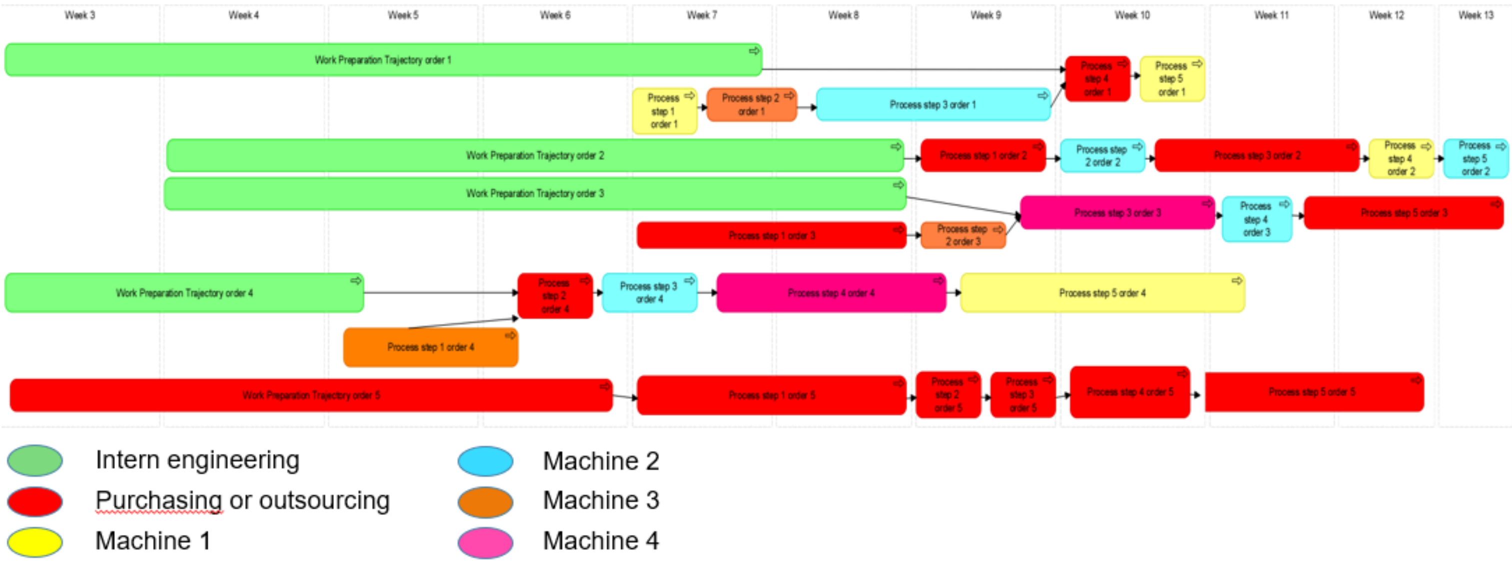
Accomplishing a high delivery satisfaction by switching to a better process-supporting planning system

A summary of the master thesis of Nynke Toering



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During this master thesis, processes at a manufacturing company with high mix, low volume production are analyzed to figure out what the company needs for realizing a high performance on delivery reliability. The company concerned during this master thesis is planning to start with a transition to a new ERP system in the near future and requested for an investigation of requirements for such a system which supports their processes and which supports in realizing a high performance of delivery reliability. Since it is useful to have a comprehensive understanding for composing requirements for such a system, processes of the concerned company are analyzed.

High performance of quality and logistics are the most important focus points of the concerned company. Important KPIs which are associated with these focus points are high quality performance and delivery reliability. However, in the current situation, the target level for delivery reliability is not met. Therefore, this research has arisen to come up with requirements for supporting processes and achieving a high performance of delivery reliability by implementing a new ERP system and improving logistic processes.

The corresponding research question of the research is:

What are the needs of the concerned company in order to improve logistic processes and implement a new digital ERP solution such that the delivery reliability rate of orders substantially increases?

To solve the main question, the research is divided into the following 3 stages:

- **The current situation**
- **The problems, shortcomings and bottlenecks in the current situation**
- **Implementations needed to fulfill needs**

To get more insight into the causes of late delivery and how the delivery reliability can be improved, the problem is approached by analyzing the current situation, performing a problem analysis and investigating what are the needs and how these needs can be fulfilled. The research approach is structured by these elements to answer the research questions.

The goal of the first stage is to investigate how processes of the concerned company are currently organized and how the current ERP system and external tools are being used in the current situation. Consequently, the goal of the second stage is to investigate what problems, shortcomings and bottlenecks currently are experienced to get insight in what improvement is desirable. Last but not least, the goal of the last stage of this research is to plot what is required to improve the delivery reliability and how these needs can be fulfilled by for example linear programming.

Methods

To come up with requirements for achieving a high performance of delivery reliability, the current situation is analyzed, drawbacks and desires are plotted, and some literature research is done. Subsequently, a model is designed for making decisions during scheduling by linear programming.

First of all the current situation is analyzed. This analysis consists of a description of how the company is organized, a process analysis, a description of the uncertainties included into the processes and a description of the current ERP system. Findings of this analysis are among others that the company makes use of dual source, customer orders of the company includes a high variety of products including projects, quality requirements are high and processes contain a variety of uncertainties.

After the current situation is analyzed, a problem analysis is done, which intend to make clear what the problems are and what problems are process related and what problems are ERP system related.

Moreover, project related shortcomings, logistics related shortcomings and quality related shortcomings are outlined in the problem analysis. Furthermore, an analysis into the reasons for late delivery is done in the problem analysis.

After the problem analysis, an investigation of requirements is done. This investigation includes desires of stakeholders and needs from insights into the current shortcomings. The investigation of needs and desires includes logistic related desires, project related desires and desires with respect to controlling quality. Moreover, the investigation of needs and desires elaborate needs of analysis options and needs of automation, digitalization and connect-ability.

For acquiring information about the current situation and drawbacks and desires experienced at the considered company, stakeholders from different sections are interviewed. Thereafter, relations are plotted in flow diagrams to get insight into process relations and root-causes of problems.

During analyzing processes and problems, a need for project planning, project management, dynamic planning and capacity planning has been detected. Therefore, literature research is done in project planning, project management, dynamic planning and capacity planning. Findings of the literature research includes that for managing projects, capacity management is important, especially for decision-making during order acceptance. Capacity can be managed by roughly planning capacity with RCCP. To consider uncertainties during scheduling, dynamic scheduling can be used with predictive scheduling for generating a baseline schedule and reactive scheduling for modifying the baseline schedule to react on unexpected events and disruptions.

Based on findings of the literature research, a solution design is given how a part of the needs can be fulfilled by linear programming. For the solution design a linear model is designed for generating a baseline schedule, which is based on RCCP and decision making procedures of the company. The model is used for making decisions about dual source assignment, machine assignment and due dates. Constraints which the model considers are capacity restrictions, machine loading, dual source restrictions, process durations, precedence relations and due dates.

Literature research

Project management and planning methodologies are much discussed in literature. Literature describes among others a project life cycle, Rough Cut Capacity Planning (RCCP) for roughly planning capacity, interrelationships of planning methodologies, conflicting goals of low inventories and efficient utilization of capacities, dynamic scheduling, integrations between production scheduling and control systems, and critical project planning and project management functionalities.

Planning of projects consist of multiple processes and projects follow a lifecycle of multiple phases. The project lifecycle includes the following phases: order acceptance, process planning, scheduling, execution and evaluation & service (Gademann and Schutten, 2005). Resources for performing projects are limited. Therefore, capacity planning is important for projects, especially during order acceptance and scheduling. RCCP is suggested in literature to use during order acceptance for roughly planning capacity and making decisions about due dates, milestones of projects, overtime of work levels, subcontracting and required capacity levels (Gademann and Schutten, 2005; Sugarindra and Nurdiansyah, 2020).

In both the order acceptance and the scheduling phases, capacity management is important (Gademann and Schutten, 2005). Because of lean management concepts, capacities have been cut down and project scheduling is increasingly important (Tormos and Lova, 2003). Decisions made in the order acceptance phase about prices and delivery times are very important, since quoted prices and delivery times determine whether a project will be gained by the organization and if the project is profitable (Gademann and Schutten, 2005).

However, in the order acceptance phase, accurate knowledge of resource capacities is not available, when due dates are committed. In that phase Rough Cut Capacity Planning (RCCP) is used as an analysis to test the availability of production facility capacity to ensure that at least the critical resources are sufficient to complete the project within time and cost limits (Baydoun et al., 2016; Sugarindra and Nurdiansyah, 2020). In that way, RCCP validates MPS and compares the available and required capacity to determine whether a production schedule requires non-regular capacity (Sugarindra and Nurdiansyah, 2020).

After project activities are specified in process planning, jobs are divided into activities and scheduling is done by Resource Constrained Project Scheduling Problem (RCPSP). Scheduling helps realizing project management objectives and is the allocation of resources over time to perform tasks. At RCPSP, projects are scheduled subject to constraints and decisions are made about when specific activities are performed including start and finish times and by which resources (both machines and employees) (Herroelen, 2005; Leus and Herroelen, 2010; Gademann and Schutten, 2005).

Scheduling can be described as the allocation of resources over time to perform a collection of tasks (Koné et al., 2011; C. Hicks et al, 2007). The resulted schedule specifies the sequence and timing of the tasks (Hicks et al., 2007). By scheduling and sequencing, the goal is to allocate scarce resources optimal to activities over time (Herroelen, 2005). Scheduling helps realizing preset project management objectives and the resulted schedule aims at satisfying one or more of these objectives (Koné et al., 2011; Tang et al., 2018). Therefore, generating a reliable project schedule is an important goal in project management (Tang et al., 2018).

In general, the performance of production planning and scheduling is measured by the customer satisfaction and production costs. To measure the customer satisfaction, the customer service level is measured, which is the fraction of customer orders that is filled on or before their due dates. In terms of production costs, the inventory costs should be minimized. On the one hand, inventory of purchased materials should be minimized, while on the other hand, materials should be on time for production (Sawik, 2007). In general, planning issues are most important early in the project implementation (Herroelen, 2005).

Literature shows interrelationships between multiple planning methodologies. For example, MPS, in which a master production schedule is prepared by forecasts and demand is divided into requirements for supply, and RCCP have interrelationships with each other. To determine when materials have to be ordered for the prepared production schedule by MPS, MRP is used. MRP translates demand for final products into a schedule with requirements for raw materials and the coordination of the flow of materials to ensure delivery on time, which includes required materials and when these materials are required (Vila Gocalves Filho and Astorino Marcda, 2001; Li et al., 2000; Zobolas et al., 2008).

Another scheduling related issue served in literature is the need for balancing conflicting goals of low inventories and efficient utilization of capacities and the importance of safety stock for dealing with uncertainties. Capacity problems fluctuate between overload and idleness problems. In case of overload, the profitability is reduced due to over-proportional high costs to deal with overload, while in case of idle resources money is lost due to low utilization (Bakke & Hellberg, 1993). Moreover, resource limitation results in resource dependencies and extending overall schedule durations (Shu-Shun and Shih, 2009). Furthermore, material management may represent a problem, because of uncertainties in long supplier lead times. Due to these uncertainties, inventories are high or critical materials and components are lacking, which results in delay of operations (Bakke & Hellberg, 1993). The importance of resources can be determined by resource productivity (Shu-Shun and Shih, 2009).

For dealing with uncertainties, capacity problems and unexpected modifications, literature suggests increasing flexibility, using dynamic regulation and to eliminate uncertainties by identifying bottlenecks (Bakke & Hellberg, 1993). To overcome unpredictable deviations, it is recommended to consider uncertainty in the project scheduling process (Palacio and Larrea, 2017). This uncertainty can be represented by stochastic activity durations (Leus and Herroelen, 2010). Stochastic project scheduling can deal with scheduling project activities with uncertain durations. By using stochastic project scheduling, the expected project duration under precedence and resource constraints can be minimized (Herroelen, 2005).

Scheduling in a dynamic environment can be done by dynamic scheduling including a predictive and a reactive mechanism. During predictive scheduling, an optimal predetermined production schedule is generated, which can be used as a guideline for a project. The generated schedule by predictive scheduling can be modified by reactive scheduling to deal with unexpected changes (Sabuncuoglu and Kizilisik, 2003; Sun and Xue, 2001; Sawik, 2007; Hicks et al., 2007).

In literature, integration between production scheduling and control systems is recommended for detailed capacity planning and simulating among others consequences of modifications and analyzing plan alternatives. It is desired that a scheduling module for generating a schedule, a controller for controlling and forwarding the schedule and a simulation model are included in an integrated system. Moreover, an integrated system may be beneficial as input for intern discussions and for having influence on placing customer orders(Sabuncuoglu and Kizilisik, 2003; Baldea et al., 2015; Sun, Xue, 2001).

Last, but not least, planning and project management functionalities are critical for projects as mentioned in literature. For projects it is beneficial to have insight into project sequences, activity scheduling, project status monitoring, resource allocation and project specification. Project portfolio management and analysis may result in better communication, a more streamlined resource management and improved productivity (Adrodegari et al., 2015; Herroelen, 2005).

Results

Based on findings in literature, RCCP and dynamic scheduling are used for designing a linear model. Moreover, other findings are that integration between scheduling and control systems and functionalities for project planning and project management are interesting to consider during migration to another ERP system. The designed linear model is intended to generate a baseline schedule and to make decisions about among others dual source assignment, machine assignment and due dates. Besides using the logic of RCCP and dynamic scheduling, decision-making procedures at the considered company are considered and implemented in the designed model.

The model considers, among others capacity restrictions, machine loading, dual source restrictions, process durations, precedence relations, and due dates. The objective of the model is to minimize outsourcing of expensive and difficult to produce products, while meeting the demanded delivery date (if feasible). All restrictions and relations of decision-making and planning are transformed in linear equations to create a linear model. The model is capable to deal with scheduling problems and capacity planning, which is desired for scheduling orders according to literature. As a result, decisions made by the predictive scheduling model include whether processes are performed intern or outsourced, which machines are assigned to intern processes and what tasks are performed in which weeks. Although these decisions are currently made by manual scheduling, this research demonstrates that scheduling and decision-making can be optimized by automation.

Based on capacity restrictions, dual source restrictions and given process routing options, the model decides to purchase or produce an order and in case of producing the order, the model decides which process steps are performed intern and which process steps are outsourced. Dual source restrictions are given by the assigned dual source category and if an intern machine is assigned to a specific process step of a given process routing is indicated by a binary value. Moreover, a decision is made by the model which process routing will be chosen and thus which machine is utilized for performing a specific process step of an order. Therefore, if a process step of an order is performed intern or outsourced is dependent on the chosen process routing and if the process step is an intern process step in the process routing.

The designed model considers engineering tasks in such a way that indications for durations of engineering tasks are used as input values and engineering tasks have to be performed before succeeding process steps can be performed. Before which process step engineering tasks have to be finished are given by an input parameter as well. If engineering tasks have to be finished before the first process step can start, engineering has to be performed completely before production is released. If finishing engineering before the first process step is not required, engineering can be done partly parallel to production. Therefore, the designed model determines that the due date for engineering tasks should be at or before the due date of the order minus the sum of durations of process steps which are succeeders of the engineering tasks.

The designed model is validated by an example problem consisting of 5 production orders with each 5 production steps. During this validation, it is checked if restrictions are met and if the decisions made by the model are logic and consistent.

Moreover, a suggestion is made for designing a model for dealing with fluctuating demand, unpredictable events and uncertainties present in the processes by reactive scheduling. It is suggested that modifications, available capacities and decisions made by the predictive scheduling model are used as input for a reactive scheduling model. Furthermore, it is suggested that decisions made by the predictive scheduling model can be considered to gain more insight into, among others, the engineering population.

Recommendations

It is recommended to have a functionality like the designed model for generating a baseline model for making decisions about among others dual source assignment and determining due dates for tasks, which can be used as a guideline for the project. Moreover, it is desired to have insight into consequences of decisions made by the baseline model on engineering capacities, engineering workload, required durations of engineering tasks and the progress of these tasks. Project management and planning are recommended for getting insight into among other deadlines, deliverables, costs, project status monitoring, resource allocation and schedules. Moreover, project management may be beneficial for communication, productivity and resource management.

For controlling processes, an integration between production scheduling and control systems including a scheduling module, a controller and a simulation model is recommended for detailed capacity planning, simulating consequences of modifications and analyzing plan alternatives, which can be used as an input for intern discussions. Moreover, it is recommended to have a functionality for getting clear overviews of the planning, progress of processes, machine loading and capacities.

Besides for controlling processes, overviews are desired for analyzing performances of the considered company. It is recommended to have overviews of processes, projects including work preparation tasks, products in quarantine and outsourcing and purchasing orders. For products in quarantine, it is recommended to get insight into reasons for quality deviations, consequences of quality deviation, the expected duration of dealing with quality deviation, for how long products are in quarantine, at what production step the problem has occurred, delay and cost of non-quality due to quality deviation and how can be dealt with the quality deviation. Furthermore, it is recommended to have a monitoring functionality for concessions which are requested to get insight into the concession process and when actions have to be succeeded for concessions.

For analysis purposes, it is recommended to have functionalities with analysis options, visual tools and simulation options. It is desired to have a standard dashboard or report for overviews of performances of KPIs. Moreover, it is desired to have functionalities for forecasting orders including an overview with forecasted orders, retrieving data fast and easy accessibility of data. For planning, analysis and controlling purposes, it is desired that orders can be easily selected.

For maintaining, controlling and updating production folders, it is recommended to digitize production folders. Moreover, digitization is beneficial for automation and connect ability with other systems. It is recommended to be equipped for automation for better traceability of orders and for having access to more up to date data. For improving communication and feedback between production steps, sections and systems, connect ability between systems is recommended.

For preventing schedule disruptions, it is recommended to consider uncertainties in project scheduling, to eliminate uncertainties by identifying bottlenecks and to consider safety stock into capacity planning. For dealing with unexpected events and modifications, it is recommended to modify the baseline schedule by reactive scheduling. It is recommended to reschedule orders by giving priority to orders based on urgency.

To conclude, it is recommended to control production processes based on a baseline schedule and to react on unexpected events and modifications by reactive scheduling, to control projects by having insight into engineering tasks, required engineering capacity and available engineering capacity and to control quality by having insight into reasons and consequences of quality issues, products which are in quarantine and clear concession processes. Moreover, it is recommended to include planning and project management functionalities into an ERP system and to include scheduling, controlling and simulation modules.

Recommendations of this research are summarized in the blueprint below:

Recommendations for ERP implementation:

- Project planning & project management functionalities:
  - Resource allocation
  - Schedules
  - Project status monitoring
  - Insight into deadlines, deliverables, progress, engineering capacities and costs
- Scheduling, controlling and simulation functionalities:
  - Insight into progress, machine loading and capacities
  - Feedback options
  - Analysis functionalities
  - Functionalities for capacity planning, dynamic scheduling and/or stochastic scheduling
  - Simulation functionalities
- Functionalities for controlling quality issues:
  - Insight into quality issues, reasons & consequences of quality issues, costs of non-quality, expected delay and expected duration of dealing with quality issues
  - Functionality for putting products into quarantine
  - Functionality for controlling products in quarantine and for controlling products in a concession process
- ERP system which includes connect ability with other

Recommendations for process improvement:

- Controlling logistic processes
- Controlling quality
- Considering uncertainties
- Identifying bottlenecks
- Update intermediate progress
- Rescheduling to react on unexpected events and modifications
- Capacity planning, dynamic scheduling and/or stochastic scheduling
- Simulating consequences of decisions
- Digitizing production folders

Roadmap for further research:

- Investigating impacts of migrating to another ERP system
- Investigating critical success factors for ERP implementation
- Investigating misfits, risks and barriers of ERP implementation
- Simulating expected effect of migrating to another ERP system on performance of KPIs

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