Scheduling the scheduling task : a time management perspective on scheduling

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Abstract

Time is the most critical resource at the disposal of schedulers. Hence, an adequate management of time from the schedulers may impact positively on the scheduler's productivity and responsiveness to uncertain scheduling environments. This paper presents a field study of how schedulers make use of their time and makes explicit what time-management decisions and behaviors are available to a scheduler. Based on observations of the field study, we propose a framework to classify and specify key characteristics of common tasks to the scheduling job in terms of their impact on the workflow and workload of a scheduler. We then discuss how such a framework may be used to assess alternative time-management decisions of a scheduler.

Keywords: Scheduling, time-management, responsiveness, workload, workflow

1 Introduction

Production scheduling is an important function for the operational performance of a company's supply chain. From an Operations Research perspective, scheduling can be defined as allocating tasks to resources in time (Pinedo, 2005). Contrary to this mechanical view on scheduling, various studies have highlighted the importance of the role of the human scheduler in interpreting information, dealing with exceptions, identifying and anticipating problems before they occur (McKay and Buzacott, 2000, McKay and Wiers, 2003).

The human scheduler's job is multi-faceted: from actively disseminating information to monitoring orders, stocks; from negotiating due dates to informing or assisting colleagues, it encompasses a variety of roles and tasks which must be accomplished (Jackson et al., 2004). Some authors have proposed task models where a sequence of steps is identified (e.g. McKay and Buzacott, 2000). However, it is not clear how tasks are executed over time in the scheduling function, nor what can be done in terms of managing the scheduler's time as a resource.

This paper presents a study where the tasks of the scheduler in time are investigated, including how these are triggered and their impact on the workflow of the scheduler. The tasks are analysed to highlight the available time-management decisions made by the scheduler. In the study, a time-management framework is developed by building on a theoretical framework used for describing white-collar work at the task execution level (Hopp, 2009). This basic framework is then complemented and applied to the scheduling setting by using a detailed field study that mixes survey and direct observational data from 7 schedulers followed during entire 8-hour shifts The framework can then be used as a basis for analyzing and implementing future improvements in the scheduler's usage of time to attain responsiveness and productivity.

This paper is organized as follows. Section 2 provides an overview of the scheduling function including what are its most common goals and performance metrics. In Section 3, Hopp's (2009) general framework for white-collar work is presented. In Section 4, the methodology for developing the general framework work is presented. In Section 5, the results of the methodology together with the general framework for characterizing the workflow of schedulers are presented. Conclusions and implications of the developed framework are given on Section 7.

2 Scheduling Task Models and Time Management

2.1 Scheduling tasks models

Production scheduling is a well-studied domain: the first books on scheduling appeared almost half a century ago (e.g., Conway et al, 1967; Baker, 1974), and since then, a vast amount of literature has been published on the topic of production scheduling (for an overview see Pinedo (2005). Although most of the research has been carried out from an Operations Research perspective (Dessouky et al, 1995), there has been a growing interest for the human aspect of scheduling (Crawford and Wiers, 2001, Fransoo et al (Eds.), 2011). Models that describe the scheduling task have been proposed by various authors, such as Sanderson (1991), Wiers and Van Der Schaaf (1997), Wiers (1997), McKay and Buzacott (2000), Jackson et al. (2004). Both Sanderson (1991) and Wiers and Van Der Schaaf (1997) base their scheduling task model on Rasmussen's (1986) decision model, which has three levels: skill-based, rule-based, knowledge-based. Wiers and van der Schaaf use a simplification of this: their model makes a distinction between repetitive tasks that can be carried out in a mechanical way, and exceptions that need human problem solving activities.

An extensive effort on scheduling task models has been carried out by Jackson et al. (2004), who make a distinction between three kinds of activities or functions that a scheduler serves. The model is shown in Figure 1.

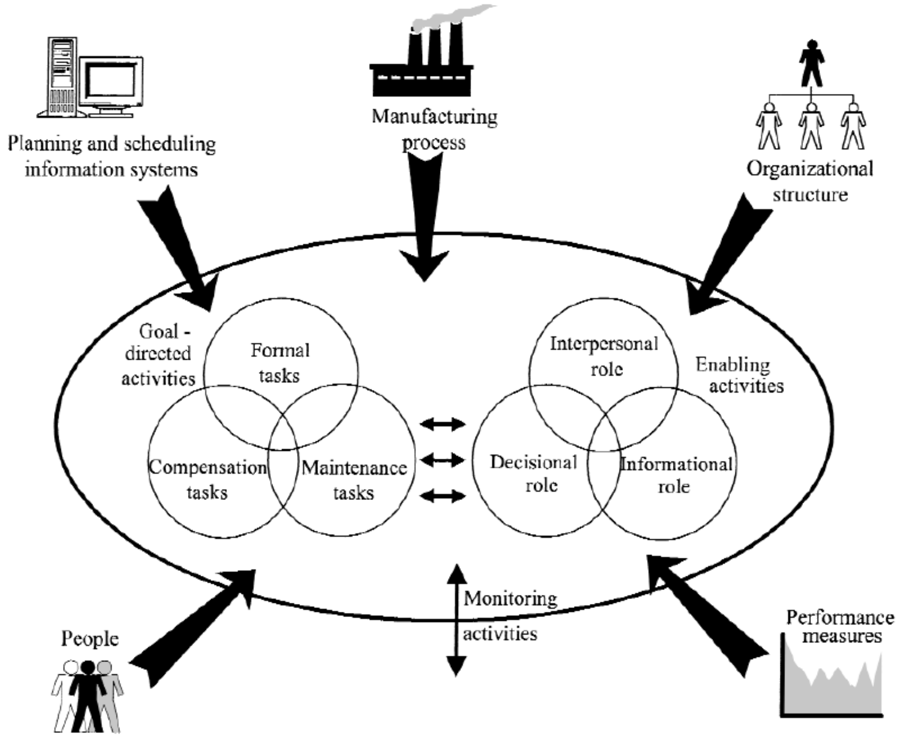

Figure 1: Model of scheduling tasks and roles (Jackson et al., 2004)

Firstly, there are the *goal oriented* activities that includes the formal *tasks* described on the scheduler function (i.e. scheduling itself) as well as other maintenance (e.g. data maintenance) and compensatory tasks (e.g. rescheduling) that support the formal tasks. Secondly, to enable the goal oriented activities, the scheduler also fulfills *enabling activities* in a number of *roles*. These include a decisional role (e.g. production orders, use of extra time), a role in which information is received, used, researched and disseminated and an interpersonal role where relationships are built for gaining access to information, being able to relax constraints and ease implementation of schedules. Thirdly, the schedulers engage in *monitoring*, anticipating any problems and the need for rescheduling.

Whereas Jackson does not prescribe a sequence in which the various roles and tasks elements should be carried out, McKay and Buzacott (2003) present a 7-step sequential scheduling task model, which is given in Figure 2. In McKay and Wiers (2004), the task model from McKay and Buzacott is described more extensively, indicating that the scheduler needs to divide his or her time between immediate problem solving and mechanical scheduling. It is suggested that the scheduler can switch between monitoring or situation assessment (step 1), exception handling (steps 2-4), monitoring again, or problem anticipation (steps 5 and 6) and mechanical scheduling (step 7). The sequence provided is a logical series of steps, but does not give information on how to divide the scheduler's time, and how the scheduler should decide to stop for example mechanical scheduling and start crisis identification.

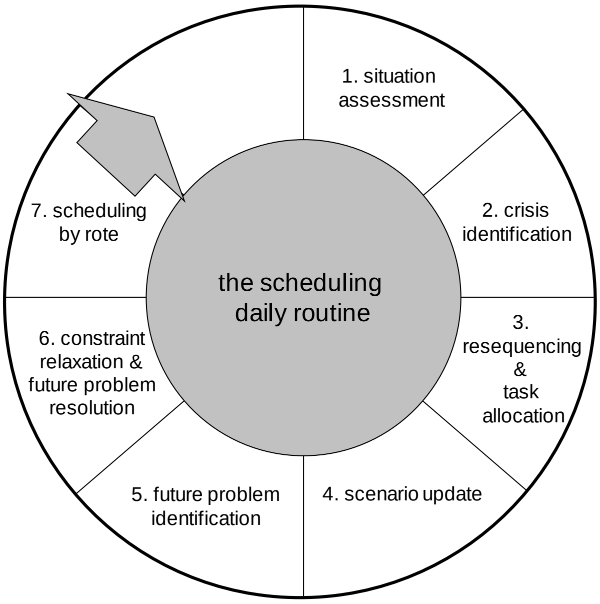

Figure 2: Scheduling Task Model (McKay and Buzacott, 2003)

To conclude, the reviewed scheduling models identify the elements of the scheduling task and a possible sequence to carry out the various sub-tasks. The models also make clear that there is a continuous tension between executing the ‘normal’ decision making and reacting to exceptions. The existing models do not make clear how schedulers deal with this conflict, in particular in the presence of stochastic events (e.g. resources failure, unexpected customer orders) that may alter the scheduler’s workflow. In other words, time-management in the scheduling task is an unexplored domain: switching between the different modes of the task. An analysis of time-management in the scheduling task is absent from models reviewed by Cerraga and Van Wezel (2011) in their paper on the objectives of scheduling task models either for designing decision support or training. Describing and explaining how different modes of task are executed over time is challenging when we observe that the scheduling context is asynchronous where schedulers are constantly gathering information that is not instantaneously relevant to the task at hand Wiers and van der Schaaf’s (1997).

2.2 White-collar task models

From an operations management perspective, Hopp and Van Oyen (2004) define *tasks* as a *process* that through the use of *labor*, *entities* and *resources* accomplishes a given objective. The labor refers to workers; the entities refer to the objects being worked on (e.g. a part, a customer or for our purposes a schedule); the resources refer to anything the workers need to accomplish the task.

Based on this perspective of a task, Hopp (2009) develops a framework to describe the white-collar worker as a production unit. Hopp’s (2009) framework can be used to model time related measures (e.g. average waiting time, throughput). The framework is applicable also to the scheduling job as it fits Hopp’s (2009) description of white collar work (i.e. work that requires intellectual, problem-solving skills and often creativity). Indeed, schedulers have been described by McKay et al. (1995) as problem-solvers that also anticipate problems and often seek non-conventional solutions to problems that have not been faced before.

In Hopp’s (2009) framework tasks (or work packages) are triggered by either of two types of entities (see Figure 1): exogenous entities and endogenous entities. Exogenous entities are external requests to the individual by any of his stakeholders. For example, in the scheduling context, an exogenous entity may be a request by a sales representative to be informed about the status of a customer order. On the other hand, endogenous entities are internally generated items that are done at the initiative of the white-collar worker himself. An example of an endogenous entity is the initiative of a scheduler to conduct a check on the progress of the released production order to avoid any future capacity problems.

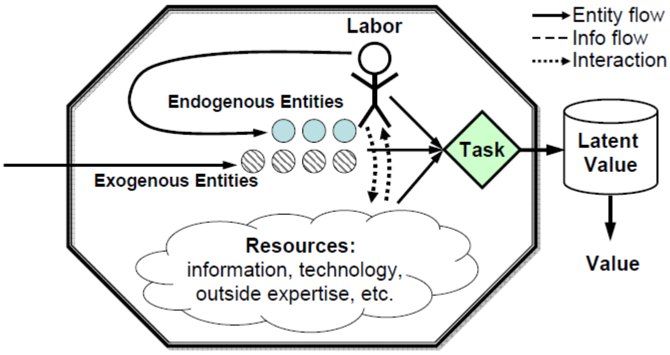

Figure 3: Individual white-collar framework (Hopp, 2009)

Importantly, Hopp's (2009) framework highlights the discretion of the white-collar worker in sequencing the tasks to be executed and spending more or less time on them. Furthermore, the model includes resources that add value to the task. In the context of scheduling, these resources may include Advanced Planning Systems, ERP systems as well as information from colleagues.

2.3 The importance of time management

In this paper, we argue that one reason why the current available descriptions of the scheduling function are incomplete lies in the time dimension where a diverse number of tasks are executed. The impact of interruptions, self-interruptions, postponements, periodic tasks among others on the workflow of the scheduler has still yet to be recognized explicitly in the analysis of the scheduler. The reviewed task models make clear that there is a distinction between the more mechanical part of the task and dealing with problems or exceptions. This implies that the scheduler constantly has to juggle between 'getting the job done' and 'putting out fires'.

Consider for example the case of a rush customer order that was not included in the schedule today, because initially it was not deemed as critical. Because the scheduler 'forgot' to review potential rush orders before releasing the schedule, it was overlooked. Not including such customer orders or including it at a later stage may result in a severe loss of customer goodwill. Consider also a counter-example where a scheduler monitors the stock movements periodically and as a result is able to anticipate capacity problems of a production unit in advance. Being able to do so in a timely manner may mean that the production unit may be able to react quickly and allocate extra-time and thus cope with the capacity problem.

In both cases, it is evident that time-management decisions like postponing the checking of rush orders, and the frequency of checking stocks (monitoring) may have important consequences that may even outweigh the consequences of the correcting (maintenance) actions themselves. These consequences relate to the responsiveness of the scheduler to problems that arise or may arise in the future. Furthermore, such time-management decisions influence the productivity of the scheduler, in terms of the time spent on the scheduling task and the time that is left for enabling activities (Jackson et al., 2004) as well as the smoothing of workload that have been found to affect the quality of decisions (Gonzalez, 2005).

The importance of time-management for the scheduling job also arises from the fact that the scheduling context via stochastic and cyclical events may impose different requirements in terms of time-management. The fact that the scheduling environment should be described also in terms of time is highlighted by Cegarra's (2008) typology for classifying the scheduling job. Cegarra (2008) identifies seven dimensions for classifying the job environment and four of them relate to time: the steadiness of the process, time pressure, cycle synchronicity of planning horizons, and the continuity of the process.

However, despite its criticality, in the scheduling practice there are no guidelines specific for schedulers on what time-management decisions are available and what behaviours affect their use of time let alone how these decisions should be taken in different scheduling contexts. The same problem persists in the scheduling literature, where despite the enlarged vision of what the scheduling function is (Fransoo at al. (Eds.), 2011), there has been no explicit consideration of the role of time on the execution of the scheduling job.

Recognizing that the execution of tasks in the scheduler function does not follow clear step-wise patterns, our contribution to the literature is two-fold. First, we contribute by characterizing the typical workflow of a scheduler, detailing the reasons behind the seemingly chaotic pattern of the daily timeline of a scheduler. Second, we contribute by specifying the available time-management decisions and detailing what information and considerations are needed for taking such decisions.

3 Planning environment

This paper reports a field study at a planning department of a Fortune 500 chemical corporation. In the planning department, 12 planners and 36 schedulers are co-located in a single facility. The planning department is a separate entity in the chemical corporation that provides planning and scheduling services to other entities of the company. The planning department provides services for all European production and distribution facilities. The planning department is in effect part of the trend to centralize planning and scheduling operations by collocating personnel in a single facility.

The advantage of a Control Tower as setting for a conducting a scheduling field study is that it provides the opportunity to collect data from different scheduling environments where a diverse array of tasks are executed. The diversity in effect, makes the conclusions of the analysis to be more context-free and thus generalizable to other dynamic scheduling settings (McKay, 1990). In this way, for example, 3 of the schedulers worked in a scheduling environment that worked in a predominantly “make-to-stock” basis and 4 schedulers worked in a scheduling environment worked in a predominantly “make-to-order” basis. There was diversity also in terms of the number of products or Stock Keeping Units scheduled in the seven schedulers studied, ranging from 30 to 500. In addition, the number of plants scheduled by the observed scheduler was diverse, ranging from one to four production plants. The geographical scope of the customer base addressed by each scheduler also varied widely from 5 countries to customers worldwide (about 60 countries).

The objective of the schedulers in the planning department is twofold: first, to produce high quality schedules and second, to provide timely feedback about the schedule to stakeholders in the organization. The goals of the schedulers involved in the study are in line with a study by De Snoo et al. (2011) who distinguish between product and process performance. Snoo et al. (2011) conclude that 45% of the respondents think it is more important to provide quick responses to the schedulers' stakeholders (i.e. responsiveness) than to optimize planning and scheduling decisions (i.e. optimization). If uncertainty of the scheduling environment is high (referred to by Wiers (1997) as "stress" shops), the percentage of respondents that consider responsiveness of a greater importance than optimization goes up to 55%. This highlights the need to study the time dimension in the scheduling job and time-management strategies to increase responsiveness at the job.

For the case studied, from a sample of 21 schedulers, from a list of six priorities, the top three priorities chosen were: 1) Avoiding lost sales; 2) Minimizing delays and 3) Quick response to requests from plant and sales personnel. In Snoo et al's (2011) classification, the first two priorities can be related to product performance whereas the third as process performance. From the case we may infer that time-management is thus important given the priorities mentioned. Whereas the third priority is directly related to time-management, a timely delivery of a complete schedule may also impact positively on the first two priorities.

In the cases observed, requests and interactions with the scheduler involved a diverse array of stakeholders, including: production and packaging plant managers which are the main users of the schedules; customer sales representative to coordinate the fulfillment of special customer orders; marketing that establish production quotas in case demand systematically exceeds supply; supply chain planners that set the long term capacity indicating shutdown periods of production plants and determining from which plants to source regional European markets and logistics planners in-charge of arranging the transport of products from plants to the customer.

4 Methodology

The field study conducted is framed in McKay's (1990) typology of production planning field studies as that of *deriving* insights from the case. This means that a specific problem, in this case the complexity of the scheduler workflow, is to be characterized from the data observed from the case. Nonetheless, it is important to note that our approach is in effect, a compromise between "studying the scheduler" with a preconceived "model" and "learning from the scheduler" by direct observation (McKay and Wiers, 2003). We use Hopp's (2009) preconceived model to be complemented, not only tested, by the field study. The field study in itself consists of two sources for gathering data; a survey, and a direct observation protocol. In the context of case study research (Hak and Dul, 2008), the presented case can be considered of the theory-building type where concepts to describe the usage of time by schedulers are identified.

The 7 schedulers that were studied were selected based on the fact that they had at least 6 months of experience on the job, where available at the days of observation and; overall, added diversity to the sample in terms of years of experience and scheduling environment (e.g. number of SKU's handled, push versus pull and number of production facilities handled).

4.1 Survey study

A general survey was applied to each of the 7 schedulers present in the Control Tower at the time of the study. The survey was used to obtain information about the basic characteristics of the scheduling environment, including the number of production plants, distribution centers, products handled, whether most of the products are “made-to-stock” or “made-to-order”, the main priorities of the job, the scope of the job (main tasks), main stakeholders, which tasks are done periodically (at what frequency and if special times where reserved for them).

4.2 Observational study

For gathering data that can be used to characterize the workflow of a scheduler, a survey methodology may be too limited because it may be unrealistic to expect that schedulers may faithfully recall all the tasks and sequence that have been executed during a day (Crawford et al, 1999 and McKay, 1990). In fact, when we compared
the self-reported frequency in which schedulers engaged in certain activities (e.g. re-schedulers to accommodate orders) with the actual frequency based on the observational study we found no correlation.

For this reason, we relied on in-situ observational data collected directly by researchers using an evolving pre-defined scheme based on Hopp’s task model (2009) and Jackson et al.’s (2004) classification of the scheduling roles. The observational study was used to obtain information about the activities of 7 schedulers for a number of shifts - 19 scheduler-shifts in total. For reasons of availability, not all the schedulers where able to be observed the same number of days; however, each scheduler was observed for at least two shifts.

Although, the observational data was collected under a scheme on the aforementioned frameworks, it needed to be completed with the experience of the scheduling job itself. To complete the scheme, we adopted an iterative procedure, identifying features required to describe the usage of time by schedulers that were initially not identified. The guiding question in designing the observational method was: do we have enough measured elements to later reconstruct the day of a scheduler in terms of the tasks executed and to observe how particular demands of the scheduling job are handled over time?

The field study methodology was refined during two site visits. In a first visit, a researcher observed two consecutive complete shifts of a scheduler. The researcher then developed a preliminary scheme to classify activities and the communication medium used. In a second visit, four researchers were, each, assigned to a given scheduler to observe its job. The last 3 hours of the first day in the second visit, the four researchers tested the applicability and completeness of the preliminary scheme developed by the single researcher on the first visit. In effect, this debrief procedure was a semi-structured interview (Crawford et al., 1999). After the first day, among the four researchers, the completeness of the options, the ease to fill-in the scheme in a spreadsheet and the definition of what a task is, where all discussed and modifications where agreed upon. In particular, the spreadsheet was simplified to be able to record tasks in a sufficiently quick way to be able to follow the scheduler’s workflow. Also, the tasks granularity was established in a pragmatic way that is consistent with Hopp’s (2009) definition: a single task is finished with a deliverable to a stakeholder (e.g. a schedule, an instruction, a report, an information e-mail, call or chat). This granularity level of the task meant that all sub-tasks that lead to one deliverable where collapsed into one

The data collected in the observational study included information related to the workflow described by Hopp (2009), namely, the starting and finishing time of each task and how the task was triggered either exogenously or endogenously and the reason why it was triggered (supply-side reasons or demand side reasons). In addition, on a first visit, it became obvious that tasks had different reasons for not being completed all in one "go": whether the task was finished, interrupted by others, self-interrupted or required further input or processing by another party. This data also allowed also to distinguish between decisions of the scheduler in terms of time-management (self-interruption) or conditions imposed by the scheduling environment (interruption by others). To identify whether a task is not a new task but rather, a resumed task that remained incomplete, the first time a task is executed but not finished is given a unique identifier. Subsequent references to such identifier imply that the task been executed had been executed before but left incomplete.

Using Jackson et al.'s (2004) framework, the data also included the role the scheduler supports support (i.e. decisional: scheduling, re-scheduling; informational: information provider, information user (e-mailing), standard reporting; other: processing documents such as delivery notes). In addition, given the predominance of the informational role in the scheduling's job we also included the type of communication medium used (i.e. face-to-face, telephone, e-mail and internal chat).

5 Workflow characterization

The development of a new workflow characterization was deduced from two sources: firstly, the process of data collection itself, where new observations previously not accounted for required adjustments in the data collection scheme, and secondly, the data collected itself. The objective of developing a systematic characterization of the workflow, is to reconstruct the timeline of the scheduling day as illustrated in Figure 4 and thus identify the elements that are necessary for its description.

Task description	Task ID	Workflow
Analyzing possible production orders sequences	Scheduling1	Self-interruption
Meeting with plant, asking for additional feedback on capacity and stocks		Finished
Asks CSR to delay orders to free capacity at the Bulk plant	Scheduling1	Was interrupted
Issue with delivery note: customer requires material later		Finsihed
CSR asks: Checking if out of stock is solved, it is an old case, it is solved		Finished
Checks mail, FYI, sales issue		Finsihed
Updating drum filling execution plan	Code002DR	Self-interruption
Break/idle		Finished
Updating drum filling execution plan -asking CSR to make order change	Code002DR	Finished
Checking e-mails		Finished

Figure 4: Fragment of data gathered during a scheduler's day

First and foremost, the observed tasks themselves are a necessary element needed for characterizing the workflow in the scheduler's job. The tasks were categorized according to the scheduler's role they support with the model from Jackson et al (2004) providing the starting point. The tasks were classified in the roles they supported during the data collection. However, after each data collection day, the classification was reviewed, and new cases were identified. In particular for tasks attached to specific roles of the scheduler that were previously unobserved, a decision among the observers was required.

Next, for explaining how tasks originate, we used the concept of endogenous and exogenous triggers as introduced by Hopp (2009). This became self-evident in the observational study.

For example, in Figure 4, the task identified as Scheduling1 is triggered *endogenously* as the scheduler at its own initiative anticipates the plant's need for production orders. On the other hand, the task related to an issue with the delivery note is triggered *exogenously* as a result of a customer sales representative. Hence, explaining how tasks start with triggers is a second element should have.

A third element required to describe fully the scheduler's day are the time management decisions of the scheduler himself. The fragmented nature of the workflow of the scheduler can be explained partly by time management decision. Consider for example in Figure 4 how the task identified as Scheduling1 in 9:42 is self-interrupted at 9:42 AM to be resumed later. The fact that the scheduler himself interrupts a task instead of it being a consequence of an external interruption demonstrates the influence of time-management decisions by the scheduler. Task, triggers and time-management decisions are the elements of the workflow characterization that are described below in detail.

5.1 Task typology

For developing the task typology we use the model presented by Jackson et al. (2004) as a starting point. However, whereas Jackson makes a distinction between activities that are goal oriented, i.e. tasks, and activities that fulfil a social position, i.e. *roles*, we use the roles as starting point to classify the tasks. The reason for this is that we see a role as something which is fulfilled by a task and reversely, every task is carried out from a specific role. We used the observational data to confirm and complement the roles proposed by Jackson et al. (2004). The resulting roles which we have used to classify the observations will be explained below:

- In the *decisional* role, the scheduler makes decisions about the schedule, including the production sequence and the choice for a specific resource. In the classical definition of scheduling, this role is seen as the most important (the only) part of scheduling (McKay and Wiers, 1999).
- The *monitoring* role is fulfilled by keeping an eye on several aspects of the involved resources: stock movements and demand (in SAP), production execution (in tailor-made systems per plant), truck deliveries (in SAP) and raw materials stocks (in SAP).
- In the *informational* role, we include two tasks modalities, when the scheduler uses external information from external parties by directly requesting this or when the scheduler uses internal information. Notice that the scheduler also generates information, but this is typically part of another task such as scheduling and thereby difficult to distinguish clearly.
- In addition to the roles detailed in Jackson et al. (2004) we have identified a significant time spent by schedulers in what could be defined as the *transactional* role. In this role, the scheduler conducts tasks that are part of the procedures of the business. For example: to arrange a delivery note to transport a customer order, or updating the master data with a new stock keeping unit.

Next to this, we clustered tasks according to their description in a small number of categories within the roles, based on the observational data on the actual job content. We organize these under the scheduler role they support obtaining a hierarchical structure as shown in Figure 5. It is interesting to note that the distinction of scheduling vs. re-scheduling has different consequences from the point of view of workflow. While scheduling is done in a cyclical manner for pre-defined horizons, re-scheduling is done as a result of a disruptive, unexpected event and thus is not done at regular time intervals.

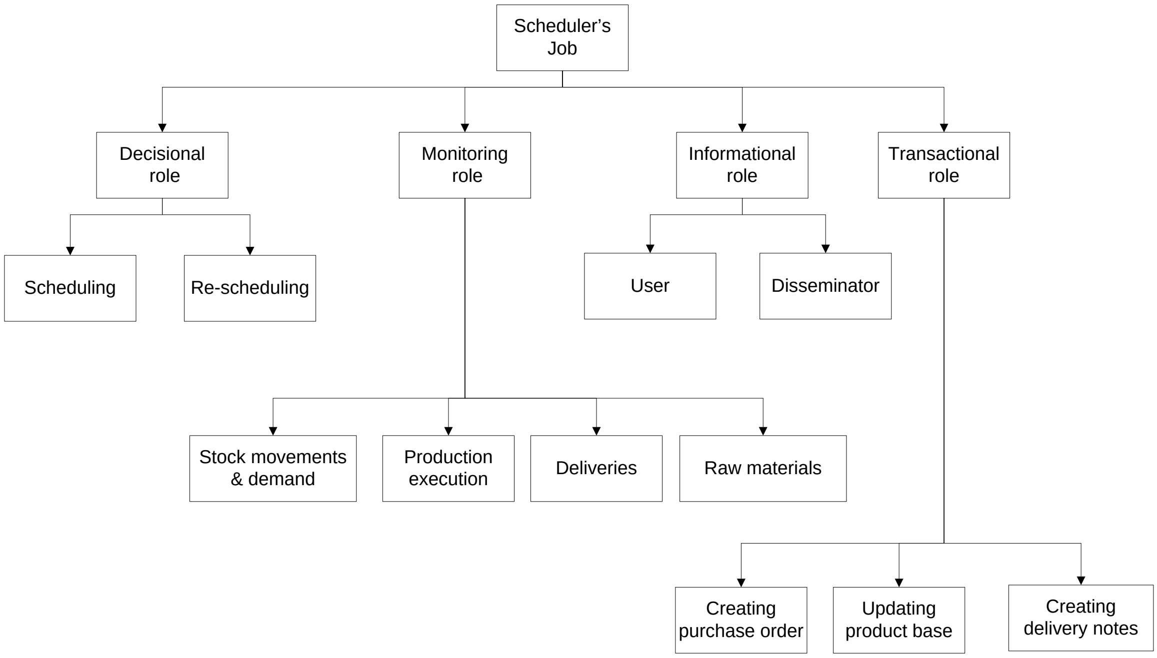

Figure 5: Taxonomy of task content

By timing and associating different tasks to the job content and the role the task fulfils, it was possible to quantify how time as a resource was used and distributed among the different roles. In the case studied, time as a scarce resource was primarily used in fulfilling the *informational* role and then the *decisional* role with significant time spent still on fulfilling the *monitoring* and transactional *role* (see Table 1). Further decomposition of the informational role indicated that the scheduler invested considerable time as both disseminator and user. This result demonstrates the position of the scheduler as a 'knowledge broker' in the organization. A further breakdown shows a roughly 50-50% division between disseminating and using information.

Table 1: Time allocated to different decisional roles

Scheduler	Decisional	Informational	Monitoring	Transactional
1	33.6%	53.8%	6.1%	6.5%
2	41.2%	36.5%	11.5%	10.8%
3	20.2%	52.9%	12.7%	14.3%
4	43.9%	34.8%	15.0%	6.3%
5	15.4%	57.7%	8.4%	18.6%
6	28.0%	43.6%	5.1%	23.3%
7	24.0%	63.9%	6.0%	6.0%
Total	**29.5%**	**49.0%**	**9.2%**	**12.2%**

The results from the study are relevant for identifying business process improvement opportunities. For example, the time spent on certain informational role tasks may be questioned. It was observed that two schedulers had to manually relay information to customer sales representatives regarding the status of certain production orders because of a delayed update of the SAP system, spending time that could otherwise be used for monitoring or decisional activities. Also, certain transactional activities, like issuing delivery notes may be further facilitated with more automated processes.

5.2 Task triggers typology

A second aspect considered in the description of the scheduling job, is to describe how the task is triggered. For developing a framework of this aspect we use Hopp's (2009) perspective as basis and complement it with observations from the field. Based on the case observations, it was concluded that exogenous triggers can either forcibly or non-forcibly interrupt the scheduler. For example, requests that arrive by e-mail are non-forcibly interrupting tasks as the scheduler may decide when to read his e-mail and when to react to it. However, if a planner phones a scheduler, the scheduler is forced to interrupt his current task.

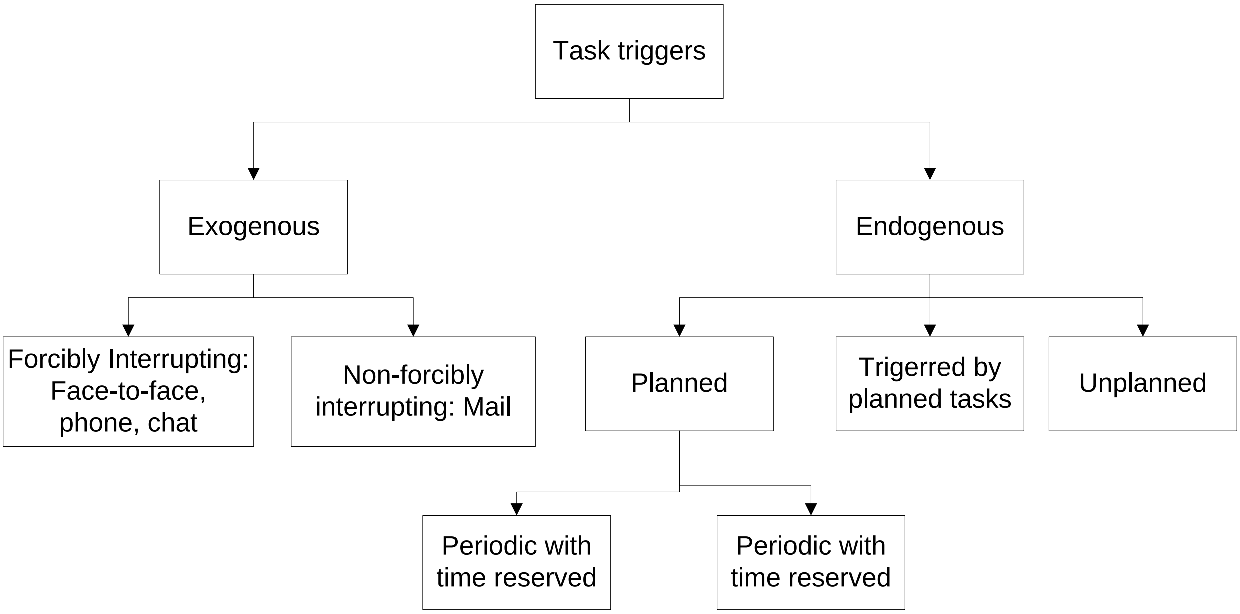

Figure 6: Taxonomy of tasks triggers

Endogenous tasks can also be sub-divided in categories: 1) planned triggers that refer to deliberate decisions to plan to execute a task, 2a) periodic triggers with special reserved times, for example, certain schedulers checked the status of production orders every three hours, or in the morning and late afternoon, 2b) triggers *as a result* of periodic monitoring tasks, such as re-scheduling when detecting a problem with the current schedule when monitoring stock movements, and 3) unplanned triggers, e.g. when the scheduler decides to execute a task at a time not scheduled in advance nor triggered immediately by a monitoring task.

In the case studied we found that occurrence of types of triggers varied widely across scheduler. On average, most activities seem to be triggered endogenously (see Table 2). The study also shows that most exogenous interruptions are of the non-forcible type (mainly via e-mail), meaning that the schedulers have certain control on when to execute these. The forcible triggers have a larger percentage for some schedulers (i.e. Schedulers 2, 4 and 7) and thus, it may be worthwhile to assess if the forcible interruptions may be avoided by restricting the use of phone communication.

Table 2: Relative occurrence of triggers

Scheduler	Exogenous	Endogenous	Exogenous	
			Forcible Interruption	Non-Forcible Interruption
1	25.3%	74.7%	7.0%	93.0%
2	57.9%	42.1%	32.3%	67.7%
3	24.1%	75.9%	6.8%	93.2%
4	38.9%	61.1%	39.4%	60.6%
5	55.8%	44.2%	9.5%	90.5%
6	41.3%	58.7%	29.2%	70.8%
7	28.2%	71.8%	7.0%	93.0%
Total	**38.8%**	**61.2%**	**18.7%**	**81.3%**

From this table it becomes clear that for 86% of the triggers, the scheduler can decide when to start a task. (endogenous + non-forcible x exogenous). This result is significant as it may clash with preconceived ideas that the scheduler is not in control of his usage of time.

5.3 Time management decision levels

The observations from the study indicate that time management decisions can be taken at different levels. During the day, the workload of the scheduler typically builds up as shown in Figure 7, which means that the scheduler must make decisions on what task to do first continuously. In some cases, schedulers were able to indicate why they picked a specific task, but often this was not possible – especially in the case of self-interruptions. As time management decisions can be seen as a cognitive problem-solving process, we have used the cognitive model of Rasmussen (1986) to identify three time management decision levels: tactical, operational and behavioral.

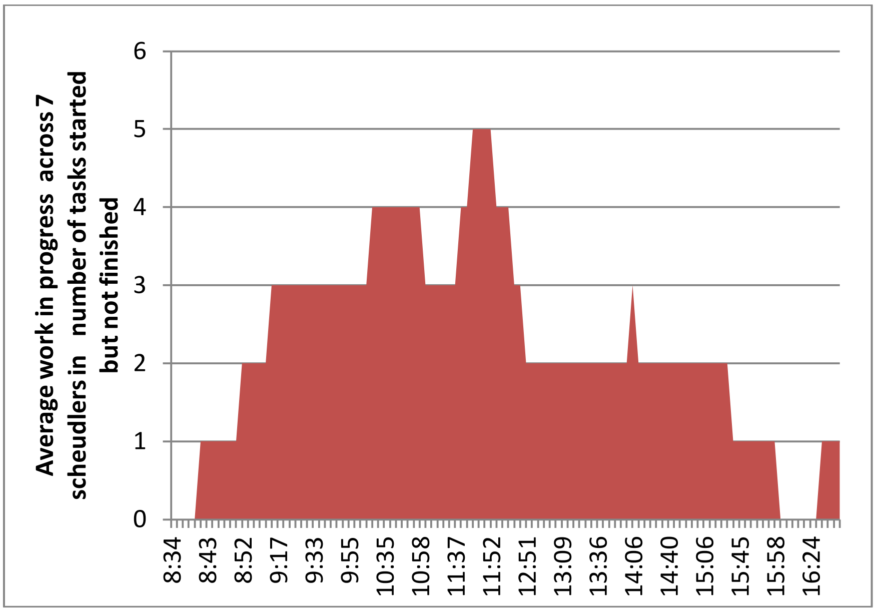

Figure 7: Evolution of work in progress (workload) in a typical shift

At the *tactical* level, time management decisions on an aggregated level are designed and reconsidered by the scheduler – how the scheduler plans to work and react on specific events in the task. Tactical time-management decisions are taken typically on a monthly or quarterly basis, depending on how frequent the scheduling environment changes. In the case studies, this level of decision making was mainly applied to monitoring and scheduling tasks. These decisions include:

- Should this task be done in a periodic way, not at all, only when needed?
- With what frequency should this task be done?
- Should we reserve special times in the day or even a special day to perform such periodic task?

At the *operational* level, we observe the time management decisions that are taken on a case-by-case basis. The decisions at this level include:

- Should I start working on this case now, or should it be postponed?
- How much time to spend on this case?

At the operational level, it was not possible to systematically observe whether a task was postponed or not, as schedulers scanned their e-mails quickly, making it difficult to register whether they were actually postponing tasks or not. Nevertheless, in the case of exogenous triggers, such as phone requests, postponement behavior could be observed in 20% of the cases. Similarly, the decision of how much time to spend was difficult to record, although large variances were seen in the time spent for specific monitoring tasks, such as stock movements.

At the *behavioral* level, decisions about time management are not made consciously – instead, they are made mechanically, in an automated way. The behavioral level compares to the skill-based reasoning level in Rasmussen's (1986) model. On average 14% of the tasks were self-interrupted, and the percentage per individual scheduler ranged from 8 to 23%. The most interesting phenomenon on this level are the self-interruptions. Most self-interruptions were classified as task-level time management decisions, as individuals often could not explain why they had taken the decision to interrupt themselves. The odds of self-interruption were found to increase when the workload increased, but decreased when the day progressed.

Although self-interruptions may be useful in special cases when a scheduler is "stuck" on a task or wants to monitor an ongoing procedure, they also have many downsides (Monsell, 2003). When a scheduler self-interrupts, this may lead to additional time needed to resume the interrupted tasks. It may lead to longer response times to requests. Therefore, self-interruptions are an important aspect for further analysis to improve scheduling processes.

6 An integral workflow model of the worker

Based on the findings from the study, the task typology, task triggers and time-management decisions of the scheduling task have been identified. Based on these findings, it is possible to create a comprehensive scheduling task model, which includes the aspect of time management. This model is presented below.

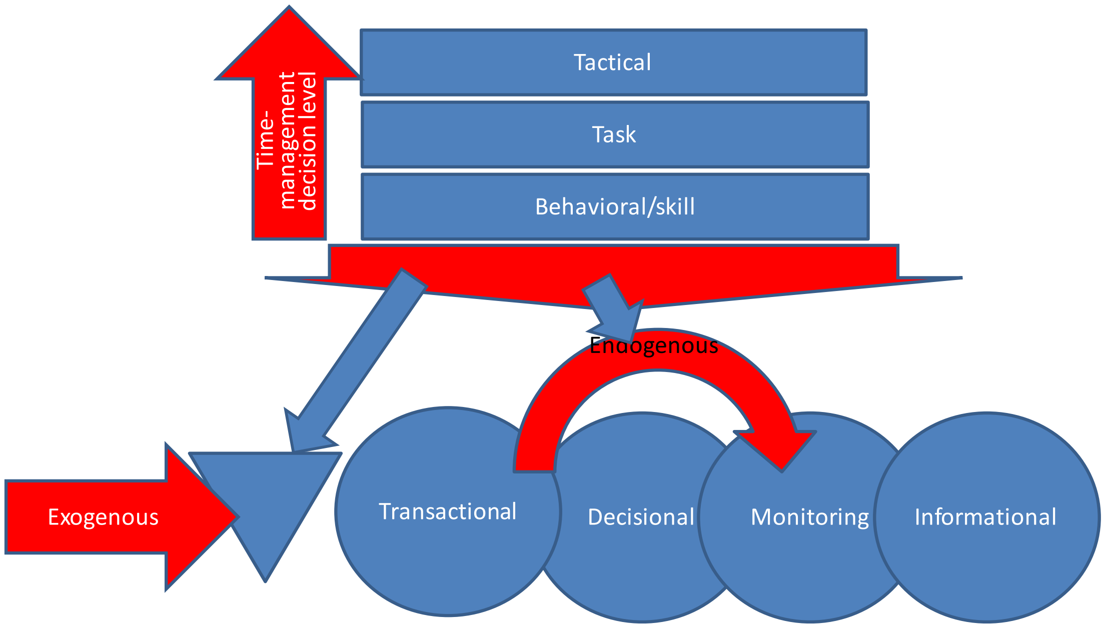

Figure 7: Task Typology and Time Management Decisions

The task typology that we presented in this paper makes a clear distinction between the task itself and the time management aspects of the task. In other words: scheduling the scheduling task. Time management decisions are relevant to determine whether exogenous triggers are being added to the workload, and whether the scheduler goes from one activity to another. In the modified task typology that we propose, the tasks are seen as supportive of roles and not as independent duties as proposed by Jackson et al (2004). In our observations, we have not seen a clear distinction between tasks and roles.

We have identified different levels of time management. However, tactical time management decisions are made by only three of the observed schedulers. These schedulers were also the ones who reported more years of experience. The other four indicated that they make all their time management decisions at the operational or task level. Exceptions to this were the stock monitoring activities, which were done in the mornings by 5 out of 7 schedulers, indicating a tactical decision on these activities. The findings of the study seem to imply that many time management decisions, especially interruptions, are not managed explicitly and that there is a lack of explicit (tactical and operational) time-management. This means that schedulers insufficiently organize the time aspect of their work, implying a potential source of improvement.

The large number of observed self-interruptions underpins our statement that time management decisions are being made in a too implicit fashion. Self-interruptions account for 50% of interruptions and are a major factor in delaying other tasks, such as responses to external requests. Furthermore, the number of unfinished tasks seems to reinforce the number of self-interruptions. Thus, the message to schedulers may be clear: try as much as possible to finish the task that already has been started before switching to another task.

7 Conclusions

In this paper, a study has been presented on the scheduling task, with a focus on the time management decisions that are taken by the scheduler: scheduling the scheduling task.

Previous studies on the human factor in scheduling have not included this aspect. At the same time, it is an important aspect of the task, as scheduling decisions usually are made under time pressure, there are many interruptions and it is unclear how a scheduler should organise his or her own work. It proved useful to identify how time is used and managed as a resource. For example, the informational role emerged as the role where schedulers spent the most time in. We observed that time was managed in a very ad-hoc manner by schedulers; an understandable result given the complexity of scheduling workflows.

The task model presented in this paper takes the model from Jackson et al (2004) as a starting point. Building upon this model, it has been studied how and why schedulers jump from one task to another. Especially, the triggers to interrupt a task and start another one have been recorded. The study has shown that time management decisions can be taken on multiple levels, but that most of them are made on the behavioural level. It is likely that making more tactical time management decisions would improve the efficiency of the scheduler's task. In line with this, the outcomes of this study have already been utilized by the company's management to set certain guidelines for typical 'interrupters' – such as agreeing to not read emails before 9.00 AM.

It is important to note that the time dimension is, however, only one of the important dimensions of the scheduling function. The actual decisions taken and the quality of the information given in the organization are other important dimensions that interact with it. Studying such interactions is important for making real progress in the analysis of scheduling environments.

The model presented in this paper will in future studies be used as a basis for a simulation used to test the effectiveness of time-management decisions and analyze possible factors that may influence such decisions. More specifically, to determine the ideal level of self-interruption – from a formal task perspective self interruptions are always negative, but when you take the context into account (people around you are served faster) there probably is some ideal level of self-interruption.

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