Coordination activities of human planners during rescheduling: Case analysis and event handling procedure

Cees de Snoo, Wout van Wezel, Hans Wortmann, Gerard J C Gaalman

Coordination activities of human planners during rescheduling: Case analysis and event handling procedure

Journal:	*International Journal of Production Research*
Manuscript ID:	TPRS-2009-IJPR-0479.R1
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	28-Oct-2009
Complete List of Authors:	de Snoo, Cees; University of Groningen - Faculty of Economics and Business van Wezel, Wout; University of Groningen - Faculty of Economics and Business Wortmann, Hans; University of Groningen - Faculty of Economics and Business Gaalman, Gerard J C; University of Groningen - Faculty of Economics and Business
Keywords:	PRODUCTION PLANNING, PRODUCTION CONTROL
Keywords (user):	RESCHEDULING, COORDINATION

Coordination activities of human planners during rescheduling: Case analysis and event handling procedure

C. de Snoo, W. van Wezel, J.C. Wortmann, and G.J.C. Gaalman

Faculty of Economics and Business, University of Groningen,
Groningen, the Netherlands

C. de Snoo*
Faculty of Economics and Business
University of Groningen
P.O. Box 800
NL-9700 AV Groningen
The Netherlands
Phone: +31 50 363 6682
Fax: +31 50 363 2032
Email: c.de.snoo@rug.nl

W. van Wezel
Faculty of Economics and Business
University of Groningen
P.O. Box 800
NL-9700 AV Groningen
The Netherlands
Phone: +31 50 363 7181
Fax: +31 50 363 2032
Email: w.m.c.van.wezel@rug.nl

J.C. Wortmann
Faculty of Economics and Business
University of Groningen
P.O. Box 800
NL-9700 AV Groningen
The Netherlands
Phone: +31 50 363 3864
Fax: +31 50 363 2275
Email: j.c.wortmann@rug.nl

G.J.C. Gaalman
Faculty of Economics and Business
University of Groningen
P.O. Box 800
NL-9700 AV Groningen
The Netherlands
Phone: +31 50 363 7491
Fax: +31 50 363 2032
Email: g.j.c.gaalman@rug.nl

* Corresponding author.

Coordination activities of human planners during rescheduling: Case analysis and event handling procedure

This paper addresses the process of event handling and rescheduling in manufacturing practice. Firms are confronted with many diverse events, like new or changed orders, machine breakdowns, and material shortages. These events influence the feasibility and optimality of schedules, and thus induce rescheduling. In many manufacturing firms, schedules are created by several human planners. Coordination between them is needed to respond to events adequately.

In this paper, the practice of coordination during event handling is analyzed by an extensive case study. The study shows that human planners spend much time in communicating events and in negotiating rescheduling solutions. Because many events demand a quick response, the possibilities for coordination are restricted by time constraints. The paper proposes a procedure to structure the event handling process. This procedure helps a scheduler to select an appropriate response to an event by evaluating its influence on schedule feasibility and the time available for coordination and rescheduling. The use of the procedure in the case company has led to improved rescheduling performance through a reduction of scheduler interactions and increasing coordination efficiency. The procedure contributes to traditional planning frameworks and paradigms, and supports the conscious selection and use of rescheduling methods in manufacturing practice.

Keywords: Rescheduling; Production planning and control; Coordination; Case study

1. Introduction

Firms have to respond to a vast range of uncertainties and events that influence the feasibility and optimality of their production schedules, like rush or changed orders, material shortages, production errors, and machine breakdowns. In literature, several terms are used to name these events, like *uncertainties*, *disruptions*, *disturbances,* and *rescheduling factors* (Abumaizar and Svestka 1997; Aytug *et al.* 2005; Koh *et al.* 2002; Vieira *et al.* 2003). Generally, it is uncertain when an event will happen and what its impact will be on one or multiple scheduled operations and resources. Complete rescheduling is usually impossible because of time constraints or undesirable because it results in nervousness on the shop floor (Aytug *et al.* 2005; Subramaniam *et al.* 2005). Therefore, schedules are adapted partially, for instance with the help of rescheduling heuristics like *affected operation rescheduling* (AOR) and *right-shift rescheduling* (RSR) (Mula *et al.* 2006; Pfeiffer *et al.* 2007; Vieira *et al.* 2003). The appropriate choice and use of rescheduling methods depends on the human scheduler who applies them. This scheduler has to evaluate and assess the effect of the event, and probably has to adapt schedule constraints to enable the recreation of a feasible schedule. This indispensable role of the human planner during rescheduling has been shown in several empirical studies (Berglund and Karltun 2007; Fransoo and Wiers 2006; Jackson *et al.* 2004; MacCarthy and Wilson 2001; McKay *et al.* 1995a). One important task for the scheduler is to determine if an event has to be resolved individually or if it requires coordination with fellow-schedulers, managers, foremen, or operators. For instance, such coordination could be necessary in case the event has an impact on the schedules that are created by other schedulers. Coordination between schedulers could result in a schedule adaptation by one scheduler, for instance by changing a production sequence, enabling a fellow-scheduler to deal with a material shortage problem. Similarly, coordination between schedulers and shop floor foremen about alternative batch sizes could solve a rush order problem.

Whereas the majority of research in rescheduling has focused on approaches to solve a single type of events within a single schedule having a single objective (Vieira *et al.* 2003), the present work has a different focus. We take our starting point in the practice of rescheduling that is characterized by a large variety of events invalidating interrelated plans and schedules that have multiple objectives (Herrmann 2006; McKay and Wiers 2006; Pinedo 2008). To deal with these events adequately, human schedulers perform a variety of tasks and roles alongside the individual problem solving task, like communication and negotiation (Berglund and Karltun 2007; Jackson *et al.* 2004; MacCarthy and Wilson 2001; McKay *et al.* 1995a). The rescheduling process is however limited by time constraints: the time needed for coordination and plan adaptation should not exceed the available response time (Van Wezel *et al.* 2006). Overall, rescheduling takes place within an organizational context; tools like algorithms, heuristics, and advanced planning systems are applied by humans working together within specific circumstances.

The aim of this research is to better understand the coordination activities of schedulers during event handling. These coordination activities concern the adaptation and mutual alignment of planning and control decisions taken by different people. Three main research questions are addressed. First, why are coordination activities by schedulers (theoretically) necessary? Second, what is the daily business practice of event handling in a production situation with multiple schedulers? Third, how could event handling in such a situation be structured and supported? An extensive case analysis is presented that shows the multitude of coordination activities performed by schedulers in a manufacturing firm. From the case analysis, the need for an instrument to structure the event handling process becomes apparent. Therefore, a procedure is developed that guides a scheduler during the event handling process. The use of the procedure in the case company shows its usability as an instrument to enhance the efficiency of event handling.

The paper contributes to rescheduling research by providing empirical evidence for the complexity of event handling and the necessity to structure the rescheduling process. The proposed procedure provides an instrument to enable a context-oriented application of rescheduling methods. The discussion about interdependencies and coordination activities within and between planning and scheduling levels demonstrates an organizational perspective on rescheduling.

The paper is organized as follows. Section 2 describes the theoretical background of our study by discussing the causes for and practice of coordination activities by schedulers. Assumptions regarding rescheduling and coordination in MRP-II are critically reviewed. Section 3 presents the case study that provides empirical evidence for the intensity and variety of human coordination during the rescheduling process. Section 4 introduces our procedure that helps the scheduler to select an appropriate response to an event by evaluating its influence on the schedules and the time available for coordination and rescheduling. The detailed description of the procedure is followed by a short explanation on how the procedure is used in the case company. Section 5 discusses the possibility to apply the procedure in different scheduling contexts and provides conclusions and suggestions for further research.

2. Theoretical background

2.1 The need to adapt the schedule

Scheduling in manufacturing usually consists of two distinct phases: creating the initial schedule and adapting this schedule. In many firms, schedules are created based on inputs from the Manufacturing Resource Planning (MRP-II) system, like the net material requirements that are calculated with the help of Material Requirements Planning (MRP-I) (Jonsson and Mattson 2006; Pinedo 2008; Vollmann *et al.* 2005). The schedules are used to execute manufacturing and purchasing operations. Adaptation of the schedule is needed when the schedule is invalidated, for instance due to a material shortage. Rescheduling can also be desirable when the schedule is still valid, but it can be improved, for instance due to an order cancellation. In literature, many rescheduling techniques are presented for different rescheduling situations that are triggered by different events (Caricato and Grieco 2008; Kutanoglu and Sabuncuoglu 1999; Raheja and Subramaniam 2002; Vieira *et al.* 2003).

Several authors have remarked that to apply rescheduling techniques appropriately, the cause, scope, and consequences of the event and of the schedule adaptations have to be considered carefully (Aytug *et al.* 2005; Cowling and Johansson 2002; Koh and Saad 2002). Rescheduling could be *un*desirable because it could result in scheduling nervousness or in nervousness on the shop floor (Aytug *et al.* 2005; Ho 2005). Nevertheless, because rescheduling operates on an existing schedule, a fast reaction is often needed to prevent further losses and infeasibilities, for instance in case of production delays. Clearly, firms need a strategy for the event handling process. However, Cowling and Johansson (2002) have noted that "the strategies [for dealing with events] which are used in industry are often ad hoc and not subject to the same kind of analytical rigor or sophisticated techniques which are applied to the scheduling decisions themselves" (p. 234).

2.2. The important role of the human planner

Studies on scheduling in manufacturing practice show the important role for the human scheduler. For reviews and empirical studies on human performance in scheduling, we refer to MacCarthy and Wilson (2001) and Herrmann (2006). Here, we will only discuss empirical studies that reveal coordination issues in scheduling. McKay *et al.* (1995a) observed scheduler Ralph who had contact on a daily basis with many contact points in the firm, including product managers, line supervisors and operators, inventory control, purchasing, other schedulers, the high level planner, and his own management, to gather important information to solve his (re)scheduling puzzles. Reporting six case studies, Berglund and Karltun (2007) have shown that "in all companies, the schedulers had numerous contacts every day related to inquiries about for example feasibility in production for potential orders and information about changes. (…) By serving as an integrating link between production and the sales department, the schedulers were able to pass on information before it entered into the scheduling software systems or transfer information that did not exist at all in the scheduling software systems." (p. 170). In this way, the schedulers play a crucial role in the goal-conflict between the sales and production departments, according to these authors. Jackson *et al.* (2004) observed in their case studies that schedulers have multiple roles: the *interpersonal* role in which interaction with other employees is achieved, the *informational* role in which the scheduler is the 'information hub', and the *decisional* role, where the scheduler makes the actual plan. Finally, McKay *et al.* (1995c) observed schedulers communicating with many parts of the organization "for two reasons: obtaining information for the decision process, and dispersing information to other key components of the system. The information gathering is sometimes conducted via reports, telephone contact, electronic mail/memos, in meetings, at coffee breaks, and in the hallways." (p. 81). In sum, this literature clearly shows that coordination with fellow-schedulers and other employees is a key activity of schedulers in dealing with events.

2.3. Event handling and coordination

However, from an in-depth case analysis of a garment manufacturer, Vernon (2001) concluded, "not all information brought to [the scheduler] and taking up his time is relevant" (p. 149); many problems brought to the scheduler could or should be sorted by others. McKay *et al.* (1995c) emphasized, "it is possible that the schedulers are looking for information they really do not need, or are looking at the wrong information. It is also possible that schedulers not seeking additional information do not know they should. (…) The informal information used by the decision maker should not be considered arbitrary or insignificant without careful analysis. Part of the planning task is to make trade-offs between competing requirements." (p. 81). Furthermore, laboratory experiments have shown that frequent coordination between interdependent decision makers results into many task interruptions, which can have an effect on task performance (Speier *et al.* 1999). Other studies have shown that different types of task interruptions, like intrusions, breaks, distractions, and discrepancies, have positive and negative consequences for the person being interrupted (Jett and George 2003). Clearly, event handling poses important and complex requirements on human performance; schedulers will have to consider both the need and possible effects of disturbing others to solve rescheduling problems.

2.4. Adapting the schedule in the context of hierarchical plans

From a theoretical point of view, this coordination between planners, schedulers, and operators is required because of the interdependencies between the planning and scheduling decisions taken by them. These interdependencies originate from the breaking down of the overall planning function into interrelated 'sub-functions'. A planning and control framework, like MRP-II, provides guidelines for this decomposition, distinguishing planning decisions, and determining the dependencies and connection points between these decisions (Meal 1984;

Vollmann *et al.* 2005). The decomposition results in several planning levels with different timeframes and details.

One of the implicit assumptions within MRP II is the value of the hierarchical production planning (HPP) paradigm. This paradigm is a descriptive model to guide organizational design, to structure information flows, and to break large problems down into manageable independent components (Bertrand *et al.* 1990; Kreipl and Pinedo 2004; Meal 1984). In general, a hierarchical approach involves the total number of decisions required being allocated among several decision levels in such a way that a higher level determines the instructions, constraints and conditions for a lower level (Mesarovic *et al.* 1970). Theoretically, a hierarchical approach has the advantage that the complexity on each level is reduced. This advantage presumes that each level can function at least semi-independently from the other levels since, if not, there will be a lack of stability (Simon 1981). Along with the way that decisions are partitioned, feedback is also important in hierarchical systems if they are to function properly (Mesarovic *et al.* 1970). Within the context of production planning, this means that the scheduling level needs to receive feedback from the execution level and, in turn, provides feedback to the planning level.

However, this line of reasoning involves two critical assumptions: first, that timely and appropriate feedback is given by the lower level; second, that the higher level is able to respond in a timely and adequate way to this feedback. The more variation there is at the lower levels, the more information the higher levels need, and the tighter the coupling between the levels (Aytug *et al.* 2005; Koh *et al.* 2002; McKay *et al.* 1995b).

Planning frameworks provide guidelines on how to deal with interdependencies during the plan creation phase. When it comes to the plan adaptation and execution phases, they provide hardly any guidelines or mechanisms to manage interdependencies (Kreipl and Pinedo 2004). The importance of such guidelines is emphasized by Van Wezel *et al.* (2006), who introduced a framework to analyze the so-called "planning flexibility bottleneck", indicating the phenomenon that the efficiency of production could be restricted by organizational limitations in the planning process rather than by physical production restrictions. For instance, a rush order that could be accepted given the actual production situation is rejected because the schedulers are not able to produce updated schedules in time.

2.5. Adapting the schedule in the context of lateral plans

Besides the hierarchical, so-called vertical, relationships between plans, these plans are also related horizontally (Cowling and Johansson 2002). The hierarchical planning paradigm assumes that these laterally related plans are largely independent. For instance, the master production schedule prescribes objectives and constraints for the semi-independent, but interrelated detailed production schedules (Vollmann *et al.* 2005). Indeed, as long as a planning decision can be adapted without affecting the feasibility of a related planning decision in another plan, this assumption holds. However, rescheduling literature shows that adaption of a single operation or work order is often not possible: other operations or work orders (both directly and indirectly affected) have to be rescheduled, i.e., various scheduling decisions have to be reconsidered to realize feasible plans and schedules again (Hall and Potts 2004; Subramaniam *et al.* 2005; Wu and Li 1995). As indicated, if these schedules are created by different schedulers, coordination between them will be necessary to solve problems adequately (McKay and Wiers 2006). For instance, events from outside the firm, like changes in order size or promised data, could require the adaptation of parts production, assembly, and distribution schedules. Events from inside the company, like machine breakdowns, could require coordination between production operators, several production schedulers, and a sales representative to discuss which orders can be postponed before applying a heuristic. In the present article, we investigate these coordination activities during event handling by the schedulers. The next section describes our case analysis of event handling in a typical manufacturing firm. The empirical data further stresses the need to structure the event handling process.

3. Case study

Given the limited research to date focusing on coordination activities of schedulers, an in-depth case analysis within one firm was chosen. Siggelkow (2007) has distinguished three important uses of case research: motivation, inspiration, and illustration. In this research, the first and third of these are the most relevant. The case study provided motivation for investigating the essence of human coordination in event handling: during an analysis of rescheduling performance, the magnitude of coordination between the schedulers triggered our attention (Section 3.2). Further, the findings from the case study illustrate the need to reconsider the organization of the rescheduling process (Section 3.3). Interpreting the findings, we propose to start with a procedure that streamlines the first steps in event handling: evaluation of the event's urgency and scope, and assigning the event-handling task to the right people (Section 4). The firm is a medium-sized manufacturer operating in a dynamic and competitive international market, and has a typical planning structure that clearly resembles the traditional hierarchical planning paradigm discussed above.

3.1 Context

The case company deals with 140-200 client-specific orders each day. Twenty-five agents are responsible for sales and managing customer relationships. Approximately 250 operators work in multiple shifts in three departments: metalworking, finishing, and assembly. Each production department has its own planner who is responsible for both the mid-term and the short-term production plans. Mid-term plans are used to balance capacity and demand by planning similar workloads for each day. Short-term plans prescribe the sequence of production orders for each workstation. The formal task of the three production planners is to provide operators with feasible schedules, and this involves both creating and adapting these plans and schedules. The planners convert the MRP I output for their production departments into schedules while taking into account the schedules previously issued.

This process starts with the planner for the assembly department. This planner determines the sequence of assembly tasks for the seven assembly stations. The assembly plan should satisfy the requirements from the warehousing and distribution departments; these departments are aiming at due date reliability for the customers and efficient transportation. The assembly plan is constrained by material availability that is determined by the purchasing, finishing, and metalworking departments (and their schedulers).

When the plan for the assembly department is complete, the planner for the finishing department can start on his plan. Finishing is done in a batch process on three production lines. The finishing planner should minimize setup times and costs, but parts should be delivered to the assembly department on time. However, frequent rework is required in this department because of parts not meeting the high quality requirements on the product.

Finally, the metalworking department planner can start to schedule her work orders. The metalworking department is organized as a job shop with products having a variety of routings and operations. The planner must balance the constraints and objectives of large batches, like a low number of setups and little material waste, with other constraints and objectives like short lead times and low inventories of work-in-progress. Moreover, the plan should be flexibly adaptable, for instance due to the insertion of rush orders.

Alongside the production planners, several other planners are employed in the order acceptance, purchasing, and final delivery departments; for most of these employees, planning is only one of their tasks. An order chaser is also employed; she tries to speed up orders that are close to their delivery date by pressing both planners and machine operators to reconsider their priorities.

Recently, an advanced planning system was implemented to support the (re)scheduling activities, but this was a failure: the performance in terms of meeting delivery deadlines decreased dramatically. The advanced algorithms could not cope with the diversity of events that required rescheduling. Consequently, the task of event handling was given back to the planners, and management decided that a more in-depth understanding of the rescheduling process was needed.

3.2 Research design and data collection

Several research methods were used in gathering data: interviews, questionnaires, observations, and ERP system data analyses, thus triangulating our findings (Voss *et al.* 2002). During the first stage of the project, planners, production managers, operators, and logistics staff were interviewed. The interviews were transcribed literally, allowing later reflection on the exact statements of each participant. The planning and production employees were also observed at work in order to understand their coordination activities better. Observation sheets, based on the fieldwork by Crawford *et al.* (1999), were used to analyze these human activities systematically. Finally, data from the ERP system were analyzed to investigate the potential reasons for rescheduling.

Aim of this first stage of the case study was to analyze the planning organization. Given the relatively simple planning structure, which was designed following the hierarchical production planning paradigm discussed above, it was not expected to see a large number of coordination activities by the planners. However, huge activity was witnessed during the observations: many phone calls, people shouting, people running around. Moreover, we quickly realized that these interactions were quite diverse: sometimes the planners were acting as bosses instructing the production operators, at other times they were acting as negotiators discussing delivery decisions with salespeople. It was apparent that different roles and functions, all fulfilled by the planners, could be recognized (cf. Jackson *et al.*, 2004). Furthermore, the reasons for the coordination activities seemed to be fairly heterogeneous. It was concluded that the researchers were not able to follow and understand all the events and coordination activities and their influences on the (re)scheduling process. Therefore, it was decided to closely involve the planners by asking them to record their coordination activities. As far as we know, such a detailed analysis of the coordination activities involved in planning and scheduling has not been performed before.

Thus, the second stage of the research project focused on a thorough investigation of interactions among the employees involved in the rescheduling process. Firstly, planners, production managers, and shop floor foremen completed a general questionnaire about their coordination activities. Using this survey, the employees' perceptions were measured regarding the frequency of operational coordination during the rescheduling process. Respondents were asked to rate the frequency of contact they had, on average, with the metalworking planner, finishing planner, assembly planner, order chaser, production managers, and production foremen (using this scale: more than 10 times a day; 5-10 times a day; 1-4 times a day; 1-4 times a week; once a week; less than once a week).

Furthermore, this group of employees was asked to complete a short questionnaire each time they were involved in an interaction with a colleague. In this way, detailed information about a large number of coordination events was collected. It was decided to collect this information over a regular working day, only interactions between 9.00 a.m. and 3.00 p.m. were recorded because employees started and ended their working days at different times. Since we were only interested in planning-related coordination, the production managers and foremen were asked to complete the questionnaire for interactions involving another manager, foreman or a production planner; the planners were asked to complete a form for all interactions they had. The short questionnaire collected information about the time of the interaction, the name and department of both participants in the interaction, the subject, and the duration of the interaction (Table 1). Twenty-five general questionnaires were returned. Nineteen employees participated in the detailed measurement of individual interactions. A total of 220 interaction questionnaires were collected, with the number generated by individual employees varying between one and 44.

---- INSERT TABLE 1 AROUND HERE ----

3.3 Results and implications

In this section, we describe and interpret the main findings from the case analysis. The focus is on the coordination activities of the production planners. The planning structure, as described in Section 3.1, is fairly standard. The notion is that dependencies between the departmental plans and schedules are dealt with by formal rules, and little communication and mutual adjustment are therefore needed. However, the reality of the work related to rescheduling destroys this utopian image. Many events invalidate the plans, resulting in a large number of interactions concerning constraint violations, possible solutions, and plan adaptations. Roughly, three groups of events are distinguished.

(1) Rush orders that have to be delivered within a shorter than standard delivery time. Rush orders are divided in three categories: mock-ups, complaint orders, and normal rush orders. Mock-ups are samples of furniture to be delivered on very short notice that could result in large customer orders in the future. Complaint orders relate to products that have to be repaired or reproduced because they do not fulfill all customer requirements.

(2) Changes to a production order, like a change in the Bill of Material, production specification, delivery date, or earliest start time of a production operation. Order changes originate from three sources: suppliers, customers, and internal processes. Suppliers who do not deliver material or do not deliver on time require production orders to be rescheduled. Customers can change the order specifications (material, type and amount of products), but also the delivery date or address, resulting in one or more schedules to be adapted. Internal causes for order changes are production errors, machine failures and maintenance, material shortages, and distribution problems.

(3) Order cancellations that lead to unused machine and employee capacity.

Clearly, events have a rather different influence on the feasibility and optimality of the production schedules. Both the scope and the timing of the event affect the number of people to be involved in the event handling process (cf. Koh *et al.* 2002; Koh and Saad 2002). Some production failures can be solved by an individual scheduler, whereas rush orders require intense coordination of several schedulers. Overall, more schedulers have to be involved if the delivery time of the order is closer, but then the time available for coordination becomes less.

The planners are informed about the events in several ways.

(1) Each morning, a list of exception messages is generated by the computer system as a result of the nightly MRP I run. The number of messages a planner receives, depends on their position in the process: the more upstream, the more messages. Whereas the assembly planner might typically receive three such messages, the metalworking department planner might get eight, and the purchasing planner anywhere between 50 and 100.

(2) During the day, a large number of email messages are circulated: from sales agents, the order acceptance department, suppliers, and various staff departments (engineering, logistics, maintenance etc.).

(3) The planning manager, the assembly planner, and the production managers evaluate issues related to schedule feasibilities and approaching irregularities during weekly meetings.

(4) Feedback from the shop floor is received through an in-house deficit announcement system. This MS Access-based system is made up of standard sheets that the operators can complete in the event of material or machine problems. We analyzed data covering a period of eleven months to gain insights into the number and magnitude of these announcements (Table 2). On average, nearly 600 problems were reported per week.

(5) Events are also reported by the operators, foremen, and production managers through phone calls and face-to-face interactions. Although all feedback and instructions should formally follow the hierarchical structure, direct communication is common to avoid time delays.

---- INSERT TABLE 2 AROUND HERE ----

All the planners process the MRP I exception messages as soon as they can at the beginning of the day. Following this, they work on the plans for the next days, but they regularly check their mailbox and the deficit announcement system. Given the large number of phone interruptions, the planners often have to process events in parallel.

Figure 1 shows the reasons for the reported interactions clustered per department. Asking-for-information is reported as the main reason for the interaction in almost half of all measured interactions (46.5%). Providing information is the reason in 31.3%, whereas negotiation and evaluation are less frequently reported reasons for the interactions.

Table 3 provides information about the initiator in the interactions. From the 138 interactions reported by the respondents from the planning department, 53 interactions (38.4%) were initiated by themselves. Thus, most of the planner's interactions were initiated by others. These interactions are interruptions in the planner's work and require the planner to quickly change his attention.

---- INSERT FIGURE 1 AROUND HERE ----

---- INSERT TABLE 3 AROUND HERE ----

From the 220 interaction reports, the average duration of an interaction for each person could be calculated. The data from the general questionnaire provides the number of verbal interactions each planner has on average on a typical working day with various work functions. By multiplying these two values together, the total time a person spends on verbal interaction activities during a working day has been calculated. Table 4 shows the results by work function. No planner spent less than two hours a day on verbal communication. Obviously, this verbal communication is only a part of the coordination activities performed by a planner, so, the total amount of time spent on coordination is even more.

---- INSERT TABLE 4 AROUND HERE ----

The intensive communication and coordination between the hierarchically and laterally related planners and other employees enabled the company to process many events. Nevertheless, a sense of hectic and unorganized fire-fighting behavior was sensed. For instance, most events were communicated immediately to a large number of people who *might* be affected by them or *might* be able to contribute to a solution. This 'over-communication' caused much difficulty in prioritizing and processing events. Apparently, a more fundamental approach to structure coordination in the rescheduling process was necessary but, unfortunately, existing planning and scheduling frameworks offered little help in this. The case analysis challenges the assumptions in traditional planning approaches concerning the organizational requirements at the lower planning levels. The data on the number and variety of interactions made by planners contest the view that planners *make* plans and that information mainly flows in one hierarchical top-down direction. In fact, they *adapt* plans and information spreads heterarchically. The findings confirm Cowling and Johansson's (2002) observation that firms need sound organizational event handling guidelines to enhance rescheduling efficiency. As an initial step, we developed a procedure for dealing with events in a more systematic way. To implement the procedure, no major adaptations were required in the scheduling process or in the scheduling systems; therefore, the procedure could be used almost immediately. The use of the procedure in the case company is discussed in Section 4.4.

4. Procedure for event handling

The previous sections have shown that event handling and rescheduling often demand coordination between several employees. To prevent unnecessarily coordination and to enhance efficient and responsive rescheduling, schedulers need a prescriptive procedure for event handling. Organization science reveals that coordination calls for an explicit organizational design (Goold and Campbell 2002). For example, distinct coordination mechanisms like hierarchical referral and lateral adjustment should be employed depending on the specific context (Galbraith 2002). In this section, we present a procedure to facilitate the processing of events, including the assessment of the event's urgency, the determination of the people to be involved in the rescheduling process, and the application of appropriate rescheduling methods. In this way, the procedure is especially meant for the first step in rescheduling: evaluation of the event (Cowling and Johansson 2002; Wu and Li 1995).

The procedure builds on the planning flexibility study by Van Wezel *et al.* (2006) who distinguish five key questions for the analysis and processing of events. These questions deal with the event type, the period the event relates to, the information processing capacity required and the throughput time necessary to process the event, and any possible shop-floor effects of the event. These questions can be combined into two types of issues that have to be considered in determining the appropriate action after an event has occurred: 1) the time that is necessary and the time that is available to handle the event, and 2) the consequences of the event and of potential solutions for the own and other's plans. Events are processed at all planning levels; the proposed procedure is developed for planners and schedulers at all these levels. Therefore, the terms 'plan' and 'schedule', and 'planner' and 'scheduler' are used interchangeable in this section.

4.1 Time necessary versus time available to process an event

The first issue to consider when dealing with an event is its urgency (Aytug *et al.* 2005; Koh *et al.* 2002; Subramaniam *et al.* 2005). Events that disturb the execution of the ongoing plan force the planner to take a quick decision in order to minimize immediate losses. After a quick fix, the planner can subsequently analyze the event in more detail and take further action. In such instances, 'damage' has to be minimized as far as possible. Nevertheless, the loss due to the event will have to be allocated somewhere; for example, a choice may have to be made between delaying an order and working overtime. If an event does not require immediate action, the event and alternative solutions can be investigated more extensively before taking action. For instance, order cancellations that are received a week before production would normally start, do not require immediate action, but are a potential enabler of schedule improvements.

4.2 Individual or joint event handling: the interconnectivity of planning decisions

The need for coordination to process events will largely depend on the organizational design of the planning function (Galbraith 2002; Goold and Campbell 2002). As discussed in Section 2, plans and schedules are related to each other hierarchically and laterally. Within a hierarchical planning structure, plans at a higher level determine the goals and constraints of lower-level plans. The feasibility of the higher-level plan is nevertheless determined by the feasibility of the lower-level plans, i.e., only if the lower-level plans can be executed successfully, the higher-level plan is valid (Aytug *et al.* 2005). Therefore, the higher level should examine if an event or an adaptation to a plan will lead to infeasibility problems in the lower-level plans (Cowling and Johansson 2002; Kreipl and Pinedo 2004). Consider, for example, the following situation: a rush order is accepted, and a stock replenishment order is postponed to create capacity for the rush order. At the aggregate level, there does not appear to be any constraint violation. However, in this example, there are sequence dependent setup-times, and as sequencing is done at the lower level, the higher level can only take into account average setup-times. Hence, one of the lower, more-detailed, levels might now not be able to create a valid schedule because the set-up time for the rush order is much longer than for the postponed stock order. In other words, one hierarchical planning decision can invalidate another. Interestingly, the same is true for plans and schedules that are related laterally. Lateral interdependencies are managed through (implicit) commitments between different planners (we refer to them as 'peers'). For example, all production planners have a fixed time slot in which all operations on an order have to be scheduled. The plan of another department could become infeasible, and it is therefore invalidated, if the own plan becomes infeasible within these lateral commitments (Koh *et al.* 2002). Violated lateral commitments are comparable with the so-called 'dependent affected operations' in a shop schedule (Wu and Li 1995).

The numbers of planning levels and/or peers that need to be involved in the event handling process depend on the urgency and the impact of the event. In general, the greater the number of participants, the more time and effort the rescheduling process will take. Therefore, the rescheduling process should begin with a detailed investigation of the event. This starts by checking whether the event invalidates any plans or allows for plan improvement, and should be followed by checks as to whether the plan can be adapted, in good time, within the constraints set by higher planning levels, within the commitments agreed with peers, and within the possibilities open to lower-level planning levels.

4.3 Procedure for structured event handling

The urgency, timing, and impact of an event lead to distinct ways to respond. Figure 2 shows the procedure consisting of a sequence of decisions and actions for a scheduler receiving an event. The boxes represent the key questions and actions at the start of the rescheduling process: information processing tasks (1a-e), 'passive' actions (2a-b) and planning tasks (3a-d). Each of the actions has consequences for the way coordination during the rescheduling process has to take place. Further, each decision limits the choice between appropriate types of rescheduling heuristics to be applied in the action phase.

---- INSERT FIGURE 2 AROUND HERE ----

1. Information processing tasks

1a. Check for invalidation. After an event has been received, the scheduler should first check whether it makes the existing plan unfeasible. The validity of lower-level plans needs to be checked as well, because an infeasible lower-level plan invalidates its parent. Thus, coordination with shop floor operators and foremen could be necessary. Events that make a plan invalid must be dealt with in one way or another. Events that do not lead to plan infeasibility, such as the cancellation of an order, can offer room for plan improvement.

1b. Check for adaptability. If the plan has to be adapted, one should check whether the proposed adaptation could be realized within the constraints imposed by the higher planning levels and the commitments made to peers. If such an adaptation is possible, the event can be dealt with locally; if not, the involvement of fellow-planners is needed. Assessing a schedule's adaptability could involve the processing of both formal and informal information received from a large number of people (McKay *et al.* 1995c).

1c. Estimate the time needed versus the time available for upward referral and/or revision of commitments. If an event requires the plan to be adapted in a way that cannot be realized without violating constraints set by higher planning levels (i.e., a problem cannot be solved at the plan's own level), the higher level should be notified so that it can modify the constraints it imposes on the level of the problem. Similarly, if an event violates commitments made to peers, then these should be contacted to renegotiate the commitments. However, hierarchical or lateral coordination may take longer than the time available to take action. For example, if a raw material is found to be out of stock, the scheduler immediately needs to know what alternative product should be made to keep the shop floor busy. However, the planning run that would normally determine this might take several hours. Therefore, the scheduler should compare the time available for rescheduling, in terms of when an answer is required, with the lead-time of the rescheduling process if others become involved.

1d. Estimate the time needed versus the time available for replanning including checking for possible lower-level invalidations. If an event can be processed locally, the scheduler should assess whether there is sufficient time for formal rescheduling, e.g., by waiting for the next regular MRP I run. Furthermore, the potential impact of the new scheduling decisions on the lower levels should be assessed since such decisions change constraints at these levels (see Section 4.2). Again, coordination with the decision makers at these lower levels could be necessary to understand the consequences of rescheduling.

1e. Assess whether the plan can be improved. If an event does not result in an invalid plan, it might be possible to improve the existing plan. However, rescheduling may be limited by possible negative consequences of plan adaptation for the lower levels or peers (Section 4.2).

2. Passive actions

2a. Refer upwards or start lateral coordination. If the existing plan is invalidated and cannot be corrected at its own level because of constraints set by the higher level, this higher level has to determine whether any, and if so which, restrictions can be relaxed (such as allowing overtime to overcome a time constraint). Similarly, if commitments to a peer are violated, the peers must be asked if they can relax these commitments (such as by receiving the delivery of part-finished products in several batches rather than all by the promised deadline). A request to the higher level or to a peer can be viewed as an incoming event for that colleague, who can process this event with the help of the procedure likewise. However, upwards referral and lateral coordination result in a task interruption in the work of a colleague. Therefore, the scheduler should carefully consider who should be involved in the event handling process at what point in time.

2b. Do nothing. If the event does not invalidate existing plans or offer opportunities to improve the plan, nothing further needs to be done.

3. Planning tasks

3a. Allocate damage. If there is insufficient time to involve the higher planning levels or one's peers, the problem must somehow be dealt with at one's own level and/or delegated to lower-planning levels. This might be a temporary fix, as the higher planning level might adjust to the changes at a later stage. Anticipating this correction is an important aspect of damage allocation. Damage can be minimized by means of coordination, for instance between a scheduler and a sales representative about which customer's order to postpone. Thus, whereas coordination in Action 2a is about adapting constraints and commitments to achieve a valid schedule, coordination in Action 3a is aimed at minimizing the losses (or costs) due to an irresolvable violation.

3b. Repair plan. If there is insufficient time for formal replanning, the scheduler should repair the plan to the extent possible. Repairing differs from replanning in that it adapts the schedule only partially, whereas in replanning the schedule is completely updated. Repair planning often results in suboptimal solutions because not all the information or options could be considered within the time limitations. Another reason for limited repair planning is the avoidance of nervousness on the shop floor due to too many changes in the schedules.

3c. Replan. If there is sufficient time, the plan can be completely revised. During this total rescheduling, all event information as well as up-to-date information from the lower planning levels should be taken into account because the actual situation on the lower levels could result in extra constraints (see Section 4.2).

3d. Improve plan. If the event enables the improvement of the plan, the scheduler should consider the consequences of plan adaptation, similarly as in the Actions 3b and 3c. While repair planning and replanning are indispensable activities to solve an infeasibility problem, improvement of the plan is optional: the schedule is still feasible.

In all planning tasks, the scheduler(s) can make use of support tools that are available in the firm's planning systems, like repair scheduling and total rescheduling algorithms, heuristics, or other methods. The procedure makes clear that some events require such a quick response that the use of extensive rescheduling methods is not possible. Therefore, the procedure shows that the different planning tasks demand for a portfolio of rescheduling methods to respond to events adequately.

4.4 The procedure applied in the case company

The procedure has been developed after our analysis of coordination activities in the case company (Section 3). We expected a decrease of the number of interactions and improved rescheduling efficiency as a result of the use of the procedure. Three months after the detailed measurement of coordination behavior (see Section 3.2), a workshop was organized in which the procedure was presented. Hierarchical and lateral planning interdependencies between the employees and departments were discussed by means of event-specific charts. With these charts, a planner could easily determine which colleagues would be affected by a number of frequent and typical events.

As an example, figure 3 shows an application of the procedure for the finishing planner at the case company. In this figure, decisions and actions are listed for the most frequent types of events. Finishing is the production activity in-between metalworking (i.e., component manufacturing), and assembly. Therefore, the main 'peers' of the finishing planner are the planners responsible for the plans and schedules for the metalworking and assembly departments. The finishing plan is hierarchically restricted by the MRP I-output and the master production schedule. Typical events received by the finishing planner deal with rush orders, product rework due to quality problems, material shortages, machine or tool breakdowns and maintenance. Furthermore, the planner is confronted with requests to adapt his plans from fellow-planners who are struggling with constraint or commitment violations. These requests are processed with the help of the procedure just like the other events (see Action 2a above). When the planner receives an event, he starts with determining its impact on plan feasibility (1a). Depending on the event's impact, the planner follows the boxes and arrows in the procedure by answering the typical questions as mentioned in figure 3. Finally, the planner ends at one of the actions 2a-3d.

---- INSERT FIGURE 3 AROUND HERE ----

To investigate the effects of the use of the procedure, we interviewed the planners, production managers, and foremen seven months after its introduction. We again asked the respondents to indicate the number of rescheduling-related interactions per day. Table 5 shows that, overall, the number of interactions have decreased. Especially the order chaser has fewer interactions per day. As an explanation, the interviewees indicated that the use of the procedure had led to a less frequent involvement of the order chaser during event handling. The planners confirmed the positive effect of the procedure as an instrument to process events in a more structured way.

---- INSERT TABLE 5 AROUND HERE ----

5. Conclusions and further research

Planners and schedulers are confronted with a variety of events that often lead to a series of plan adaptations. Frequently, the consequences of an event are not restricted to a single plan or schedule. Because planning and scheduling tasks are, in many firms, shared among several employees, they have to coordinate their rescheduling decisions to maintain the alignment of their plans and schedules. However, this coordination is under the pressure of time constraints: events often require a quick response as a result of which there is not sufficient time available for coordination.

This study contributes to rescheduling research and practice in several ways. First, the causes for coordination were elaborated: hierarchical and lateral interdependencies between the planning and scheduling decisions made by different people require mutual alignment. Further, the case analysis of a typical manufacturing situation showed the magnitude and diversity of human coordination activities of planners and the need to structure the event handling process. Third, we presented a procedure to facilitate and structure the event handling process. The procedure supports a scheduler evaluating the urgency and scope of an event and selecting the right group of people to be involved in the event handling process. The evaluation of the use of the procedure in the case company provides evidence for its usability and its positive influence on rescheduling efficiency. Due to the general and abstract phrasing of the decisions and actions, the procedure is applicable in a wide variety of firms that employ multiple, interdependent planners and schedulers. We expect the proposed procedure to be especially useful in scheduling situations characterized by a high number and high variety of events, because of the difficulty to prioritize and process events efficiently. These situations appear in many firms, irrespective of the production strategies they use, like make-to-order or make-to stock. Certainly, the complexity of event handling differs between firms. In make-to-stock firms, client order changes will probably have fewer consequences than in make-to-order firms. However, setup changes will probably have more consequences in make-to-stock environments than in make-to-order situations. Therefore, the usability of the procedure is not restricted to a special type of firms. In all these situations, clear strategies and procedures for event handling are necessary. Further research is planned to investigate the applicability and usefulness of the procedure in different scheduling environments. The event handling procedure forces the schedulers to respond in a prescribed way; implementation of the procedure implies a formalization of human behavior in response to events. The result of using the procedure will therefore be investigated over a longer period of time to understand its influence on human dynamics in scheduling and rescheduling.

Several other directions for future research are worth to be mentioned. First, the case findings and the procedure show the need for a portfolio of rescheduling techniques to process the variety of events under different time and coordination conditions. Therefore, the planning tasks in the procedure should be extended by classifications of rescheduling techniques that can be applied in each of the tasks. Existing classifications can be used as a starting point

(Aytug *et al.* 2005; Koh *et al.* 2002; Vieira *et al.* 2003), but careful analysis of the assumptions in the techniques is needed. Second, the allocation of planning tasks to several planners and schedulers has important consequences for the need for coordination between them during rescheduling. The relation between planning structure and event handling requires further research efforts to extend planning frameworks like MRP II, and to integrate planning, scheduling and rescheduling models and methods. Third, this paper has shown the importance of accurate coordination activities of planners and schedulers. The proposed procedure supports them determining *when* coordination during rescheduling has to take place. Future research is planned to investigate *how* these coordination activities should be organized, managed, and supported. For instance, the role of information systems to support information sharing, communication, and negotiation activities within the rescheduling process will be investigated. Another research topic is related to the measurement and the management of the efficiency of these coordination activities to preclude superfluous interactions but encourage essential communication.

Finally, events often require a quick response, but an appropriate reaction is regularly only possible after coordination between several people. Therefore, procedures and working methods are necessary that provide guidelines for efficient event handling. Possibly, such procedures will also lead to a wider use of rescheduling methods and techniques in practice.

References

Abumaizar, R.J. and Svestka, J.A. 1997, Rescheduling job shops under random disruptions, *International Journal of Production Research*, 35 (7), 2065-2082.

Aytug, H., Lawley, M.A., McKay, K.N., Mohan, S., and Uzsoy, R. 2005, Executing production schedules in the face of uncertainties: A review and some future directions, *European Journal of Operational Research*, 161 (1), 86-110.

Berglund, M. and Karltun, J. 2007, Human, technological and organizational aspects influencing the production scheduling process, *International Journal of Production Economics*, 110 (1-2), 160-174.

Bertrand, J.W.M., Wortmann, J.C., and Wijngaard, J. 1990, *Production control: A structural and design oriented approach*, Amsterdam, NL: Elsevier.

Caricato, P. and Grieco, A. 2008, An online approach to dynamic rescheduling for production planning applications, *International Journal of Production Research*, 46 (16), 4597-4617.

Cowling, P. and Johansson, M. 2002, Using real time information for effective dynamic scheduling, *European Journal of Operational Research*, 139 (2), 230-244.

Crawford, S., MacCarthy, B.L., Vernon, C., and Wilson, J.R. 1999, Investigating the work of industrial schedulers through field study, *Cognition, Technology and Work*, 1 (2), 63-77.

Fransoo, J.C. and Wiers, V.C.S. 2006, Action variety of planners: Cognitive load and requisite variety, *Journal of Operations Management*, 24 (6), 813-821.

Galbraith, J.R. 2002, *Designing organizations*, New and revised ed. San Francisco, CA: Jossey-Bass.

Goold, M. and Campbell, A. 2002, *Designing effective organizations*, San Francisco, CA: Jossey-Bass.

Hall, N.G. and Potts, C.N. 2004, Rescheduling for new orders, *Operations Research*, 52 (3), 440-453.

Herrmann, J.W., ed. 2006, *Handbook of production scheduling*, New York, NY: Springer.

Ho, C.-J. 2005, Examining dampening effects for alternative dampening procedures to cope with system nervousness, *International Journal of Production Research*, 43 (19), 4009-4033.

Jackson, S., MacCarthy, B.L., and Wilson, J.R. 2004, A new model of scheduling in manufacturing: Tasks, roles, and monitoring, *Human Factors*, 46 (3), 533-550.

Jett, Q.R. and George, J.M. 2003, Work interrupted: A closer look at the role of interruptions in organizational life, *Academy of Management Review*, 28 (3), 494-507.

Jonsson, P. and Mattson, S.-A. 2006, A longitudinal study of material planning applications in manufacturing companies, *International Journal of Operations & Production Management*, 26 (9), 971-995.

Koh, S.C.L. and Saad, S.M. 2002, Development of a business model for diagnosing uncertainty in ERP environments, *International Journal of Production Research*, 40 (13), 3015-3039.

Koh, S.C.L., Saad, S.M., and Jones, M.H. 2002, Uncertainty under MRP-planned manufacture: Review and categorization, *International Journal of Production Research*, 40 (10), 2399-2421.

Kreipl, S. and Pinedo, M. 2004, Planning and scheduling in supply chains: An overview of issues in practice, *Production & Operations Management*, 13 (1), 77-92.

Kutanoglu, E. and Sabuncuoglu, I. 1999, An analysis of heuristics in a dynamic job shop with weighted tardiness objectives, *International Journal of Production Research*, 37 (1), 165-187.

MacCarthy, B.L. and Wilson, J.R., eds. 2001, *Human performance in planning and scheduling*, London, UK: Taylor & Francis.

McKay, K.N., Safayeni, F.R., and Buzacott, J.A. 1995a, 'Common sense' realities of planning and scheduling in printed circuit board production, *International Journal of Production Research*, 33 (6), 1587-1604.

McKay, K.N., Safayeni, F.R., and Buzacott, J.A. 1995b, A review of hierarchical production planning and its applicability for modern manufacturing, *Production Planning & Control*, 6 (5), 384-395.

McKay, K.N., Safayeni, F.R., and Buzacott, J.A. 1995c, An information systems based paradigm for decisions in rapidly changing industries, *Control Engineering Practice*, 3 (1), 77-88.

McKay, K.N. and Wiers, V.C.S. 2006, The organizational interconnectivity of planning and scheduling. *In*: W. Van Wezel, R.J. Jorna, and A.M. Meystel, eds. *Planning in intelligent systems: Aspects, motivations, and methods.* New York, NY: Wiley, 177-201.

Meal, H.C. 1984, Putting production decisions where they belong, *Harvard Business Review*, 62 (2), 102-111.

Mesarovic, M.D., Macko, D., and Takahara, Y. 1970, *Theory of hierarchical, multilevel, systems*, New York, NY: Academic Press.

Mula, J., Poler, R., García-Sabater, J.P., and Lario, F.C. 2006, Models for production planning under uncertainty: A review, *International Journal of Production Economics*, 103 (1), 271-285.

Pfeiffer, A., Kádár, B., and Monostori, L. 2007, Stability-oriented evaluation of rescheduling strategies, by using simulation, *Computers in Industry*, 58 (7), 630-643.

Pinedo, M.L. 2008, *Scheduling: Theory, algorithms, and systems*, 3rd ed. New York, NY: Springer.

Raheja, A.S. and Subramaniam, V. 2002, Reactive recovery of job shop schedules - A review, *International Journal of Advanced Manufacturing Technology*, 19 (10), 756-763.

Siggelkow, N. 2007, Persuasion with case studies, *Academy of Management Journal*, 50 (1), 20-24.

Simon, H.A. 1981, *The sciences of the artificial*, 2nd ed. Cambridge, MA: The MIT Press.

Speier, C., Valacich, J.S., and Vessey, I. 1999, The influence of task interruption on individual decision making: An information overload perspective, *Decision Sciences*, 30 (2), 337-360.

Subramaniam, V., Raheja, A.S., and Reddy, K.R.B. 2005, Reactive repair tool for job shop schedules, *International Journal of Production Research*, 43 (1), 1-23.

Van Wezel, W., Van Donk, D.P., and Gaalman, G.J.C. 2006, The planning flexibility bottleneck in food processing industries, *Journal of Operations Management*, 24 (3), 287-300.

Vernon, C. 2001, Lingering amongst the lingerie: An observation-based study into support for scheduling at a garment manufacturer. *In*: B.L. MacCarthy and J.R. Wilson, eds. *Human performance in planning and scheduling*. London, UK: Taylor & Francis, 135-163.

Vieira, G.E., Herrmann, J.W., and Lin, E. 2003, Rescheduling manufacturing systems: A framework of strategies, policies, and methods, *Journal of Scheduling*, 6 (1), 39-62.

Vollmann, T.E., Berry, W.L., Whybark, D.C., and Jacobs, F.R. 2005, *Manufacturing planning and control for supply chain management*, 5th ed. New York, NY: McGraw-Hill.

Voss, C., Tsikriktsis, N., and Frohlich, M. 2002, Case research in operations management, *International Journal of Operations & Production Management*, 22 (2), 195-219.

Wu, H.-H. and Li, R.-K. 1995, A new rescheduling method for computer based scheduling systems, *International Journal of Production Research*, 33 (8), 2097-2110.

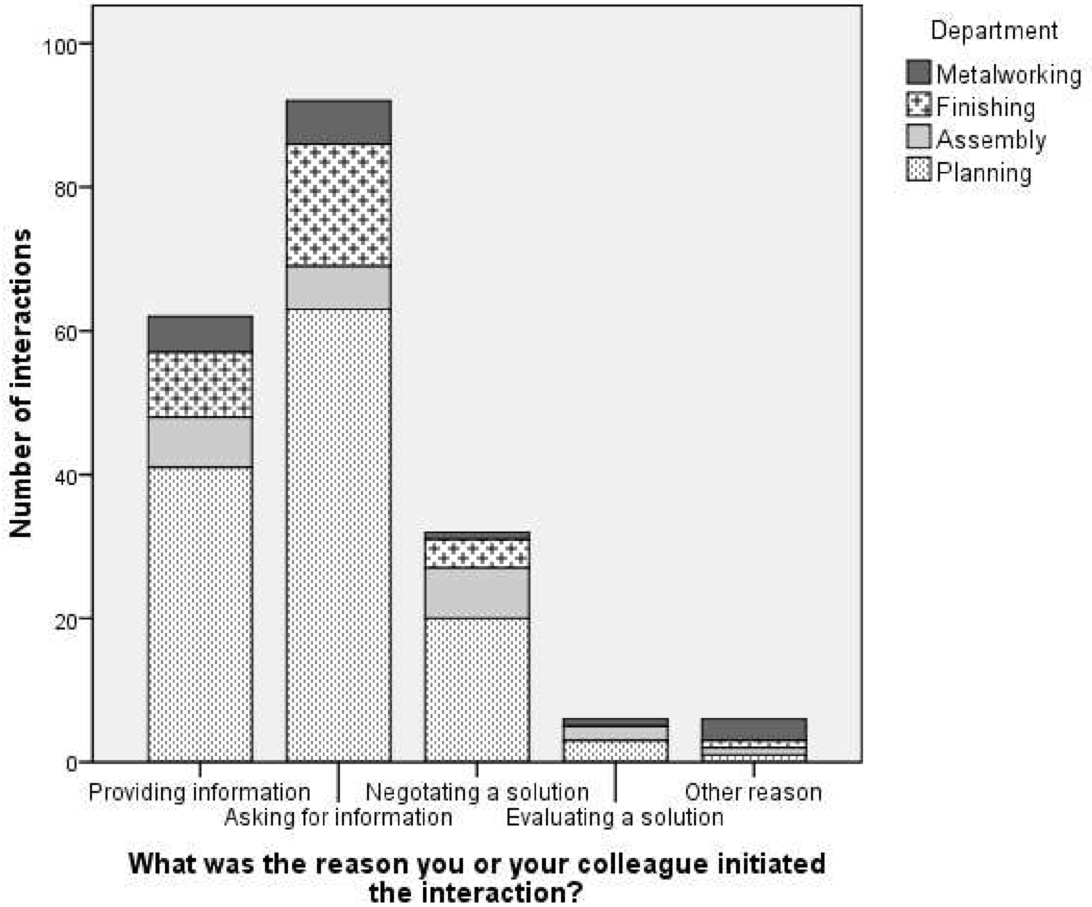

Figure 1. Reasons for the interactions.

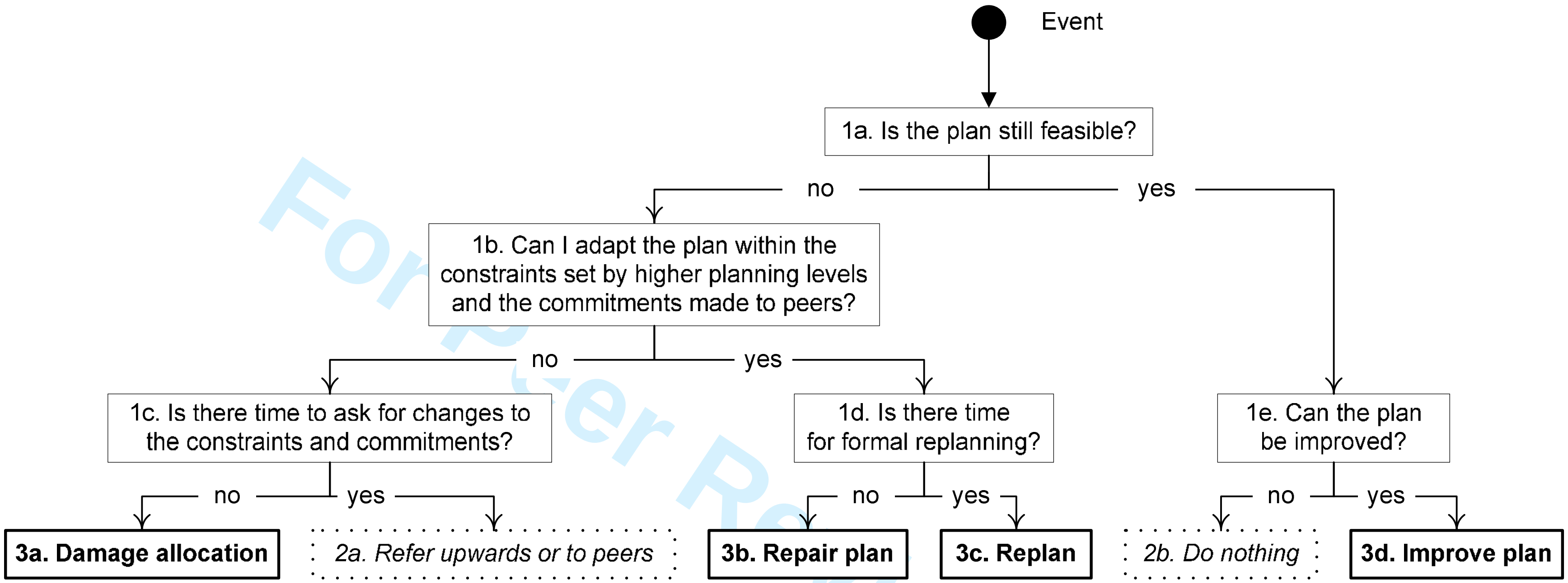

Figure 2. Procedure to structure event handling.

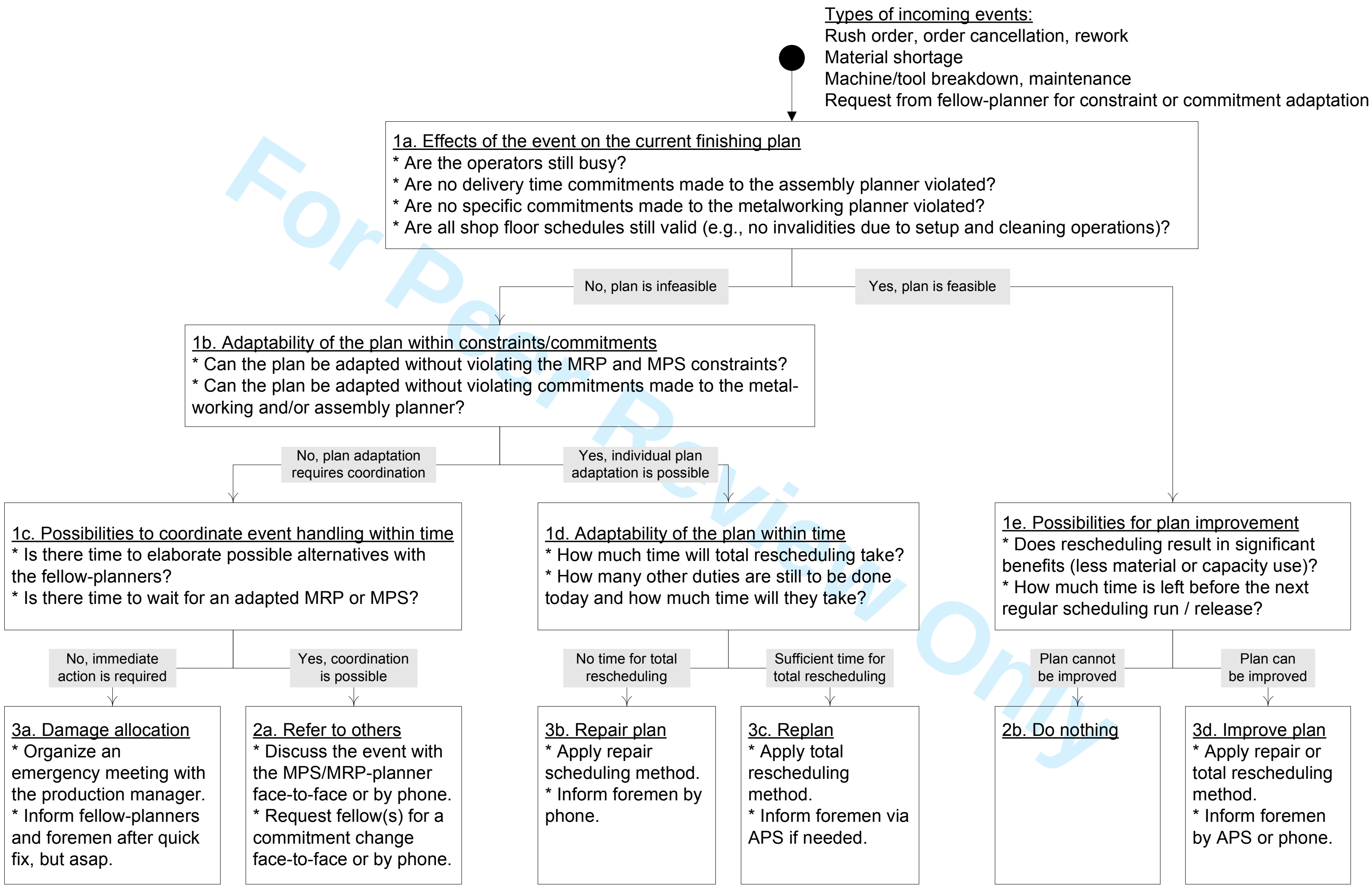

Figure 3. Application of the procedure for event handling for the finishing planner in the case company.

Table 1. Questionnaire items in interaction survey.

Issue	Question
Time	When did the interaction start?
Participants	What is your name? With whom did you have contact?
Initiator	Who initiated the interaction?
Subject	What was the subject you dealt with?
Duration	How long did the interaction last?

Table 2. Shop-floor pronouncements influencing plan feasibility (over 220 days).

Reason	Number of announcements	Average per week
Missing product parts	19534	444
Production failures (no repair possible)	2274	52
Production failures (requiring refinishing)	1688	38
Inventory inaccuracy	2715	62
Rejection of material from supplier	152	3
Total	**26363**	**599**

Table 3. Initiator of interactions per department.

		Who initiated the interaction?		
Department	**Data**	***You***	***The other***	***Total***
Planning	Number of interactions	53	85	138
	Percentage of interactions	38,4%	61,6%	100,0%
Metalworking	Number of interactions	17	8	25
	Percentage of interactions	68,0%	32,0%	100,0%
Finishing	Number of interactions	11	21	32
	Percentage of interactions	34,4%	65,6%	100,0%
Assembly	Number of interactions	12	11	23
	Percentage of interactions	52,2%	47,8%	100,0%
Total	Number of interactions	93	125	218
	Percentage of interactions	42,7%	57,3%	100,0%

Table 4. Frequency of interactions and time spent on operational coordination.

	Planner metal-working	Planner finishing	Planner assembly	Order chaser	Production managers	Production foremen
# interactions with planners	> 10	> 10	1 - 4	> 10	1 - 4	> 10
# interactions with order chaser	> 10	> 10	> 10	> 10	5 - 10	> 10
# interactions with production managers	1 - 4	1 - 4	1 - 4	5 - 10	5 - 10	5 - 10
# interactions with production foremen	> 10	> 10	5 - 10	> 10	5 - 10	5 - 10
# interactions with production operators	5 - 10	>10	5 - 10	> 10	5 - 10	5 - 10
# interactions with order acceptance	< 1	< 1	5 - 10	5 - 10	< 1	< 1
# interactions with purchasing	1	1	1 - 4	5 - 10	< 1	< 1
# interactions with expedition	< 1	< 1	1 - 4	5 - 10	< 1	< 1
Total number of interactions per day	> 50	> 50	± 50	> 75	± 35	± 40
Average length of interaction (minutes)	2 min	2 min	3 min	3 min	5 min	5 min
Total time spent on communication per day	± 2 hours	± 2 hours	± 2½ hours	± 4 hours	± 3 hours	> 3 hours

Table 5. Frequency of interactions seven months after the introduction of the procedure.

	Planner metal-working	Planner finishing	Planner assembly	Order chaser	Production managers	Production foremen
# interactions with planners	> 10	> 10	*> 10*	> 10	1 - 4	**5 - 10**
# interactions with order chaser	**5 – 10**	> 10	**5 - 10**	> 10	**1 - 4**	**1 - 4**
# interactions with production managers	**< 1**	1 - 4	1 - 4	**1 - 4**	5 - 10	5 - 10
# interactions with production foremen	> 10	> 10	**1 - 4**	> 10	5 - 10	5 - 10
# interactions with production operators	*> 10*	>10	**1**	**1**	5 - 10	*> 10*
# interactions with order acceptance	< 1	< 1	5 - 10	5 - 10	< 1	< 1
# interactions with purchasing	1	1	1 - 4	5 - 10	*1*	< 1
# interactions with expedition	< 1	< 1	**1**	**< 1**	< 1	< 1
Total number of interactions per day	**± 40**	> 50	**± 40**	**± 50**	**± 30**	**± 35**

Figures in bold show a decrease of frequency, figures in italics show an increase of frequency.