cognitive task analysis helps then by offering insight into the knowledge aspects embedded in the organization. Understanding the knowledge, rules and skills will then lead to improvements in not only computerized systems by which effective decision support is achieved, but also to improvements in the business processes itself.