Cogn Tech Work (2018) 20:1–10
https://doi.org/10.1007/s10111-017-0443-1

ORIGINAL ARTICLE

Scheduling the scheduling task: a time-management perspective on scheduling

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Received: 10 July 2017 / Accepted: 9 October 2017 / Published online: 28 October 2017

Abstract The objective of this study was to characterize how schedulers spend their time interacting with external parties. Time is the most critical resource at the disposal of schedulers; however, its usage has been overlooked by prior empirical studies. Seven schedulers for a total of nineteen 8-h shifts were observed. Detailed time data about their activities and how these were interrupted were collected. Schedulers interrupt themselves significantly, and most of their activities are triggered externally. Despite this, schedulers are able to decide in most situations which activity to perform next. Schedulers spend more time on their informational role than on their decisional role, mostly at the requests of others, suggesting insufficient information system support to others in the organization. Schedulers other main role, besides making scheduling-related decisions, is to relay information. This implies that schedulers are subject to several external requests for activities. However, due to asynchronous communication that e-mails provide, they are still able to decide on their own schedule to do tasks. The methodology used can be used to evaluate an individual use of time, in particular for time critical such as scheduling. The analysis may provide insights as to how to improve the efficiency of such jobs.

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Keywords Scheduling · Time-management · Responsiveness · Interruptions · Self-interruptions

1 Introduction

The scheduling job has traditionally been addressed in the literature from the decision-making point of view. Schedulers, however, perform a diverse array of tasks including gathering and relaying information, monitoring the state of resources among others. The scheduling task is embedded in the organization (Crawford et al. 1999), making it highly complex and context dependent (Akkerman and Van Donk 2009). Scheduling is usually part of a production control structure, which encompasses planning, scheduling and dispatching (McKay and Wiers 2003). Traditional performance measures of schedulers have been focused on the quality of their product, i.e., the plans and schedules themselves. Nonetheless, a survey study by de Snoo et al. (2011) identified that performance metrics used in practice focus not only on the quality of the product, but on the process of scheduling itself, in particular to try to measure the timeliness of when the schedule is released.

The need for measuring timeliness suggests the time-critical nature of the scheduling function. Schedulers are immersed in a highly dynamic context where requests from the demand side (client representatives) or supply side (plants, transport) arrive and must be dealt with. It is up to the scheduler to decide when to react to these requests and when to engage in other tasks of preventive nature such as checking production orders and stock levels. The importance of characterizing the time-management dimension in the scheduling job has also been highlighted by Cegarra (2008) where the steadiness of the process, time pressure, cycle synchronicity and continuity of the process were all time-related aspects that affect the cognitive demands on the scheduler. 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).

However, despite its importance, in the scheduling practice there are no guidelines on time-management decisions, let alone how these decisions should be taken in different scheduling contexts. The same problem persists in the scheduling literature, where despite the elaborate vision of what the scheduling function entails (Fransoo et al. 2011), there has been no explicit consideration of the role of time on the execution of the scheduling job. As such, it is important to identify the locus of control of the scheduler in deciding how to organize his own time as a resource, distinguishing it from unavoidable external interruptions from the scheduler's stakeholders.

Recognizing that the execution of tasks in the scheduler function does not follow clear stepwise patterns, our contribution to the literature is twofold. 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 extent to which scheduler can be in control of his time and how he can allocate his time among the different roles he serves.

2 Scheduling task time management: theory and hypotheses

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. 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) and Jackson et al. (2004). Cegarra and Wezel (2011) present a review of models from the perspective of the objective of the model—either for designing decision support or for training.

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

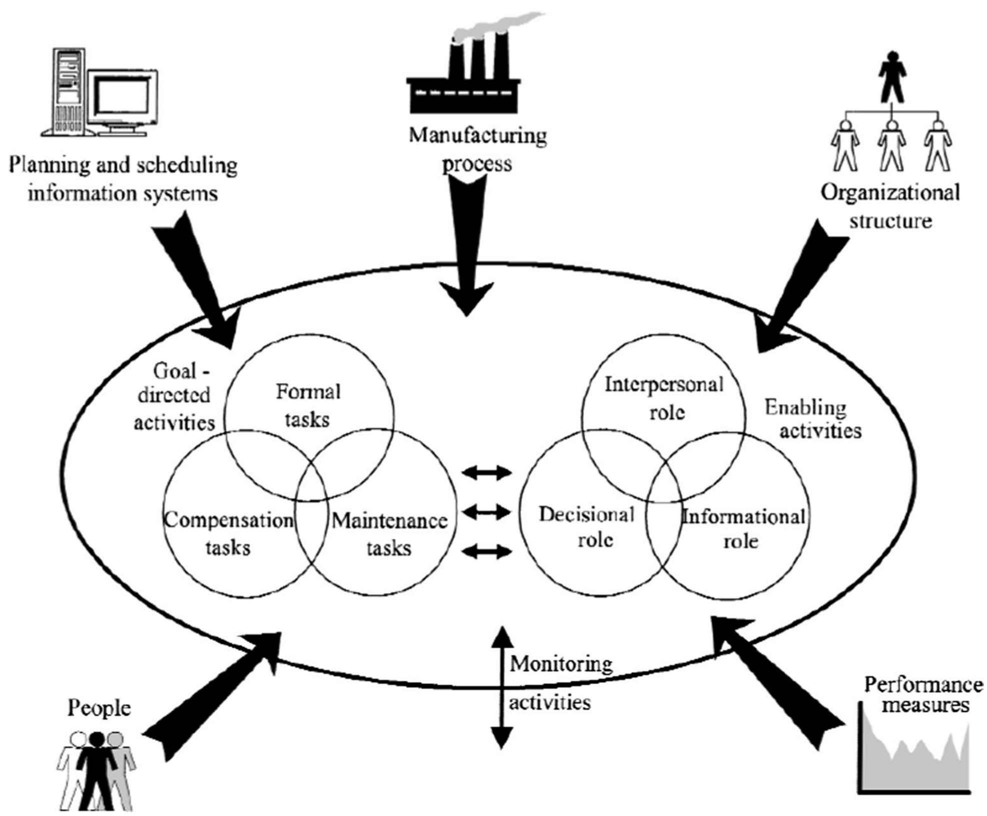

Fig. 1 Model of scheduling tasks and roles (Jackson et al. 2004)

Firstly, there are the *goal-oriented* activities that include 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 and 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. To our knowledge, Jackson et al.'s model is the most comprehensive description of the scheduling task. However, the description is primarily qualitative and conceptual and does not take the perspective of time into account. Nevertheless, some of the qualitative descriptions in their work do suggest that the decisional role, often perceived to be the dominant scheduler's activity, occupies a relatively small share of the time spent.

The model presented by Jackson suggests that the scheduling job consists of several tasks and roles that simultaneously require attention by the human scheduler. Some of these are initiated by the scheduler himself, while others are triggered by other persons or events. Conducting endogenously triggered activities and responding to exogenous requests compete for the same scarce time of the scheduler. The existing models do not make clear how schedulers deal with this time-management issue, in particular in the presence of stochastic events (e.g., resources failure, unexpected customer orders or interruptions by colleagues in other organizational functions) that may alter the scheduler's workflow. In other words, time management in the scheduling task is an unexplored domain.

In a different stream of literature, Hopp et al. (2009) present a general framework that can be used to model time-related aspects of white-collar work (e.g., average waiting time, throughput). The framework is applicable also to the scheduling job as it fits their 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. (1989) as problem-solvers that also anticipate problems and often seek non-conventional solutions to problems that have not been faced before.

In the framework by Hopp et al., tasks (or work packages) are triggered by either of two types of entities (see Fig. 1): exogenous entities and endogenous entities. Note that the trigger entities are not the tasks themselves but the initiators of the tasks. 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. 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. The triggers, in turn, bring about tasks which, when executed, may generate value for different stakeholders. As the effects of these tasks are not seen immediately (Hopp et al. 2009), the value is then taken as latent (Fig. 2).

The existing literature on scheduling task models has different views on the interruptive nature of the task. The model presented by Jackson et al. (2004) suggests that there are several tasks and roles competing for attention, whereas other models such as the one by McKay et al. (1989) seem to suggest that the scheduling task is executed according to a predefined flow, which is controlled by the scheduler. Nevertheless, McKay et al. (1989) indicate that dealing with unpredicted events is a major role for the human factor. In this paper, we therefore hypothesize that interruptions play a major role in the scheduling task and that schedulers can influence how they react on interruptions. In line with the model presented by Hopp et al. (2009), we expect that interruptions are both caused by external factors—exogenous interruptions—and by the human scheduler interrupting his own work—endogenous interruptions.

The considerations above lead to the following set of hypotheses that we investigate in this study.

Hypothesis 1 The number of interruptions in the scheduling task is not negligible; at least 10% of tasks are left unfinished due to interruptions.

Given the nature of the scheduling task as described by Jackson et al (2004) whereby several goals interact and compensation and maintenance activities take place, it is likely that new information and new requests arrive at random times during the scheduling job. The arrival intensity of such interruptions has not been documented in earlier studies. We hypothesize that the number of triggers is substantial and

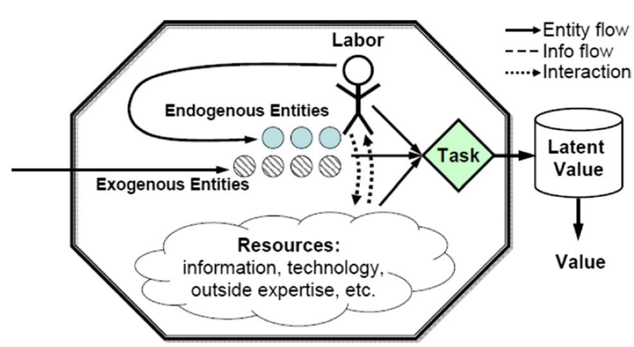

Fig. 2 Individual white-collar framework (Hopp et al. 2009)

that consequently the scheduler is interrupted many times during the execution of his task at least in about 10% of tasks he undertakes.

Hypothesis 2 The tasks triggered exogenously are more frequent than self-initiated, endogenous tasks.

The model by Jackson et al. (2004) suggests that the scheduler is operating in substantial operational interaction with many others in the organization to fulfill in particular his informational and interpersonal roles. Even for the decisional roles, the scheduler is highly dependent on others in the organization, as the resulting schedule determines the work and associated performance of others in the organization, such as process operators. This type of function would suggest that the scheduler is often triggered and subsequently interrupted by others in the organization. In an operational environment, we expect these exogenous triggers and subsequent interruptions to still dominate over the endogenous interruptions initiated by the scheduler himself.

Hypothesis 3 The human scheduler has a major influence on how to deal with interruptions, being able to avoid them in most situations.

The impact of endogenous interruptions can be controlled by the scheduler: it is his decision whether to interrupt his current task and continue working on another (endogenous) task in his work queue. For exogenous interruptions, it is less clear: some of them they may be forcible, and some of them not. In some cases, the scheduler has no option but to interrupt his work, for example when someone enters his office and asks a question. However, it seems reasonable to assume that the majority of triggers come in by e-mail, which are regarded as unforced triggers, as the scheduler does not need to take immediate action. This assumption is in line with the results of a study in a knowledge work setting by Straub and Karahanna (1998), which identifies that workers are less likely to use asynchronous media such as e-mail for less urgent communication.

This effect is amplified by the trend to centralize the scheduling function in control towers (De Kok et al. 2015), thereby introducing a physical distance between sources of interruption and the scheduler. In such cases, most contact takes place via e-mail or telephone, and this has changed the nature of triggers, as an e-mail trigger is much less forcible than someone's physical presence. Therefore, we hypothesize that the scheduler can exert considerable effort over the execution of his task, by avoiding task interruptions to a large extent.

Hypothesis 4 The human scheduler spends more time on his informational role than on his decisional role.

Jackson et al. (2004) qualitatively suggest that the informational role consumes most of the time of the scheduler. This is in line with other studies, which note the fact that scheduling has multiple stakeholders, implying a large number of requests from them with regard to information. However, this is yet to be verified with a time study where the time spent in each role is carefully registered (Fig. 3).

The above picture presents an extended version of the model by Hopp et al. (2009), which forms the basis for the stated hypotheses. Task triggers can be endogenous and exogenous, and these can interrupt a task, which is then put in an internal work-in-process queue, to be finalized later. 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. In addition, it may occur that the scheduler decides to start new activities even if he has not finished the current one.

The internal work-in-progress of tasks increases with one unit when the scheduler is forcibly interrupted, decides to allow to be interrupted by non-forcibly interruptions or starts another self-initiated activity before finishing the current one. It is also possible that the scheduler cannot finish a task because he requires input from another party in which case, he needs to wait for a response from the other party in order to resume such a task.

3 Methodology

3.1 Scheduling environment

This paper reports a field study at a planning department of a Fortune 500 chemical corporation. In the planning

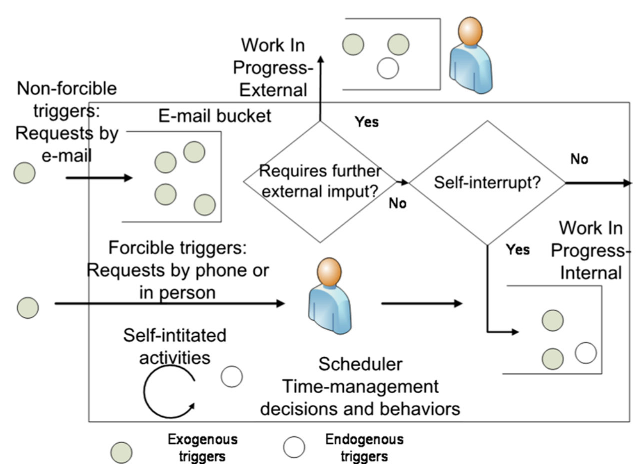

Fig. 3 Task framework extended by triggers and interruptions

department, 12 planners and 36 schedulers are colocated in a single facility. The planning department is a separate entity in the chemical corporation that provides planning and scheduling services to all European production and distribution facilities. The planning department is an example of the trend to centralize planning and scheduling operations, by colocating personnel in a single so-called control tower.

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, as a survey conducted in the planning department asking to rank their priorities has indicated. 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. de 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 considers responsiveness of a greater importance than optimization goes up to 55%. To understand the impact of the requirement to be responsive on the scheduling task, a better understanding is needed of time-management strategies as practiced by schedulers.

In the cases observed, requests and interactions of the scheduler with others in the organization involved a diverse array of stakeholders, including:

- production and packaging plant managers, who are the main "users" of the schedules,
- customer sales representatives, to coordinate the fulfillment of special customer orders,
- marketing, which establishes 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.

3.2 Sample

In a typical company, only a small number of human schedulers can be studied. Therefore, most studies on human scheduling are based on a one or a couple of schedulers per company who are studied in-depth. For example, Jackson et al. (2004) report findings on seven schedulers distributed over four companies; this distribution makes gathering detailed observational data in a unified format very difficult.

The company that has been studied for this paper has the advantage of having a Control Tower structure, which means that schedulers that are responsible for different plants are grouped together physically in one location, using the same procedures and information systems to execute their work. At the same time, the subjects were operating in different scheduling environments; this makes the conclusions of the analysis to be more context-free and thus generalizable to other dynamic scheduling settings. Within this Control Tower, a total of 21 schedulers were active. From this group, eight schedulers have been included in the study. Criteria for inclusion were that they all had at least 3 months of experience on the job and were available at the days of observation. For reasons of availability, not all the schedulers were able to be observed the same number of days; however, each scheduler was observed for at least two shifts. A total of 19 scheduler-shifts were observed.

Five of the subjects worked in a predominantly "make-to-stock" environment, and four schedulers worked in a predominantly "make-to-order" environment. There was diversity also in terms of the number of products, or Stock Keeping Units, scheduled by the eight schedulers studied, ranging from 20 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 regional to global (Table 1).

Table 1 Description of the scheduling environment

Scheduler	Number of SKUs	% of SKU's make-to-order	% of SKU's make-to-stock	Plants	Planning Scope
1	500	25	75	4	European
2	200	0	100	1	Global
3	40	75	25	1	Global
4	20	50	50	1	European
5	130	80	20	4	Global
6	50	60	40	2	Western Europe
7	500	10	90	4	European
8	60	10	90	1	Global

3.3 Data coding

The objective of the data coding is to unify the method of data collection by using an agreed and unambiguous coding scheme. This way, the data collection is objectified between the four researchers that were involved in the data collection process. The recorded variables include the starting and finishing times of the task, a description of the task and its classification, an ID of the task to identify a task that is later resumed and finally an indication of the workflow. (Whether the task is finished, interrupted, self-interrupted or could not continue because it needed an input of third party.) The process to achieve this coding scheme is described below.

1. In a first site visit, the lead researcher observed two consecutive complete shifts of a scheduler. The researcher then developed a preliminary coding scheme to generate a classification of tasks according to the domain that effectively standardizes the task content description.
2. In a second site visit, each of the four researchers involved in the study was assigned to a given scheduler to observe its job as a pilot observation day, using the preliminary coding scheme. The last 3 h of the pilot day, the four researchers tested the applicability and completeness of the preliminary scheme developed by the lead researcher on the first visit during a debrief session with the scheduler involved and subsequently with the other researchers. During the debrief session, the completeness of the options, the ease to fill-in the scheme in a spreadsheet and the definition of what a task is, were all discussed and modifications were agreed upon. In particular, the coding spreadsheet was simplified to record tasks in a sufficiently quick way to follow the scheduler's workflow. Also, the task granularity was established consistent with Hopp et al. (2009) conceptualization of a task: 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).

The data coding scheme that was used for the observation studies had the following information: tasks that were exogenously triggered were identified by an R and tasks that were endogenously triggered were identified with an A, as shown in "Appendix."

3.4 Data collection

We rely on in situ observational data collected directly by four researchers using the predefined scheme discussed above to classify the scheduling roles. The data coding has been implemented in a spreadsheet, and the codes, description and start/end time were entered by the observer. An example of raw observation data is listed in Table 2.

In total, 1595 entries were recorded by the observers. (Note that the number of observations is larger than the number of tasks, as some are interrupted and potentially resumed.) Our unit of analysis is the scheduling shift with a sample of 19, 8-h shifts. Although the sample is small, the large number of activities reduces the variance of summary statistics per day. When a task would be interrupted, a recurrent indicator would be recorded by the observer, so that when the task was resumed in a future observation, a reference indicated at which initial observation the task started.

Given that the data observed was mostly objective and not subject to the interpreter, the researcher had only limited influence in the data: namely in classifying a task and in considering whether a task was finished or not. At the same time, the need to minimize the impact of the researcher on the scheduler work made it impractical to have more than

Table 2 Example of observation data

Start time	End time	Duration (min)	Task description	Task code	Task ID	Workflow
9:35	9:42	7	Analyzing possible production orders sequences	A1	Scheduling 1	Self-interruption
9:42	9:51	9	Meeting with plant, asking for additional feedback on capacity and stocks	A16		Finished
9:51	9:58	7	Asks CSR to delay orders to free capacity at the bulk plant	A19	Scheduling 1	Was interrupted
9:58	10:01	3	Issue with delivery note: customer requires material later	A19		Finished
10:01	10:04	3	CSR asks: Checking whether out of stock is solved	R26		Finished
10:04	10:06	2	Checks mail, FYI, sales issue	A13		Finished
10:06	10:27	21	Updating drum filling execution plan	A1	Code002DR	Self-interruption
10:27	10:33	6	Break/idle			Finished
10:33	10:35	2	Updating drum filling execution plan-asking CSR to make order change	A1	Code002DR	Finished
10:35	10:36	1	Checking e-mails	A13		Finished

Table 3 Descriptive data of interruptions on a typical scheduling day ($n = 19$)

	# of tasks finished	% Interrupted
Maximum	484	31.0
Minimum	45	14.2
Mean	132.7	25.2
SD	100.3	4.8

one researcher observing the same scheduler day; hence, no inter-rater reliability measure could be obtained.

To control for such influence, the pairing of researcher to scheduler was randomly made. In this way, Researcher 1 was assigned to Schedulers 4 and 6, Researcher 2 was assigned to Schedulers 1 and 7, Researcher 3 was assigned to Schedulers 2 and 8, and Researcher 4 was assigned to Schedulers 3 and 5. In addition, at the end of the scheduling day, researchers reviewed each other's match between the long description of an activity and its classification. Less than 2% of the activity entries were contested, and for such cases, a consensus was reached.

4 Results

4.1 Interruption statistics

Table 3 shows the summary statistics on number of tasks finished and percentage of tasks interrupted on a scheduling day. Across, the 19 scheduling days studied; on average, 25.2% of tasks started could not be finished before being interrupted. This means that Hypothesis 1 is strongly supported ($p < 0.001$) as on a normal scheduler day more than 10% of tasks are interrupted ($M = 25.2\%$, SE $= 1.12\%$).

However, when exploring the origin of interruptions, Table 4 shows that most interruptions in the case studied were self-initiated rather than exogenously triggered.

This means there is strong evidence to support Hypothesis 3, where using a related means t test, we find that on a typical scheduling day, there are statistically significant more interruptions triggered endogenously than exogenously [$t(18) = 4.70$, $p < 0.001$].

Contrary to what might be subjectively thought by the schedulers themselves, Table 4 shows that in most tasks triggered, the schedulers are more often in control of the work flow than not ($M = 84.8 > 50\%$, SE $= 3.07\%$), thus supporting Hypothesis 4 [$t(18) = 3.01$, $p < 0.01$]. Table 4 shows two reasons behind this fact. Firstly, the scheduler is in control for all the tasks triggered endogenously; these account for 44% of the total. Secondly, when tasks are triggered exogenously, the scheduler is mostly only in control of his time; only when there is a face-to-face communication or phone calls are received, he is forcibly interrupted.

The source of triggers was further explored. The results indicate that indeed most of the endogenous triggers (self-interruptions) was for actually reading e-mail and updating the knowledge state of the scheduler. Next in importance was to attend to requests for information of Customer Sales Representatives, arguably the most important stakeholder of the scheduler. Interestingly, the main source of exogenous interruptions was responding to requests from peers from help, highlighting the role of control centers to facilitate learning processes. Taken as a whole, the results show that tasks that relate to the informational role are the main driver for schedulers' workflow (Table 5).

Table 4 Descriptive statistics of number of type of triggers per scheduling day ($n = 19$)

	Exogenous triggers			Endogenous	Total triggers	% in control
	Forcible	Non-forcible	Total			
Max	9	23	27	20	44	100.0
Min	0	2	7	3	10	50.0
Mean	3.9	13.9	17.8	10.9	28.7	84.8
SD	2.7	6.5	5.7	4.8	8.0	13.0

Table 5 Descriptive statistics of triggers' top sources

Endogenous		Exogenous forcible	
Request from peer for help (job)	21.1%	Reading e-mail	52.6%
Request of information from customer sales representative	13.2%	Request of information from customer sales representative	8.1%
Request from logistics for information	13.2%	Scheduling (for a time horizon)	5.2%
Request of information from plant	13.2%	Preventively checked stocks	3.5%

4.2 Task statistics

In analyzing the nature of tasks performed by different schedulers, a large degree of variation can be observed in terms of the number of tasks accomplished for specific type of tasks as evidenced by the large coefficients listed in Table 6. These results reflect the different contexts that the schedulers are subject to. For example, some schedulers have to manage more stock keeping units to manage and thus have to monitor stocks more frequently; other schedulers deal with older plants that breakdown more often and thus need more attention in monitoring the execution of production orders. At the same time, the complexity of each task varies widely, implying that some scheduling environments imply a large number of tasks that take less time than others.

To observe emerging patterns, we take two approaches: cluster data and focus on time spent. We then group the tasks according to the scheduler role they are related to, using the model presented in Jackson et al. (2004) as a basis. To group the tasks, the standardized description of the tasks was then associated in a one-to-one mapping with the role it serves. So, for instance, any task that involves scheduling or rescheduling was to be considered as serving the decisional role, whereas any task that involves checking stocks or production orders was to be considered as serving the monitoring role. The observations are grouped into roles as follows:

- 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).
- In the *monitoring* role, the scheduler keeps an eye on several aspects of the involved resources: stock movements and demand, production execution (in tailor-made systems per plant), truck deliveries and raw materials stocks (in an Enterprise Resource Planning software).
- 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 the *transactional* 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. We have identified this role in addition to the roles detailed in Jackson et al. (2004).

Mapping the standardized description of the task to the corresponding role served, the time spent to these roles is given in Table 7.

In Table 7, it can be shown that in the case studied, schedulers spent significantly more time on an informational role than on a decisional role using a related means t test [$t(18) = 4.17$, $p < 0.001$], providing strong support for Hypothesis 4.

Table 6 Descriptive statistics of tasks finished per scheduling day ($n = 19$)

	Max	Min	Mean	SD	CV
Decisional role					
Scheduling	2.00	0.00	0.69	1.75	2.55
Rescheduling	12.50	3.33	7.73	18.27	2.36
Monitoring					
Stock movements and demand	4.00	0.00	1.43	3.66	2.57
Production execution	3.50	0.25	1.74	4.22	2.43
Raw materials	2.00	0.00	0.84	2.06	2.44
Informational role					
User	50.50	5.00	23.19	56.05	2.42
Disseminator	32.00	6.00	14.28	34.07	2.39
Transactional role					
Updating product base	2.00	0.00	0.42	1.19	2.85
Creating delivery notes	1.50	0.00	0.67	1.66	2.48
Transactional problem-solving	8.00	0.00	3.27	8.07	2.47
Total	80.50	29.00	54.25	128.06	2.36

5 Discussion

From the number of interruptions reported in Table 3, it becomes clear that about one quarter of the tasks are interrupted, either by the scheduler himself, or by being forcibly interrupted by others. From this finding, we conclude that a significant fraction of tasks is interrupted, supporting Hypothesis 1. Following this result, we conclude that time management is a critical skill for the productivity and response time of a scheduler, as it is the scheduler who decides in most cases what task deserves attention.

Table 7 Time allocated to different decisional roles

	Informational (%)	Decisional (%)	Monitoring (%)	Transactional (%)
Max	76.9	53.8	39.2	19.7
MIn	23.1	6.0	2.2	0.0
Mean	50.5	27.1	10.6	4.6
Stdev	17.6	14.6	9.0	5.3

Indeed, Table 4 shows that most interruptions are self-initiated, supporting Hypothesis 2. Exploring the personality factors and other determinants of self-interruptions may be important to recommend best recruiting and communication policies in the scheduling function. 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, as precious time will be lost for every interruption.

Table 4 also shows that for an average of 84.5% of the triggers, the scheduler can decide when to start a task, counting all endogenous triggers and exogenous triggers of non-forcible nature (via e-mail). Therefore, a counterintuitive hypothesis is supported (Hypothesis 3); in most occasions, the scheduler can control his workflow.

Another important result is the fact that in the case studied, more time is spent on the information role than on the decisional role as listed in Table 7 (Hypothesis 4). This result is important, as scheduling has been studied mainly from the point of view of its decisional role. Similarly, most efforts for improving the scheduling function have been focused on the scheduling role itself. Underpinning the task model presented by Jackson et al. (2004) with quantitative data provides both academia and practice with the important finding that efforts to improve scheduling should include the informational role.

This case study is unique in taking the exhaustive approach of registering every single activity a scheduler performs along regular days. Although it is limited in the small sample of scheduler days collected (19), this is counterbalanced by the fact that in a single day many tasks are performed (an average of 55 tasks) and that the emerging results analyzed are particularly clear, resulting in low variance for most statistical tests. Further research should investigate new forms of gathering daily information in a noninvasive ways.

Acknowledgements This paper is a partial result of the project 4C4-More, which is supported by Dinalog, Dutch Institute for Advanced Logistics.

Appendix

Code	Tasks triggered exogenously	Role
R1	Request of information from customer sales representative (CSR)	Informational
R2	Request of information from plant	Informational
R3	Request of information from planner	Informational
R4	Major rescheduling change of sales trend	Decisional
R5	Minor rescheduling to accommodate customer orders (CSR)	Decisional
R6	Major rescheduling involving major disruption at plant	Decisional
R7	Minor rescheduling involving minor disruption at plant	Decisional
R8	Major rescheduling because of lack of raw materials	Decisional
R9	Minor rescheduling because of delivery issues	Decisional
R10	Major rescheduling at request of planner	Decisional
R11	Minor rescheduling at request of planner	Decisional
R12	Other rescheduling	Decisional
R13	Request for new GMIDs (product)	Monitoring
R14	Request for rescheduling transport (demand)	Decisional
R15	Request for rescheduling transport (supply)	Decisional
R16	Request from peer scheduler for rescheduling	Decisional
R17	Request from peer scheduler for information	Informational
R18	Request from peer for help (job)	Informational
R19	Request from supplier for information	Informational
R20	Request from logistics for information	Informational
R21	Minor rescheduling of raw materials	Decisional
R22	Minor rescheduling involving minor disruption at drum filling facility (plant)	Decisional
R23	Request for information from quality control	Informational
R24	Request for making purchase order	Transformational
R25	Request for information from R&D	Informational
R26	CSR requests a delivery note (DN)	Transformational

Code	Tasks triggered endogenously	Role
A1	Scheduling (for a time horizon)	Decisional
A2	Preventively checked stocks of raw materials	Monitoring
A3	Preventively checked stocks of finished products (at its own initiative)	Monitoring
A4	Preventively checked production orders execution	Monitoring
A5	Meeting with (European) Planner	Informational
A6	Other meetings	Informational

Code	Tasks triggered endogenously	Role
A7	Create delivery note (at scheduler initiative)	Transactional
A8	Create transport order to depots	Monitoring
A9	Make a request to peer for help	Informational
A10	Making feedback report to planners	Informational
A11	Asking to CSR to make an order change (entry error)	Informational
A12	Asking to CSR to make an order change (schedule problem)	Monitoring
A13	Reading e-mail	Monitoring
A14	Request information to marketing	Informational
A15	Request information to CSR	Informational
A16	Request information to plant	Informational
A17	Request information to logistics	Informational
A18	Request information to supplier	Informational
A19	Rescheduling triggered by preventive task	Decisional
A20	Other administrative	Transactional
A21	Make a request to peer for information	Informational
A22	Request information to quality control	Informational
A23	Self-study or formal training	Informational

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