

HUMAN, TECHNOLOGICAL AND ORGANIZATIONAL ASPECTS INFLUENCING THE PRODUCTION SCHEDULING PROCESS

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Abstract

The complexity of planning and scheduling, that its activities are comprised of and influenced by technical and social aspects, has been highlighted in earlier studies. The objective of this paper is to assess how the outcome of the production scheduling processes in four companies is influenced by human, technological, and organizational aspects. A conclusion is that the outcome of the scheduling process is influenced by the scheduler adding human capabilities that cannot be automated, problem-solving when the technical system fails, and negotiating between groups of employees to handle incompatible goals. Technology influences by limitations in the scheduled production system as well as the scheduling tools available. The organization, finally, influences the outcome through degree of proximity between employees, meeting structures, the schedulers' position in hierarchy and their work role interconnecting activities of different organizational parts.

Keywords:

case study; humans, technology and organization; planning, scheduling and control

1 INTRODUCTION

Production scheduling is an activity in which many demands and restrictions concerning fulfilling deliveries must be handled and negotiated. The current trend towards reductions in lead times imply that the scheduling tasks must be performed under a continuously reduced available space with respect to time. At the same time, reductions of inventory, removed buffers and fulfillment of increased customer demands must be reached. Therefore, it can be assumed that production scheduling is increasingly difficult to handle for many enterprises. To succeed in coping with these difficulties, the performance of the production scheduling activities is critical [1].

The dominant research and development concerning scheduling has been aimed mainly at solving technical, logical or mathematical delimited problems with limited concern on what scheduling in practice actually encompass. Further studies have highlighted the complexity of planning and scheduling, that it is comprised of and influenced by technical, organizational and human aspects [2]. More recent research has developed knowledge about and described scheduling from perspectives including the function of the human scheduler [3], [4], [5], [6], [7]. Scheduling is for instance, apart from the influence of organizational issues, also influenced by such aspects as roles, trust, respect and interpersonal interaction [8]. Recent research has thus identified skill and performance of production schedulers as important for a company to achieve high productivity and flexibility [9].

The distinction between planning and scheduling is somewhat unclear. One definition is that scheduling involves issues when the production process is running, while planning is associated with decisions made before the production process starts [10]. However, the precise interaction between production planning and scheduling is unclear and it is justified to assume that planning and scheduling represent a continuum of activities across space and time [5]. Dispatching may also be included in this continuum of activities ranging from deciding which

operation to be performed next at an individual workplace to overall planning of the annual production capacity of an entire corporation [11]. The work activities studied here involved activities dealing with capacity, scheduling of production as well as dispatching individual orders. However, the term "scheduling" is used for these activities throughout the paper.

The results presented here are part of a study concerning practice of production planning scheduling in four Swedish woodworking companies: a sawmill, a parquet manufacturer, a furniture manufacturer, and a house manufacturer. The objective of this paper is to assess how the outcome of the production scheduling processes in the case study companies was influenced by individual human aspects, technology and organizational aspects. A further objective is to draw some conclusions whether an analysis based on these aspects will make it easier to understand under what conditions a scheduler performs.

2 HUMANS, TECHNOLOGY AND ORGANIZATION

A concept taking into account humans, technology and organization for analyzing and improving e.g. work systems has been used in Swedish organizations and it will in the following text be referred to as the HTO-concept (Humans-Technology-Organization). The concept was developed during the 1980's within the nuclear power industry. The aim was to improve overall safety. When developing safety, strong focus was first put on technical improvements, which resulted in reduced number of near-accident incidents caused by technical failures. As a result, the incidents caused by humans became more "visible" as they represented a larger share of the incidents. After a period focusing on the field of potential "human error", safety further improved. Thereby, it became obvious that it was necessary also to consider organizational issues, i.e. all three components in the system to improve safety [12].

The system view of the HTO-concept was considered successful for improving safety and developing a more

thorough safety culture and has thus spread to other domains [13], [14]. The HTO-concept has then been widely used as a meta-concept that may be applied to analyze and develop further understanding of any type of business or activity of high complexity. The main point is that successful development is only achieved if all three components are regarded. The concept is complementary to the research, in which a special focus is chosen, for instance focusing technology while human and organizational aspects are treated as influencing factors [15]. There is a relation to the earlier sociotechnical systems theory, which aims at improving working conditions as well as organizational performance [16]. The HTO-perspective, however, distinguishes between the individuals and the organization.

In the HTO-perspective, the "H" stands for the importance of aspects that are strictly individual and at the same time considered important for the ability to perform a task or a change. Such aspects may e.g. include individual skill, knowledge, experiences or established relations, and they are not easily replaceable in a short term perspective. The component thus focuses on the individual's contribution to the business process. The "H" may be described at any of the following four levels: 1) The biological level. 2) The cognitive level, where the human is considered as an information processing system, including thought processes, representations, decision-making etc. 3) The psychological level, where the human has a unique history, leading to a specific subjective processing of the situations he/she experiences. 4) The social level, emphasizing that every single individual is a member of several social groups with different cultures, which will partly determine his/her values and habits [17]. In this study, the humans were principally considered at the cognitive and social level respectively.

The "O", on the other hand, represents the H-component in an aggregated sense. It is therefore not considering single humans but humans in a statistical interchangeable way [15]. However, the O-component consists of more than humans. It also comprises how the work is organized and structured, both formally and informally. Furthermore, it includes rules, procedures and cultural factors as well as relations between system components and subsystems. Examples of this are job definitions, responsibilities and powers, hierarchical positions, policies, business goals and strategies. In addition there is a physical aspect of the O-component regarding where people are located. This affects the scheduler's work in a very concrete way. A typical problem in organizations, which schedulers also must deal with, is goal conflicts between departments (subsystems).

The third component, the "T", stands for the technical system. This can be divided into two different parts. First, there is the primary technical production system including the production equipment that is primarily devoted to maintain the abilities of the company to stay competitive in the business and to produce customer value. As complex systems these technical systems can be described in different ways concerning technical limitations, problems (both recurrent and stochastic), availability, reliability etc. The complexity also calls for to regard these systems as being networks of linked autonomous parts which are to a large extent separately controlled and managed. Main examples of this are the entire woodworking machinery in the studied companies. A secondary technical system is the system that assists the administration and procedures of the company but is not directly associated with the business as such [18]. This information system includes both hardware and software that the scheduler uses as decision support tools.

In a system perspective these components will interact in different ways. One assumption is that it is in the interaction between the components that many of the interesting characteristics of the work of the schedulers are to be found. The interest here is limited to the work of the human scheduler why the analysis is delimited to the interaction between the H- and T-component and between the H- and O-component respectively.

Regarding the HT-interaction, some criteria that have proven to be valid for the design of the information system are whether it is integrated with the task, whether it is tolerant of errors, whether it provides relevant feedback, and whether it is transparent for the scheduler, i.e. that the scheduler can understand or has confidence in the relation between the decision support and his/her own understanding of the situation.

The interaction between the scheduler and the organization is naturally very extensive and can be described at different levels and from different perspectives. Drawing from role theory, there are role expectations and roles sent from different parts of the organization, naturally from managers following the hierarchical position but also from colleagues and workers. The roles become more complex when they require the individual to be simultaneously involved in two or more subsystems, since each is likely to have its own priorities and to some degree its own subculture [19]. In the case concerning the schedulers, there is thus reason to believe that the demands and expectations held on them may contribute to the complexity of scheduling practice and the schedulers' performance.

3 METHOD

The methodological approach chosen for the overall project was ergonomic work analysis [20]. It is based on analyses of work activities carried out in real work situations in order to learn about the employees' knowledge and competence, how information is collected and treated as well as how decisions are made. The method used included a detailed description of the mission, i.e. why the enterprise accepted to participate in the research project, the scheduling task, and the work context comprising technology, work process, roles and activities. Data collection was carried out in three stages, by acquiring knowledge of scheduling as initially described by the companies, as further described in the researchers' interviews with the staff, and scheduling activities as observed by the researchers.

Data were collected through discussions and open interviews with the scheduler, management and other employees the scheduler identified as crucial for his work. The interviews concerned production scheduling, the interviewees' own involvement in scheduling, or contacts with the scheduler. Documents, software support and the characteristics of the technical production system as well as the product demands were studied and described. These collected data served as the authors' pre-understanding of scheduling work at the particular companies before carrying out the observations of scheduling activity in practice. Furthermore, it provided the authors with the dominant descriptions within the company of what was supposed to be carried out in scheduling work.

Each scheduler's work was observed during five entire working days although not in the same week. Observations took place each day of the week (a Monday, a Tuesday etc.) to allow for regular variations in work to be observed. During the observations, all notable work activities were recorded in terms of descriptions of tasks, time, people involved, use of aids, initiatives to activities taken, communication pattern, physical placement etc.

After the observations, a second set of interviews were carried out, in which the interviewees evaluated the state of

scheduling practice in their company, their expectations on the scheduler, how their work was effected by the scheduler, and how they effected the work of the scheduler. The interviewees selected for this second part were the schedulers in focus and those who during the observations were identified as having close contact with the scheduler. Some of those had been interviewed earlier and some not. The interviews were conducted with 15 people in the sawmill, 23 people at the parquet manufacturer, 11 people at the furniture manufacturer, and a total of 19 people at the house manufacturer. These interviewees included schedulers, operators, forklift truck-drivers, production supervisors, market representatives, managers etc.

To assess the value of applying an HTO-perspective the data collected were analyzed concerning the different components and their interaction. The interaction between the components "O" and "T" was omitted as the collected data did not support that analysis. Furthermore, the interaction between the schedulers and their decision support system was not elaborately studied why the analysis on these issues is only made at a cursory level.

4 COMPANY DESCRIPTIONS

4.1 The sawmill

The sawmill belonged to a larger sawmill group. It was organized in two sub-units. One was the sawmill with 42 employees, out of which five were white-collar workers, including the sawmill scheduler and the plant manager. The other was a secondary woodworking industry performing planing operations and producing some own products such as cable drums and storage shelves. This unit had about 90 employees.

The sawmill produced about 110,000 m³ sawn wood mainly for the international market. Products manufactured for the building and construction market were beams, tongue and groove boards, and scaffold planks. 40% of company production was exported to Japan, a smaller quantity to Taiwan. The sawmill's primary focus on the Japanese market put new demands on the company, such as producing beams with very fine tolerances and specific shipping conditions.

The planning and scheduling work analyzed was performed at the sawmill. The company aimed at selling most of the production on long-term contracts usually made up for a three-month period at a time. The company had its own marketing manager, making up the contracts. The customer then sub-ordered needed volumes within the contract terms.

4.2 The parquet manufacturer

The parquet manufacturer was a major parquet manufacturer on the world market with sales agents in many countries. Its weekly production was more than 100,000 m² of parquet. It had about 2,000 employees in different plants, most of which situated in Sweden. This study was carried out in the main plant, which had about 1,400 employees with 1,200 employees in production. Scheduling involved co-ordination of this production with that of the other plants. The production scheduling function belonged organizationally to production and it consisted of four people, two of whom were involved with daily production and two worked with the computerized scheduling system and development projects.

4.3 The furniture manufacturer

The furniture manufacturer was a family-owned company with 220 employees. It produced yearly 1.3 million bookshelves in different models for an international furniture retailer. This production constituted about 97% of

company turnover. The company faced strong competition and hard cost pressure, but it had at the time three-year agreements with the retailer. A large investment in an automated production line had recently been made, which was expected to strongly increase productivity and production volume. Production set-up was time-consuming why long production series were sought. There was one production scheduler who was responsible for master scheduling as well as for the MPC-system used.

4.4 The house manufacturer

The house manufacturer produced wooden houses for the Swedish market. It had 370 employees. Two thirds of the employees were white-collar workers and the remaining blue-collar workers. The large portion of white-collar workers was caused by the large amount of design and administrative work that was connected to building and contracting management. About 90 % of all houses sold were delivered including erection and installations at the building site. Main market was Sweden, but the company delivered to some other countries in northern Europe as well. From the scheduler's point of view, there were two different processes to manage, single family houses to private customers and larger houses or groups of houses with one external building contractor. The company was undergoing a change from being a standard house producer towards delivering houses with a more customized standard. The company therefore modified its organization and production continuously to improve its performance in this sense.

5 FINDINGS

5.1 Human aspects influencing the scheduling process

The study showed that scheduling in practice required high degree of cognitive tasks as scheduling work was characterized by abrupt changes from one work task to another, initiated by someone calling, entering the office, discovery of unexpected data in the scheduling software tool, or urgent e-mails. There were numerous examples of several issues being elaborated at the same time [8], and a strong need to work in a flexible manner. The schedulers were also expected by others to be flexible and discuss changes when initiated from other employees or the market. They should allow themselves to be influenced [21]. Another example of human aspects at a cognitive level was that scheduling practice included a great deal of problem solving [7]. This was carried out as part of the schedulers' planned activities, but often also as a consequence of something unplanned occurring in production, new information from the market etc. The numerous unanticipated events resulted in high degree of uncertainty, which derived from sources both within and outside the company. The high degree of uncertainty resulted in the schedulers continuously searching for process feedback. In many cases, the only way to receive necessary feedback was for the schedulers to visit other offices or production premises. While walking around, they often checked up on earlier problems, controlled that production was running as planned, and frequently visually inspected the amount of produced goods.

Related to the expectation of being flexible, the schedulers were expected to find compromises and negotiate between groups in the company. One example of this was the schedulers' need to continuously handle and make compromises on different, sometimes incompatible time scales, varying from single hours to two months for fulfilling operations or deliveries. Furthermore, the schedulers were expected to balance between different groups of employees, such as production units, delivery, market or

purchase that had different goals that sometimes were incompatible.

Production personnel, production supervisors, market representatives and the parquet manufacturer's quality manager strongly pointed out that they expected the production schedulers to solve problems in a more general sense. Apart from the areas earlier referred to, problem solving included handling of unexpected events, coordinating different production units, participating in production and product development etc. By that, the schedulers should have good understanding of the problems, be able to suggest and discuss different solutions, and carry through the solutions chosen. The schedulers themselves confirmed that they believed that others in the company considered them to be problem solvers, someone to turn to with all kinds of questions and problems [21]. To fulfill the role as problem solver, the schedulers needed thorough knowledge about details and functioning of the production system. In all four companies, the schedulers had long personal experience from working within production at the same sites as they were scheduling. As a result, the schedulers possessed necessary detailed knowledge about the production system and a well developed network of contacts within the production department. It formed a personal base for carrying out the scheduling tasks and may therefore be categorized as the earlier described psychological level of the human aspects.

Human aspects at a social level, finally, included that the schedulers spent a significant amount of time in contact with other people in the organization, such as the production personnel, production supervisors, production engineers, the market department, forklift truck drivers etc. Issues dealt with were production feedback, manning, work orders, quality control, development projects, product development, deliveries etc. By that, the schedulers acted as informal coordinators, as nodes, through which information was spread and contacts between people were arranged in the organization. The schedulers pointed out how important these personal contacts were in order to obtain information. Forklift truck drivers were for instance one group that was emphasized as having good overview of current production status and therefore represented an important source for information. Having personal contact with the scheduler was also perceived as very important for production leaders. During the personal contacts, the schedulers continuously and actively searched for or received information from other groups of employees. Through all sources of information, the scheduler actively paid attention to small pieces of information and reflected on what consequences that would give on production scheduling. The schedulers were also expected to serve as information suppliers and to keep up continuous communication with others in the organization. The interviewees expected a dialogue with the schedulers, as a basis for collaboration [21].

Many dialogues were held in a "humorous spirit" and one scheduler explicitly pointed out that he tried to cheer up the others. By having a good relation with other groups of employees, he would easier gain their support in case of troubles with certain production orders [7]. This social aspect of the schedulers' work role was further emphasized in the interviews. The schedulers were expected to adapt to specific situations within or outside the company and show consideration for prerequisites and consequences of their scheduling for other departments or group of employees. The scheduler should, for instance, make schedules considering consequences on other employees' working hours [21].

5.2 Technology influencing the scheduling process

Technology influenced the scheduling process in terms of limitations in the scheduled production system, the primary technical system. In the studied companies the schedulers had to deal with uncertainties or technical design failures in the production process that restricted scheduling. Examples in the sawmill were uncertainties in raw material delivery concerning quality, volume and timeliness. The schedulers in both the sawmill and the parquet manufacturer must deal with uncertainty regarding the outcome of production with respect to quality and volume until production results were known. Therefore, the schedulers were obliged to make assumptions and estimations, mainly based on experience, instead of working with exact figures. This was considered as frustrating. There were also examples of technical design failures, such as a large drying kiln only working at full capacity (too slow to run for optimal output but at the same time necessary for the overall capacity).

Another influence from technology was through the design of the secondary technical system, the scheduling software tool, which offered possibilities but also limitations as an aid in the scheduling process. All companies had standard MPC-systems, but in all cases company specific tools and Excel software solutions were developed as a complement and used frequently. The Excel sheets were continuously developed by the schedulers to improve scheduling. One important reason for developing the Excel sheets was the schedulers' great need for information of reliable data about the incoming material, production status and planned orders, data that were not possible to obtain from the MPC-system. There were examples of these Excel sheets being distributed to other groups of employees as well.

It was not possible to fully trust the data given by the computer system due to several reasons. One was that the market representatives placed preliminary reservations that were later not executed as customer orders, another that mistakes in data input were made regularly. At the parquet manufacturer, the scheduler depended on reliable information from the sales department with respect to preliminary orders placed in the MPC-system. Therefore, there were examples of him trying to influence them to make decisions by delimiting the available stock in the system.

Other technical shortcomings constraining scheduling work were incompatible computer systems resulting in work in parallel computer systems and in one case difficulty with computer failures.

5.3 Organizational aspects influencing the scheduling process

In all companies, the schedulers participated in several regular meetings every week in which representatives from various departments, including management, participated.

In the studies, the schedulers worked in a position where the marketing department's expectations on flexibility, short delivery times and responsive customer service were to be coordinated and negotiated with the manufacturing department's expectations on more stable conditions. These departments both contributed to the overall aims of the company but followed entirely different logics concerning how these goals should be reached and how the different departments should be managed. The scheduling process took place in the middle of this main built-in goal conflict of the enterprises [22]. In the studies the schedulers served as a strong link between production and the sales and customer service department. In a majority of the companies, the schedulers had numerous contacts every day related to inquiries about feasibility in production for potential orders, information about changes etc. In one case, the customer helpdesk secretary even

moved into the scheduler's office in order to improve collaboration with the customer service department. By serving as an integrating link between production and the sales department, the schedulers were able to pass on high-value information before it entered into the computer systems as well as information that did not exist at all in the computer systems.

In all companies the schedulers were physically located in central locations, for instance close to production but at the same time well placed to easily be reached by employees from other departments and in some cases also by external suppliers. This central physical location contributed to their role as an information node and problem-solver. The location in conjunction with participating in meetings with management and representatives from various departments further facilitated the schedulers role as an integrating link between the departments. Although there were many good examples of this "bridging" function, there were also in the studied companies examples of lack of proximity and collaboration between the schedulers and the sales department, which negatively influenced the scheduling process.

6 DISCUSSION

The study showed that scheduling was characterized by high demands for flexibility, a need to deal with high degree of uncertainty, problem-solving and performing parallel activities. These are examples of human contribution to the scheduling process at a cognitive level and thus part of the H-component. Regarding the psychological level, all schedulers had long experience from working in production. Due to this personal experience, the schedulers gained legitimacy from "bottom-up" and had strong links to the production department. This legitimacy was based on the schedulers' ability to understand the production process, its limits and under what conditions work was executed. One interviewee further emphasized that "scheduling was not a paper work carried out in the office".

Regarding human contribution at a social level, the studies showed the importance of the schedulers' frequent contacts with different groups of personnel and departments in the organization. These contacts were necessary to fulfill the schedulers' role as an information node. The need to negotiate between incompatible goals, the expectations to show social concern about consequences of the schedule for the employees as well as the schedulers' dependency on others' willingness to help out in acute situations were other examples that raised strong demands on the schedulers' social abilities.

It is therefore possible to conclude that the outcome of the scheduling process may be influenced by the scheduler adding human capabilities that cannot be automated, such as problem-solving of considerable proportions, and negotiating between and linking together groups of employees to handle incompatible goals.

If we look at the interaction between the H- and T-components we must again treat the two main parts of the technical system differently. The interaction between the primary technical system and the scheduler can be described from different aspects. It is obvious by previous writings [23] that there are a multitude of interactions and that many schedulers devote a large part of their working hours to interact with the primary technical system. A main issue here is information to keep control; the schedulers used much effort to gather information about the past, present and expected future state of the system. A complicating aspect with respect to the need of control was the high degree of uncertainty. Uncertainty derived for instance from customer and market fluctuations, the

availability of raw material and various production resources. Uncertainty also emerged from inside the company as soon as something did not occur exactly as the scheduler had anticipated in his/her schedule. It is important to point out that the capability of the primary technical system was determined at a detailed subsystem level. There was thus a theoretical maximum capacity, but the ability to achieve this was determined by the production unit's ability to reach this capacity and the schedulers' ability to produce a feasible schedule, integrating the maximum capacities in the different subsystems. This ability was for instance limited by circumstances, such as availability of raw material and practical/technical restrictions in parts of the machinery.

The interaction between the secondary technical system and the scheduler is twofold. The secondary system is an additional provider, in some cases the only, of information on the state of the primary system. In this study, however, this feedback was only partially provided by the information systems studied, and therefore must be searched for. As described before, visual inspection of production and stock, informal talks, and conscious network building within and outside the company were examples of measures used for this.

The secondary system is also a provider of decision support. However, the available secondary system has been criticized for providing poor decision support for the planning task. The schedulers in the studied companies faced high expectations to be able to provide information to others in the organization; information that in some cases was more detailed than was possible to obtain from the MPC-system. The insufficiency to provide the type of information that the schedulers needed resulted in development of spreadsheets that might be regarded as a powerful flexible aid that complemented the MPC-system.

In the studied companies, technology thus set prerequisites for the scheduling process through the primary technical system and its limitations as well as through the MPC-systems' ability to provide sufficient data and control the production process. Dealing with the MPC-system, there were many examples of situations which needed human interaction and support to sustain a scheduling process that achieved its set goals.

Also the O-component created prerequisites for the scheduling process. In the studied companies there were several examples when the schedulers worked closely to both production and the marketing departments, and that they often had to negotiate between the conflicting logics of the departments. There were strong links and interdependencies between the schedulers and many other employees in the studied companies. Due to the schedulers' role as integrating link and information node between various departments, they possessed high-value information. As others were dependent on this information as well as the results of the schedules developed, the schedulers thus exerted influence on the production, marketing and purchase departments (including management). The schedulers thus exerted control without having the formal authority to do that. The study also showed examples of the importance of the physical location of the schedulers, so that they could easily obtain information from the production process and other employees, but also to efficiently solve scheduling problems.

Organizational aspects may thus influence the scheduling process through degree of proximity between employees, meeting structures, the schedulers' position in hierarchy and their work role interconnecting activities of different organizational parts.

The study showed that the H-, T- and O-components are strongly interlinked. As this project initially had a focus on

the scheduling work performed in practice and the schedulers' work role, there is an emphasis on the H-component. The analysis showed, however, the relation to and importance of analyzing and understanding the T- and O-component as well. All three components created prerequisites and limitations for the scheduling process. There is thus reason to believe that in analyses for improvements of the scheduling process, it is suggested to include all three components. By taking perspectives from all components into account from the beginning in a study, it is possible to better visualize what aspects contribute to the outcome of the scheduling process and more easily define what performing-shaping factors one should focus on.

7 CONCLUSION

The conclusion of this study is that the outcome of the scheduling process is influenced by human aspects such as personal experiences, problem-solving when the technical system fails, and negotiating between groups of employees to handle incompatible goals. Technology influences through limitations in the scheduled production system as well as the scheduling tools available. The organization, finally, influences the outcome through the degree of proximity between employees, meeting structures, the schedulers' position in hierarchy, and their work role interconnecting activities of different organizational parts. Furthermore, a conclusion is that it is likely that these three aspects of the work performed significantly influence the outcome quality of the scheduling process or task. It is therefore recommended that companies do pay attention not only to the technical system as such, but also to human and organizational aspects of scheduling when improving their businesses.

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