THREE PERSPECTIVES OF A PRODUCTION PLANNING SYSTEM

Case: Improving the production planning process of a small Swiss manufacturer

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Abstract
The coordination of resources in manufacturing organizations can have a huge impact on the success of a company. While over the years many ways to coordinate production have been developed, suiting varying complexities, it is beneficial to examine the unique needs and perspectives of the manufacturing system.

This study examines the steps that a Swiss manufacturing company has taken to create a more structured and formalized planning system in order to improve the efficiency of its production. The core of the paper consists of the explanation of the production planning tools and processes that the author of this paper created as an employee of the subject company.

The study chose the organizational, decision-making and problem-solving perspectives to be key aspects to take into consideration when analyzing and designing the planning system. Addressing the organizational perspective and arguably the most important schedule for a manufacturer, the master production schedule (MPS) was developed in order to align the complex combination of resources. A seven-step routine to production planning and control was adopted in dealing with the decision-making perspective. Lastly, focusing in on the problem-solving perspective, a machine scheduling tool prototype was developed, eventually leading to capacity planning utilization in SAP.

The thesis has contributed to solving the resource coordination problem within the subject company through creating tools to formalize and establish a basic production planning system. The applied research should be of interest to management, researchers and consultants of small manufacturing companies and individuals in production planning and control.

Keywords
Production planning and control, planning system, production planning tools, master production schedule, machine scheduling

Miscellaneous

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1 INTRODUCTION

Manufacturing organizations have complex systems that combine material, people and machines in a coordinated way in order to deliver promised goods to their customers. Over the years, workers, managers, consultants and engineers have developed many ways to control the coordination of production. How the coordination of resources transpires is intriguing and is likely to have a huge impact on a company's bottom line and ultimate success.

This study examines the steps that a Swiss manufacturing company called XYZ has taken to create a more structured and formalized planning system in order to improve the efficiency of its production. The core of this paper consists of the explanation of the production planning tools and processes that the author of this paper created as an employee of XYZ.

A common method used in production planning is creating and maintaining a Master Production Schedule (MPS) that aligns the complex combination of resources. In practice, the MPS sets a master plan for an organization to procure, produce and deliver order to the customer. According to Slack et al. (2010), the MPS is the most important schedule for a manufacturer. Through the MPS the quantities and timing of requirements are formalized, creating a plan the whole operation uses. The MPS is the basis for planning people, parts and equipment. It is also an informative tool for sales to inform customers of progress and issue delivery confirmations. This paper will show how the MPS was employed at XYZ.

Two common problems for all manufacturing firms are priority and capacity (Wright, 1984). These are precisely the challenges at XYZ as well. As Herrmann (2010) elicits, many manufacturing firms have an inadequate way of coping with the complexities of production. They produce and ship goods to customers, but lack a structured and cohesive coordination between people and departments. Instead, they ignore production schedules and engage with incomplete information, while rushing from one urgent issue to the next without seeing the overall production process. Herrmann's description applied well to the state of XYZ's production when this study began.

Production systems always rely on the human element of decision-making and need help with sorting through the complexities of real-time events occurring continuously (McKay and Wiers, 2004). In order to cope with these complexities, Slack et al. (2010), Guinery and MacCarthy (2005) and Herrmann (2006b) delve into the importance and approach of planning and control, while Vieira et al. (2003) establishes a framework for rescheduling. The work of the former authors will be used as a basis and background for XYZ planning, while the latter author's rescheduling framework will be used specifically to rescheduling techniques; adding consistency and structure to a disorganized method of planning.

Herrmann (2010) recognizes that a key element in understanding the production control function in a firm is analyzing the organizational, decision-making and problem-solving perspectives. This is thus the approach this study takes, and these perspectives are addressed in the process of creating the production planning tools at XYZ. A planner must take a lot of information into account when scheduling and rescheduling (McKay and Wiers, 2006; Herrmann, 2006a). By examining the production planning system with respect to Herrmann's three aforementioned perspectives, one can ensure critical elements are considered when building planning and organizational tools for the firm.

The paper will begin with theoretical review of Slack et al. (2010) planning and controlling basics. Then this study will develop an understanding of Herrmann's three perspectives and follow up by reviewing scheduling environments, strategies and methods presented by Vieira et al. (2003), and expanded upon by Herrmann (2010). Finally, the following practical tools that have been developed for XYZ to cope with the complexity and lack of a cohesive planning system are explored:

- Master Production Schedule (organizational perspective)
- 7-step routine (decision-making perspective)
- Gearing Gantt tool to help optimize the main engine of XYZ (problem-solving perspective)

Each three tools satisfy each perspective of the firm. The master production schedule (MPS) serves as a tool to coordinate resources, a basis per se, and satisfies the organizational perspective to planning. While the seven step routine is more a structured process, it serves as a formalized tool to follow as the weekly production schedule is created and events trigger a rescheduling. This satisfies the decision-making perspective. Lastly, the problem-solving perspective is met through creation of the machine scheduling tool to configure capacity and sequencing of orders in the gearing department.

Further analysis of the three perspectives will be examined after introduction of basic planning concepts in chapter two.

With the aid of these three tools born from analyzing the firm from three different perspectives, the system should help XYZ steer a course towards proactive planning and more optimized production. The scope of this study addresses the planning system and does not delve into the firm's performance numbers. The goal is to create a system of interaction between departments, an MPS to maintain a more cohesive plan to produce over a longer horizon than previously planned and a tool to configure production capacity. All of these tools work together to create a new planning system in order to better understand the firm's capabilities and delivery terms.

1.1 Background

XYZ is a small Switzerland-based manufacturing company with 25 employees specializing in gear production. It is a member of a larger globally operating group which is headquartered in Country X, assembling and selling miniature- and micromotors. The group is a consortium of about fifteen companies, and the Country X parent company holds a high degree of power to shape the direction of the group's subsidiaries. The officers of the parent company sit on the boards of many smaller subsidiaries, thus influencing the strategic plans and general direction the group takes. While each subsidiary CEO holds an independent style to operations and management, XYZ is facing increased scrutiny due to many recent changes.

XYZ found itself in a position of scrutiny in the summer of 2013 after moving into a new building and adding a new Enterprise Resource Planning (ERP) system – SAP. The push for the new ERP system came from the parent company in order to create more transparency being that 85% of XYZ's sales are within the group. In addition to the implementational issues pertaining to the new system, another planning specific challenge required attention. With the lack of a formalized planning system and a capacity configuration tool, the old way of doing things – rubber stamping orders on paper upon arrival – did not properly estimate lead time in order to accurately confirm delivery dates based on actual procurement and production situations.

The motivation for coming up with the idea to create tools to address the three perspectives was born soon after realizing that although the production situation had some degree of predictability, the reactive nature to rubber stamping and processing customer orders lacked a clear and objective way of planning production. Often times what was planned was weeks late. The impact this has had on the entire supply chain of the group has obviously been negative, when one of its members consistently delivers late and short the quantity confirmed. A properly functioning manufacturing system would need firm objectives that are followed up on and corrective measures taken when called for.

In this particular case under examination, the following three aspects were developed in order to transform planning from a reactive situation lacking a cohesive and integrative system to a proactive system:

1. An organizational master plan to base all plans

2. A consistent routine to control and update production and planning
3. A tool for capacity configuration

An organization with many interdependent processes needs a tool to pull the departments together, especially keeping a short communication link with appropriate parties. What good is a production update of only order quantities, or an update that is released on Thursday when the production meeting was Wednesday? A consistent, objective, timely and accurate method of planning is essential for successful production plans. Lastly, a manufacturer without a capacity tool is like driving a car without a speedometer and fuel gauge – no telling how far you can go and when you will get there.

This thesis presents how a planning system that combines data from the ERP system in coordination with the MPS and insight from responsible parties involved in production planning was created at XYZ, leading into better production planning. Ultimately the combination of the tools creates a planning system which better reflects actual production capacities and maintains production progress.

1.2 Research approach, strategy and problem

When the author started working for XYZ there was a general idea to find a business problem to research. While considering this idea to find a problem to research and after six months experience on the job, a working purpose to "*improve the planning process at XYZ*" was established (Kjellsdotter-Ivert, 2009).

After having the working purpose defined it was necessary to define a research approach, strategy and method (Bryman and Bell, 2011; Flick, 2009; Saunders et al., 2007). Defining this process is often referred to peeling back of Saunders et al. (2007) "research onion," from the outside, epistemological perspective to the inside, practical methods of carrying out the research; although the process may not proceed in sequential order from the outside layer, in (Crotty, 1998).

The research epistemology is subjectivism (Saunders, et al. 2007) from a phenomenological interpretivist perspective (Crotty, 1998), employing an inductive approach due to the lack of research and the company specific nature (Flick, 2009).

This research is a qualitative case study that combines initial exploratory survey research with action research (Saunders et al, 2007). The author of this study is both a researcher and a participant through designing, conducting and participating in on-the-job research. Due to the subjective nature (Crotty, 1998; Saunders et al., 2007; Bryman and Bell, 2011) this research is value-laden and therefore biased; and the values of the author can affect how results are interpreted (Malhotra and Birks, 2007).

Because of the nature of the author's employment with the company and a lack of prior experience from the industry, along with an exploratory approach, a literature review has been a logical choice (Kjellsdotter-Ivert, 2009). This takes advantage of the flexible nature of the approach through adapting as more information is gathered. With the aid of McKay and Wiers (2004) expert survey modeled after assessing countless manufacturers' production planning systems globally, this approach allows for later direct involvement in developing solutions to the production planning problem.

Research problem

The central research problem that is resolved in the course of this study is captured in the following question:

How could the production planning and coordination at XYZ be improved?

The most essential sub-questions that are addressed during the research process are as follows:

1. Where is XYZ currently at with its production system based on a formalized scoring model?
2. What kind of processes should be established?
3. What are the planning tools that the firm could benefit from?

The research questions arise from the following qualitative observations of day to day operations of XYZ:

Initially, the firm lacked a cohesive way of coordinating production. Schedules and time frames were arbitrary in nature, changing daily at times. Thus planning had to be developed from a reactive approach to a forward looking system that plans production efficiently. With the original methods in place, the supposed planning window for production was four weeks, but due to suboptimal practices, the company was largely only able to determine the stage of its current production without any foresight into the future. Many times orders were just approved on a mechanical twelve week lead time.

Due to failures in delivering orders as promised, orders were often late or under-delivered. With so many variables, processes and much information to consider, the difficulty in planning is not a surprise. McKay and Wiers (2004) point out that often the planning gets blamed for “bad planning” when an informed look into all processes recognizes a more holistic organizational approach. This was also warranted at XYZ - the existing planning system lacked a consistent, objective, timely and accurate method.

2 PLANNING AND CONTROL IN THEORY VS. PRACTICES AT XYZ

As (Herrmann 2006 a) refers to, Frederick Taylor stressed the importance of the production control office, proposing a separation of planning and execution. Up until the early 1900s, plans and execution were largely enacted by the same individual in production. As technology advanced and organizations grew more complex, this concept has further formalized into modern production control with evermore sophisticated tools to help Taylor’s planning office.

Production planning and control align the market demand with an organization's ability to deliver (Slack et al., 2010). Planning and control are central to an organization's success (Guinery and MacCarthy, 2005; Kjellsdotter-Ivert, 2009; Vieira, 2006); a clearly designed manufacturing system, with well-defined processes and cooperation to effectively support production activity can increase productivity. Conversely, a poorly designed system with ill-defined processes can ruin overall productivity.

Despite sophisticated technological developments to assist production planning and control, the human element to planning remains relevant (McKay and Wiers, 2006; Guinery and MacCarthy, 2005). Empirical evidence suggests that humans better cope with flexibility, communication, negotiation and intuition (McKay et al., 1989; Crawford and Wiers, 2001). Although some manufacturing plants have minimal to no change to computer generated scheduling, most plants consistently experience amendments to plans.

This illustrates that implementing an ERP system is only one component in production planning and control. As MacCarthy (2006) and MacCarthy and Wilson (2001) so rightly explain, although the real-time status information is helpful for planning overreliance on IT systems can have limitations. The firm must optimally organize processes, people and information in a collaborative way in order to take advantage of the efficiency improvement potential (McKay and Wiers, 2004; 2006; Herrmann; 2006a; Herrmann, 2010).

In order to set the backdrop for planning and controlling the following issues are addressed in line with chapter 10, Slack et al. (2010):

1. Mix of planning and control
2. The volume-variety effect on planning and control
3. Uncertainty in supply and demand
4. Planning and control activities

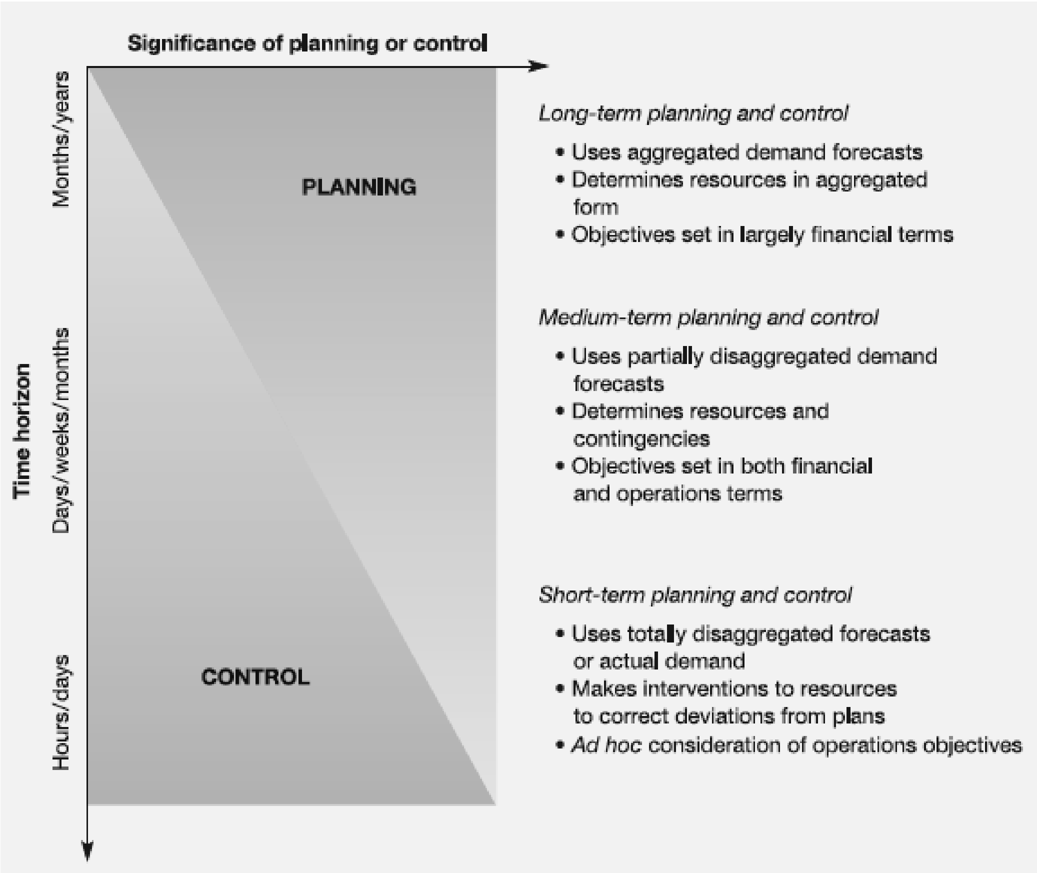
Following establishing the planning and control basics mentioned above, the paper's main perspectives (organizational, decision-making and problem-solving) will be examined in order to develop an understanding of the influence and incorporation into the tools developed to improve the firm's planning system.

2.1 Mix of planning and control

Slack et al (2010) highlight the fact that the division between planning and control is not easy to finitely distinguish; it is generally accepted that planning formalizes what should happen in the future, while control deals with the changes that happen. There are many variables that can go wrong, changing the course of the planned outcome: machine failures, procurement issues and customer changes. This is when the need for controlling comes into play. A manager intervening to prioritize, finding a new supplier to procure more quickly, or rescheduling production to factor the changes into a new plan that properly copes with the situation is a good example of controlling.

How much a company needs of planning or control depends on the time horizons of the industry, production area and changing business environment. Over the past few years, XYZ has experienced decreasing order volumes and shorter contract and order lead times, ultimately having an impact on the approach to planning. In the past, with long-term contracts and large order volumes, the planning aspect to the mix of the planning/control ratio was much more significant. Since then, the importance of controlling has increased. The figure adopted from Slack et all 2010, illustrates this point.

FIGURE 1. Planning to control paradigm



Empirical evidence from XYZ's day-to-day operations is that the controlling aspect to planning has not been given much attention. Following the model, it appears that XYZ should sharpen its focus on the controlling aspect and it would benefit from a more balanced approach to planning and control overall. If we look at the time horizons of orders being shortened to months and weeks, the medium-term horizon is the most crucial.

2.2 The volume-variety effect

Diverse orders in small lots require plenty of planning input. The simple fact of having more procurement and production orders, set-up times and resulting need for control emphasizes the need for planning. More coordination, communication, follow-up and maintaining schedules are required.

Conversely, large lot volumes and homogeneous product types are less planning intensive. A smaller number of procurement and production orders, along with set-ups calls for a different approach to planning. Due to the large volume nature of these types of orders, planning is more concentrated on keeping the machine going. Elimination of the need for many set-ups lowers costs. As a consequence, there is a usually extra stock on hand in case of an urgent order. This logic reverberates throughout the supply chain and we find the same phenomenon when procuring common, large quantity contracts.

At XYZ, a diverse range of pieces of smaller quantities requires a lot of setup time, sometimes even longer than actual production time. Orders like these require more manpower, adding costs. When a large number of orders of hand-crafted pieces are scheduled, also planners are required to spend considerably more time on personnel schedules than in the case of more straightforward large orders.

In sum, the volume-variety effect is something a planner should consider early on in the overall production planning – there should be clear limits as to what kind of orders can be accepted in given quantities and when such orders can be accepted to make production feasible. In day-to-day operations with many small and diverse orders, the emphasis should be in coordinating the process, whereas with larger volumes and standardized pieces and fewer aspects to control, an emphasis of longer-term planning to keep utilization high is relevant.

2.3 Uncertainty in supply and demand

The final aspect of the Slack et al. framework concerns the coping with an ever-present challenge common to most firms – uncertainty in supply and demand. The more uncertain the demand is, the more difficult it is to plan; therefore greater emphasis should be placed on control and vice versa.

There are two major types of demand, dependent and independent. Dependent demand is demand that is fairly predictable due to the fact that it is known to exist.

On the other hand, independent demand is relatively unknown. Management and operations have very different responses to these types of demand.

As Slack et al. so clearly indicate, the planning and control necessary for dependent demand is called “resource-to-order.” Operations waits for an order from its customer before it starts production, planning and control. On the other end of the spectrum, operations produces in anticipation of the customer order, what is called “produce-to-stock,” illustrating an independent demand type.

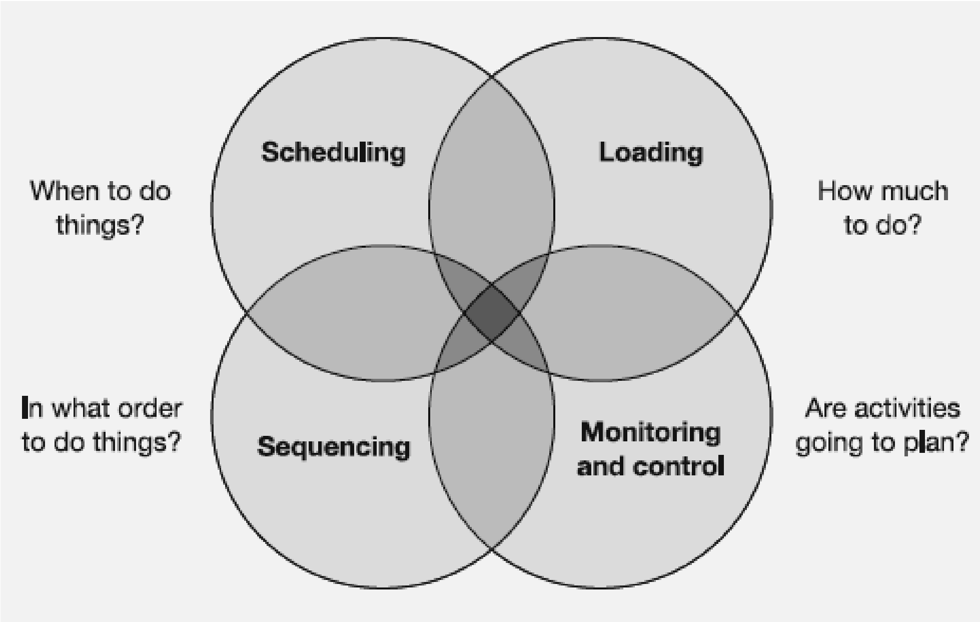
These two have differing planning and control logic. Producing to stock focuses more on the longer term and planning in anticipation for future orders. This is a more planning driven logic, where time may not be so critical, therefore control is not a focus. For example mass production of large contract orders of homogeneous pieces can be produced to stock in anticipation of the customer orders, leaving the bulk of the energy to planning.

Resource-to-order demand can have different implications for the planning control department, as a consequence of waiting for the order, typically time is of essence and production control becomes more important. For example orders of smaller quantities with varying pieces or pieces with plan changes cannot be anticipated. Therefore the planning starts upon customer order, with resource-to-order logic and the bulk of energy spent on production control.

2.4 Planning and control activities

In order to balance the demand and supply situation it is important to speak in terms of volumes and quality and incorporate the time element into the picture. Therefore it is essential to examine the activities constituting planning and control of production. Slack et al (2010, pp. 277-78) show how planning and control can be grouped into four main over-lapping categories: loading, sequencing, scheduling, and monitoring and control.

FIGURE 2. Planning and control activities



2.4.1 Loading

Loading deals with the amount of work allocated to a work center or machine. Planning must take loading constraints into account. When a machine runs continuously, it is theoretically possible to load that machine for 168 hours per week. In practice, however, this is rarely the case. One must incorporate many inhibiting factors. Aspects such as quality losses, breakdowns, set-ups, planned and unplanned downtimes all contribute to a loss in productivity.

Another approach to loading is finite and infinite loading. Finite loading allocates a set amount of work to a work station. It factors the real capacity of that work station, allowing no more slack for planning. This approach is suitable for predictable and known production situations, for example the maximum weight allowed on the aircraft. Infinite loading approach does not limit the amount of work, but tries to cope with it. In some production situations, the constraints are more flexible and can be exceeded.

XYZ has used an infinite loading approach due to the unsophisticated status of its relatively new planning department. A movement to finite loading is in play relying on more clear understanding of constraints.

By knowing the finite capacities of each work center or machine, a planner can utilize this information to create more accurate plans. This reduces risk of a potential disruptive rescheduling in the future. XYZ has an ongoing project to update operating times for each new order before the order is released. The bulk of the common order operating times have been updated in SAP, thus creating a more realistic scenario when scheduling the order loading quantity and configuring sequencing and delivery dates.

2.4.2 Sequencing

While loading logic helps combat uncertainty with capacity planning, sequencing highlights the decision one faces when work arrives simultaneously or reorganizing based on grouping similar parts together when possible; ultimately one deals with prioritizing the tasks. There are many sequencing techniques to production scheduling: customer priority, due date, first-in-first-out, longest operation time, and so on.

At XYZ, it is sufficient to say that there are physical constraints with set-ups, personnel, and raw material quality problems that create a great challenge to adopt any specific sequencing logic. Sometimes, while against customer priorities, production must proceed with a certain sequencing on a machine to avoid down time caused by a change in set-up. This may seem like a risky sequencing decision for business, but in light of facing these challenges, production is trying to minimize future risk in the best possible way.

In reality, XYZ’s product mix is too diverse to develop any coherent strategy for well-functioning production. The complex job shop situation for this small company cannot afford the luxury of specialized labor for minute business functions. This creates a relatively reactive production situation. In other words, with many employees having to cover a broader range of duties and increased workloads, XYZ's current planning system follows primarily customer priority and due date sequencing logic. To add to that, the difficulty of the quality and size of many pieces produced – Quality 6 and below one millimeter diameter – limits the number of material supplier. XYZ relies on two firms and has to deal with far too many supplier returns which disrupt the planning and sequencing processes.

2.4.3 Scheduling

The initial production scheduling is an integral part to getting all the pieces together in order to produce and deliver products. Production schedules coordinate operations and information in order to increase productivity. They enable parties involved to recognize problems and ensure materials are delivered on-time.

Scheduling relies on medium term planning, 1-2 years, and concentrates on the upcoming 3-6 months on a rolling basis (Huactuo et al., 2007). Scheduling process takes aggregated production plans projected over longer periods of time, breaking them up into more accurate schedules reflecting actual expected demand and production situations in the short-term (Herrmann, 2001). XYZ's medium-term horizon is more suitably examined over the 6+ month time period, with scheduling focusing on the 3-6 month window and rescheduling from 1-3 month window.

No matter how sophisticated the planning system, whether involving integrated software or having a more hands-on approach, the original schedule seldom goes as planned. MacCarthy and Liu (1993) address the gap between scheduling theory and the actual situation in practice, in that the sophisticated models sometimes are considered in isolation outside the planning environment, while Cowling and Johansson (2002) highlight the fact that sophisticated software is incomplete in its ability to obtain and utilize real-time information. That is where rescheduling comes into play and shows the ever important human element to this matter.

XYZ is scheduling in a reactive fashion, largely in response to individual customer requests, lacking a cohesive grip of the 1-3 month window, much less the 3-6 month period.

2.4.4 Rescheduling – an integral aspect to production planning

There are many examples of problems that arise throughout the production process: material delay, quality problems with material and production, machine failures, inadequate manpower and rush orders. It is up to the planners involved to be able to recognize these issues and reschedule production in an efficient and effective manner in the least invasive way to prevent unnecessary downtime that affects the overall throughput of a company, ultimately increasing costs (Hermann, 2001).

Rescheduling mediates the theory-based planning with the initial schedule and uses real-time information to reflect the current production situation and many times relaxes constraints caused by delaying events, allowing production to continue in the best way forward. While there is a large market for planning tools, the fundamental strategies and practical methods of rescheduling are often overlooked and underappreciated (Huactuo et al., 2007).

Bean et al. (1991) highlight the fact that rescheduling combines the reactionary, disruptive approach that problems often cause to future information, in order to create a plan for the future to deal with the disruption. Armed with tools, information and a methodical approach a planner can prevent unnecessary delays of inaction and minimize overreaction to problems.

Rescheduling framework

Traditionally rescheduling was a consortium of methods used to describe rescheduling approaches (Herrmann, 2006 c). There was no standard method to create and repair a schedule with policies to try maintaining robustness with disruptions occurring. To try to formalize and understand this work, Viera et al. (2003) created a framework for rescheduling through looking at the rescheduling environment, strategies and methods together, in order to develop a control strategy to cope with a variety of manufacturing environments.

As Herrmann (2006 c) explains the rescheduling environment analyzes the set of jobs a firm has to produce. The rescheduling strategy determines the necessity of generating and/or updating a schedule. A rescheduling policy determines when the scheduling should occur, and the rescheduling method describes how the scheduling should be executed. Below is the rescheduling framework.

FIGURE 3. Vieira et al. (2003) Rescheduling framework

Rescheduling Environments				
Static (finite set of jobs)		Dynamic (infinite set of jobs)		
Deterministic (all information given)	Stochastic (some information given)	No arrival variability (cyclic production)	Arrival variability (flow shop)	Process flow variability (job shop)

Rescheduling Strategies				
Dynamic (no schedule)		Predictive-reactive (generate and update)		
Dispatching rules	Control-theoretic	Rescheduling policies		
		Periodic	Event-driven	Hybrid

Rescheduling Methods				
Schedule generation		Schedule repair		
Nominal schedules	Robust schedules	Right-shift rescheduling	Partial rescheduling	Complete regeneration

Although for the most part there exists a finite set of jobs at XYZ, there is a continuous arrival of new part types while some expire. Being that these new part types create a scheduling challenge, using the same machines as many parts that have been produced for a long time, the dynamic environment was recognized. For the most part each job needs scheduling before it can be processed. The nature of process flow variability is such that there are many products but a limited number are being produced at the same time. Some future information is known regarding common large quantity orders, but information is subject to change as new or urgent jobs arrive, along with current jobs in production delayed or stopped.

As Herrmann (2006 c) points out, a predictive-reactive scheduling strategy is common for dynamic manufacturing systems. This type of scheduling has two major themes, initial scheduling and rescheduling due to a disruption to plan. There are three different rescheduling policies that dictate when rescheduling should occur: periodic, even-driven and hybrid. XYZ's scheduling system reflects a hybrid policy due to the scheduled weekly rescheduling and of course rescheduling triggered by an event.

Referring to the rescheduling methods elicited above, XYZ continuously intends to generate robust schedules thorough most optimally combining resources despite disruptive production events. However tirelessly XYZ attempts to attain a robust production situation, it is impossible to be as robust as a world-class operation. With that said, there are times where a partial or complete schedule is regenerated, while sometimes only a right-shift scheduling is regenerated on one machine with urgent scheduling problems. A right-shift rescheduling is when for example due to a delay a current production order needs more time to complete, resulting in following orders mechanically delayed in a right-shifting nature of the same amount of extra time the current order needs to finish.

In the context of the robust scheduling of a small firm, the limitation of a lack of specialization a small firm affords is due to the mutli-tasking nature of many of its positions. Although XYZ and specifically the planner would like to continuously update the entire schedule, with time constraints the planner can minimally generate a complete scheduling and typically has time for a partial or isolated machine right-shift rescheduling.

2.5 Three perspectives to planning

Hermann (2010) illustrates an improved production situation by combining works of Taylor, Gantt and Johnson; he creates an integrated approach to planning by combining the organizational, decision-making and problem-solving perspectives.

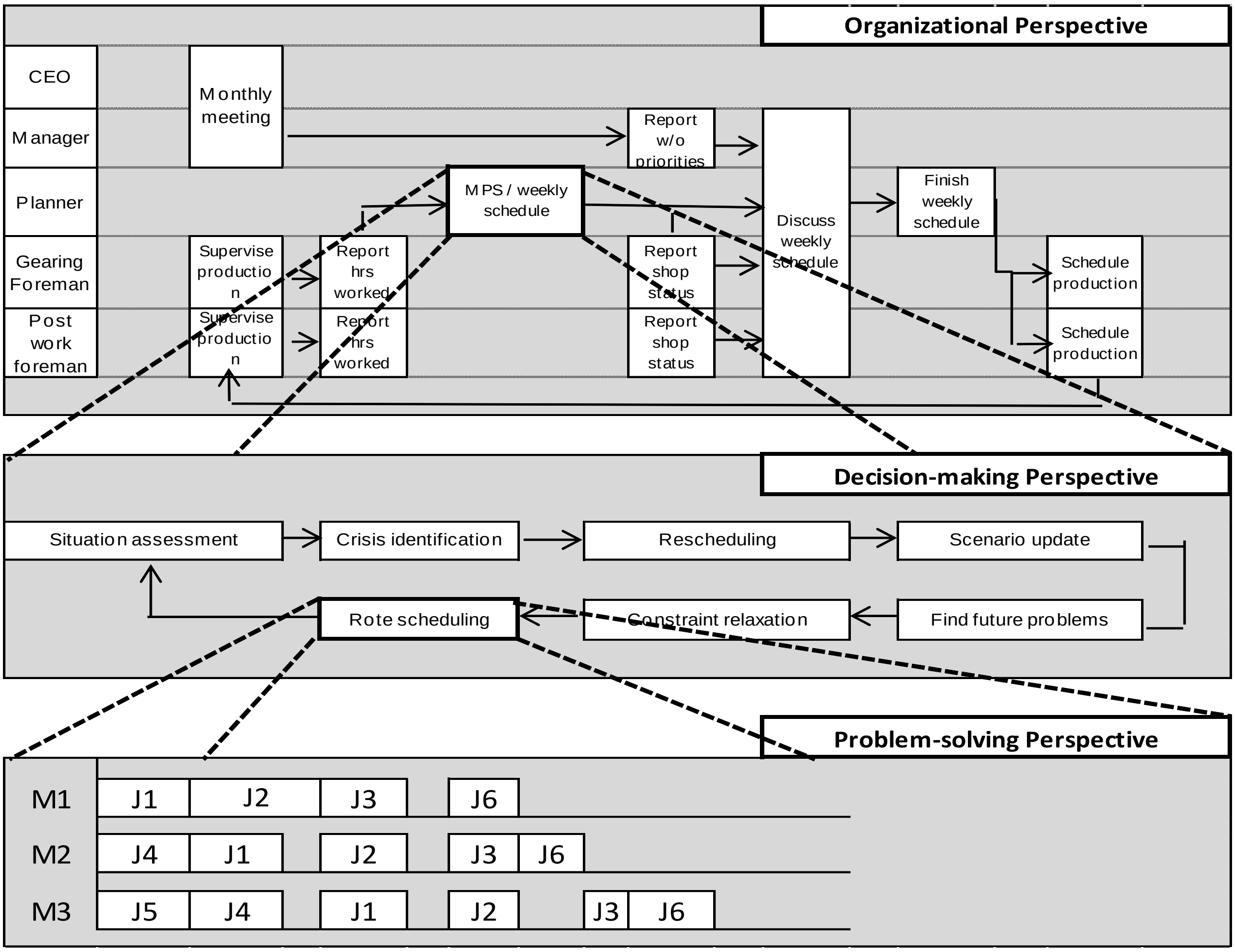
At any given moment of XYZ's three hundred open orders to be planned, a change in one term or status can have an impact on production orders behind it, shop floor situation and the ability to maintain delivery dates as a whole. How does one address the detailed status of one order, yet maintain the overall control of operations?

Hermann explains that one must have a well-defined and established system design considering the system as a whole, while simultaneously addressing single shop floor issues. Figure 4 shows the idea at a conceptual level following the organizational perspective; information moves in and between departments and persons all the way to how one detailed scheduling decision is made from this organizational exchange. The figure is in a sense starting from the production planning organization and then focusing in on the single task of a machine setup decision. Thus the organizational perspective to planning has to address the question of how is the organization best designed and employed in the process.

The goal of the author of this paper in creating the MPS, machine scheduling and weekly schedule updates, is just this: to create organizational design and planning tools to help planning and production keep focused on one production order status, yet maintain the overall production operation awareness. Information and how it is assembled to create plans based on organizational goals and objectives is of strategic importance to the firm. The MPS is the interface between strategic and tactical planning in an organization (Vieira, 2006). It is essentially a statement to production for gross requirement and the basis from which all other plans are created. Thus the quality of the information assembled, and accuracy of the planned production and customer confirmation dates are important.

While Vieira (2006) examines the make-up, objectives and importance of the MPS, Herrmann (2006 a) defines decision-making systems in production scheduling and how information is used in the organization. In this review, it is enough to examine the key responsibilities for each department leader with respect to production planning and the timing of their analyses, exchange and input towards updating and discussing the weekly schedules and MPS.

FIGURE 4. Perspectives to planning



Adapted from Herrmann 2010

2.5.1 The organizational perspective

The relationship and process flow is illustrated in the organizational perspective section in figure 4. Each member is included on the left side of the figure with their corresponding responsibility graphed to the right. The arrows drawn depict the relationship between responsibilities and members and how they are related to the MPS. The CEO and manager discuss more aggregate topics like key performance indicators or possibly a high priority order from an important customer, bringing these issues to light in the weekly meeting, although not yet given priority. The foremen report on production progress, hours worked, order problems or specific resource issues. Finally the planner takes all issues into account that affect production, updates the MPS and/or prepares a suggestion for schedule repair to discuss in the weekly meeting.

The MPS is essentially a reflection of the relationships and process flow findings to organize resources in the most effective means possible. In the case of XYZ, one can understand the importance of the MPS through looking at how weekly meetings are organized to discuss production status and issues, comparing them to what was previously planned and resolving them with reference to the MPS.

Once the decision-making system within the planning process is defined, specialization along business functions is enabled, ultimately facilitating an environment where the right person is analyzing the right data at the right time. While the system obviously has as short a communication chain as possible within departments and the organization as a whole, it is still crucial to define a system which facilitates exchange of information on crucial issues.

Practice has shown that at XYZ, some issues cannot wait for the next weekly meeting. It is also physically impossible for any one party to know every issue, sort through all the information and immediately recognize and address issues. Defining the decision-making system with swimlanes, specialization, short communication chains and timing of analysis and discussion is therefore key. The organizational perspective in the diagram above attempts to construct this system at a basic level.

2.5.2 The decision-making perspective

The decision-making perspective examines the daily routine a planner executes with regard to establishing situational awareness and the resulting rescheduling of problems arising. Rather than considering the organization as a whole, it focuses on one person’s method to working their key responsibility. In this case, we examine McKay and Buzacott (2000) 7-step routine to maintaining the MPS. This routine involves a consistent method to recognize production issues in order to best keep on top of the production situation, employing certain coping mechanisms in order to minimize deviations to the MPS.

The decision-making perspective is important to consider. Its implications can be as far reaching as having a negative impact on the bottom line, in case of a randomly organized method of production control, jumping from one task to another. Without consistency one may forget to reschedule orders behind a delay, inform a customer or overlook a potential optimal sequencing scenario that would prevent an additional setup.

Adapted from McKay and Buzacott (2000), these tasks are:

1. The planner many times begins the day with an initial **situation assessment.** The planner may want to see what was recently delivered, built to stock and any fluctuations in demand or supply.
2. After the assessment **crises are identified**. These problems are likely to be the usual bottlenecks that the people at operations are aware of, but many times there are also returns, delays or personnel absences. The problems are prioritized and addressed accordingly.
3. Sometimes these problems are solved by **resequencing** or adjusting resource quantities, material, dates or overtime requirements.
4. Then the MPS is renewed by running a **scenario update.** This allows recognition to any additional issues the re-sequencing solutions may have caused.
5. Often the update creates additional schedule conflicts that should be resolved as well. The planner will then use this update to **identify future problems**. These are issues outside of the immediate time horizon and can be resolved or rescheduled in the short term.
6. First, these problems will be attempted to be solved through sequencing. If further issue, they will attempt to resolve them through **relaxing constraints**.
7. All other routine work that is not constrained will be **scheduled by rote**, eg. mechanically dealing with the rest of the problem.

The main intent of this routine is to give consistency and structure to production planning and control. The positive effects experienced will be highlighted in section 4.

2.5.3 The problem-solving perspective

The final perspective takes a closer look into one component of the decision-making perspective, zooming in on the scheduling aspect of the 7-step routine process. By focusing on one element of the routine, we can see how one specific problem is solved in the order sequencing on a machine.

Being we are dealing with decisions regarding machine scheduling, this implies that a machine capacity tool is necessary in order to properly calculate machine capacity for orders over time. Without a proper tool to reflect capacity there is no telling the implications on orders behind a late production order. With XYZ being a gear manufacturer, knowing machine capacity is knowing a large part of the firm's capability. In the results section we will look more in depth at the tool developed to cope with this perspective.

Whether we examine each perspective individually or together as an interrelated system, they are important to consider for optimal resource allocation.

3 RESEARCH METHOD

The case study research takes a mixed method approach, beginning with the initial exploratory research in order to develop an understanding of key elements to improve from a combination of literature review, company data, interviews (Kjellsdotter-Ivert, 2009) and unstructured discussions; transitioning to being directly involved with developing solutions, a characteristic of action research (Malhorta and Birks, 2007; Saunders et al., 2007).

Although literature and company documents and reports have been reviewed, the bulk of the weighting of the exploratory part of the paper presents overall analysis of the production situation based on a survey "Production Control Profile" from McKay and Wiers, *Practical Production Control.* Nevertheless, the survey incorporates the findings of the literature and company document review through the structured assessment.

After recognizing the overall production situation and developing a feeling for the organization as a whole, this work transfers into action research and zeros in to a more detailed problem-specific level. The goal is to analyze and develop a system from the organizational, decision-making and problem-solving perspective (Herrmann, 2010). The three perspectives will be addressed, and development of production planning tools will become a concrete result of this research.

For the purposes of this research, plenty of information is available from the on-going production situation. However, the following data in specific is needed to carry out the analysis:

1. Overall production profile analysis – exploratory research from the author's perspective
2. Continual informal discussions with management and department leaders to recognize critical aspects to consider when making the MPS and machine scheduling tool
3. Continuous feedback from employees
4. Feedback from parent company logistics manager

Because the firm recently transferred from a paper-based system much of the data is inaccessible, making a quantitative and statistical method impractical; it is deemed suitable that the research employs a qualitative method (Malhorta and Birks, 2007). Much of the research will be conducted by the author, a characteristic of action research (Saunders et al., 2007), through surveys and mostly observation and reflection. Additionally, giving credit to the qualitative method, the firm was absent an MPS until the author's inquiry and research, therefore inferring suitable qualitative methods such as: survey, interviews and discussion logical (Crotty, 1998; Malhorta and Birks, 2007; Saunders, 2007).

Finally, being that SAP adoption is yet in its infancy, it is sensible to assume that data in the ERP system is not yet trustworthy and will continue to be updated, further making a qualitative approach and associated methods more suitable over quantitative and statistical analysis.

3.1 Data analysis

The qualitative data collected for this research originates in reviewing literature, planning related company documents (informal due to unsophisticated nature of firm), discussions and continuous observation on-the-job, as well as a survey on the production planning. This data is informally aggregated and will be integrated and compared with the textbook examples of successes, failures and world-class planning and control systems (Herrmann 2006a; 2006c; Kjellsdotter-Ivert, 2009; MacKay and Weirs, 2004; Vieira, 2006) in order to develop the solutions to improve the planning system.

3.2 Implementation of the study

As the motivation for the research was largely the author's personal desire to improve the organization, the nature of data collection had to be integrated along-side regular working times and workloads. Most of the qualitative data collection took place over a period of about six months. The flexible nature of this research allowed more time to observe, discuss and gather feedback from interested parties.

The first requirement was to acquire the approval from XYZ's management to conduct the research in the first place. The management was seeking to improve the accuracy and integration of production so it gave a broad mandate in terms of time span, methods and data access. A production profile analysis was conducted along with several informal discussions and related observations.

Discussions and questions regarding this study were focused on essential aspects to planning, for example identifying critical information to include in the MPS and machine schedules. It is relevant to add, that language barriers with some of the department leaders and employees made this study more difficult to conduct. The management, department leaders, employees and two representatives from the parent company all contributed to this study by sharing their views and knowledge.

The author's manager was consulted for assistance with SAP data, recognizing critical aspects and feedback. Following that, two department leaders were involved in discussions to recognize critical aspects to planning and variables to include in the planning tools. In addition, four employees were asked to give feedback on the format, usability and effectiveness of the MPS.

The factors evaluated for the MPS involved extensive on-the-job discussion with all levels in the firm. With minimal time for structured research, informal and on-going broken discussions took place continuously. The manager and foremen served as key contacts in recognizing critical aspects of production to include in the MPS. After recognizing the aspects to production, reflection needed to take place in order to create a meaningful and cohesive tool to pull the organizational aspects and practical methods together.

After the tools were developed, they were submitted to two representatives of the parent company that were simultaneously conducting their independent analysis on the planning system.

Once XYZ's management has analyzed all the relevant data regarding the new MPS tools and the independent analysis of the parent company, it will decide what kind of a planning system and tools will be implemented.

4 RESULTS

This section begins by forming a production profile for XYZ and discussing the company's production methods prior to any improvements were made. After the initial production profile is evaluated, as Slack et al. (2010) and Vieira (2006) point out, the most important tool for organizing the firm is the MPS. Thus the next section explains how the MPS was created at XYZ by following along the same structure of the three perspectives. A planning and controlling routine will be explained and finally a gearing department machine scheduling tool developed.

4.1 Production profile – understanding what needs improvement

This study utilizes the production profile survey by Mckay and Wiers, which consists of a series of 39 questions, assessing different aspects of the firm's production planning and control system. The survey is explained in depth in their book, *Practical Production Control,* which analyzes many aspects of production planning and control, and gives advice how to improve production control. The following aspects are covered in the survey:

- Information
- Predictability
- Recovery Options and Flexibility
- Goals, Objectives and Constraints
- Control Structure and Environmental Factors

The full survey can be referenced in the appendix. It contains 39 questions, of which each is rated from one to seven points, with lower scores associated with better performance. The maximum score is 273, which indicates a production system in a chaotic state.

XYZ's survey result reached a score of 163. While the firm was not on the verge of chaos as it is total score was less than 200, it was not indicating a world-class shop either as the score was not below 100. The methodology of Mckay and Wiers rated XYZ's situation as bad, but normal for many manufacturing firms. The production profile had issues with every category evaluated. Some of them were organizational, departmental and specific, meaning many levels of the firm could be improved. The quote by McKay and Wiers illustrates XYZ's situation well:

> "If you have a score 100-200, we think you have a hard job, and have a bad situation to deal with. It is not life threatening and there are days that are really ok. Might even be a few in a row. You can do some planning and scheduling in terms of loading work, but nothing like tight sequences that can be expected to execute."

4.1.1 Findings from the production profile survey

Everything from customer demand to factory shop floor status is included to plan, produce and deliver each order. When there is a lack of information or a coordinated way to assemble and process it, as was the case with XYZ, planning becomes difficult. To address the malfunctioning transfer of information in and between departments, the people at XYZ needed to realize how information is assembled, used and exchanged in the existing setup. This allowed the developing of a tool to address the problems.

The predictability of the production situation was rated of medium difficulty. Deviations to plans were a normal production situation. Setup times, quantities produced and allotted production schedule time were mostly not kept. With a great amount of variance to original schedule, reliability of planning became poor. As a result, the personnel running the production could not be sure which aspect to production would be kept and which would be exceeded.

Recovery options and flexibility were at a minimal level and although this was not a terrible situation, it inferred another medium difficulty situation. XYZ's lead times were longer than preferred by the assembly logic of its parent company. With the lead times being a reflection of the complexity of production, it is no surprise the recovery options and flexibility levels were low. Poor flexibility became evident for example in a situation in which raw material was deemed faulty requiring replacement just before production was scheduled to begin. XYZ's production function had no option but to wait until acceptable material arrived, causing a delay to not only the order in question but many orders behind it. With many capacity constraints and limited number of machine types for each piece it made the production situation more challenging to plan.

With the lack of consistent and clear goals and objectives it is no surprise that the firm faced a somewhat chaotic situation. With a score of 27 out of 42, it indicated that there is a medium difficulty, but decisions could be made and options worked out. Because of the lack of information and accuracy of data, it had an impact with production objectives being unclear. In addition, there were sometimes official, unofficial and interchanging goals and objectives stated by management. A clear system and consistent routine to planning seemed necessary for the production situation.

The control structure and environmental factor aspect to planning scored in the middle, getting 16 out of 24 points. Problems such as dispatching outside of the plan without appropriate consultation, whether being due to a lack of time to evaluate the best decision or a just way of doing things, was and still is often ineffective. The absence of a clear and cohesive control plan in and between departments had an impact of the overall performance in an organizational, decision-making and problem-solving way. It became evident that decisions should not be made independently, but by involving others and multiple systems. As such, the control and environmental factors should be considered.

4.1.2 Challenges with the IT infrastructure

An existing challenge before taking on the project was keeping track of about three hundred positions on a weekly basis, constantly changing the approach from planning to control as scheduled production times neared. Points considered were only tracking changes to schedules, keeping on top of negative developments rather than updating all positions.

XYZ lacked an auto-populated schedule that would automatically keep track of all production developments. Even after SAP implementation there was no tool that the

ERP system could automatically compare the demand to the production development. There was no way to generate a situation update for all orders in the company's twelve week production window and highlight the schedule discrepancies. Even though there are specific functions in SAP to recognize schedule mismatches to purchase and production orders, the very nature of these functions is mostly intended for larger organizations that can benefit from specialization.

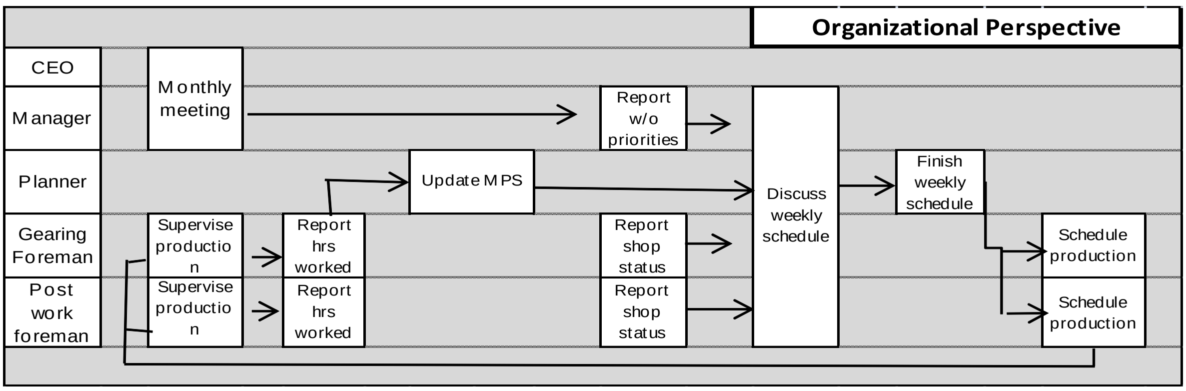
For a small dynamic firm where the planner is responsible for customer order processing, procurement, production planning and control, one needs a tool that combines the big picture overview with a detailed status of each order. This was not possible to generate from SAP. After extensive discussions with management and other managers within the group, there was no other way but to proceed with the manual nature to production planning and control.

4.2 The path to better production coordination at XYZ

This section describes how the process of planning the Master Production Schedule (MPS) was defined and what the MPS looks like in practice. The benefits of the new system are then discussed.

4.2.1 Defining the process of planning the Master Production Schedule (MPS)

FIGURE 5. MPS planning process



Recalling the organizational perspective previously discussed, after analyzing the production profile and seeing the lack of clear system exhibited, it was obvious that the firm could benefit from cohesive planning and a more timely and accurate method. Therefore, the weekly planning process becomes noteworthy. It was and still is the author’s primary responsibility to update the MPS and release weekly plans for production at XYZ.

The weekly meeting was selected as the central venue for planning the MPS. The chart above depicts the key stakeholders in the process. The chart shows how the MPS is continuously updated, involving each key stakeholder and their applicable contribution to the update. By following the flow of the arrows you can see how parties bring objectives or recent developments to the planner and/or meeting in order to update the MPS. Then everyone discusses relevant issues at the weekly meeting and after the results of the meeting are updated into the new plan, the foremen update their respective machine schedules.

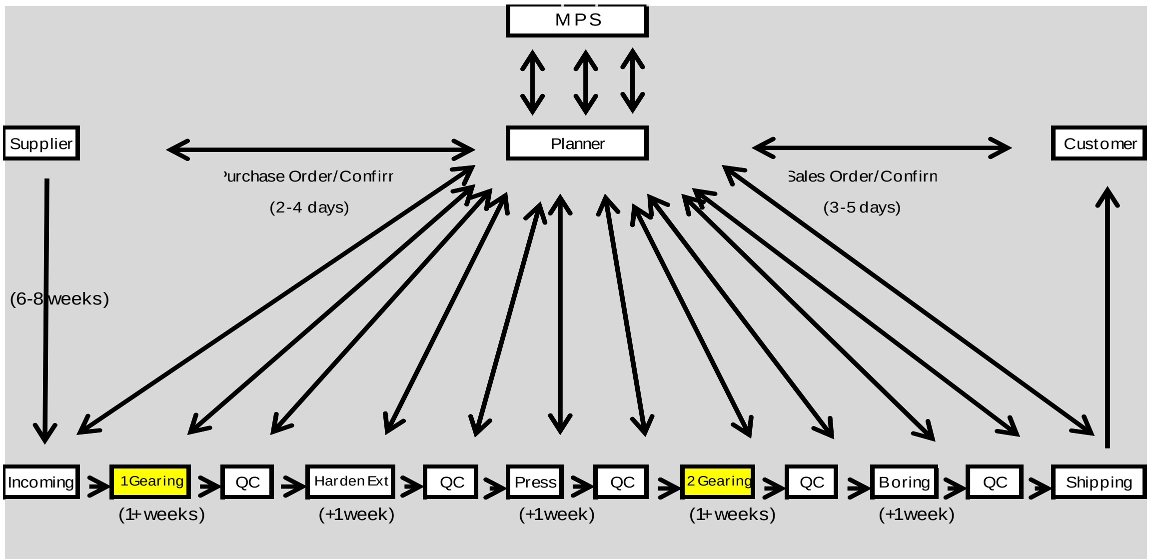
Although the model over-simplifies the actual involvement of each member and the discussions that take place throughout production planning and control, it is worthwhile to highlight the importance of the key responsibilities of each party and present a structured process to keep production flowing. From the CEO’s views all the way to an individual laborer, the necessary input should make it into planning through this process to create the MPS.

The beginning of the week gives time for the planner and foremen to assess the production situation and updates on orders to factor them into the weekly plan for the meeting. The remainder of the week gives time for production to follow up on the plans and to schedule new orders as well as to recognize further arising constraints.

4.2.2 Sharing essential information and the flow of goods

While the planner's primary responsibility is to mediate issues in production in coordination with the MPS, the daily tasks he conducts in order to maintain the MPS do not capture the flow of information and most of the standardized processes depicting the flow of goods. The way the planner manages the production is equally important to examining the tasks associated to maintaining the MPS.

FIGURE 6. XYZ's flow of information and path of goods from order to delivery



At XYZ, with many process steps of production and the fact that lead times may reach up to over sixteen weeks, one can see the complexity of production planning. The diagram simplifies this and shows the importance in considering many variables when planning or rescheduling orders. Things such as procurement terms, machine and component quantity requirements are easily determined while other information such as capacity levels, expertise and sensitivity of machines at times cannot be fully known. Besides consulting the ERP system for capacity level configuration, a planner often needs to discuss with production.

The arrows in the diagram above capture the interactive nature of the planning department. While the planner does not need to take into account each minute detail for each individual sales and production order, he must be aware of them for order statuses. In turn, he must also know which parties to discuss with for initial confirmations on more complex parts and whom to inform should a schedule change take place in the beginning of production. The flexible and intermediary nature of a planner becomes obvious here as well. The awareness of a usual delay or problem with one of the production steps can alert the planner to give extra control measures and communicate with that department. The diagram above displays the importance of feedback loops regarding production should any issues occur.

All discussions on terms and issues require consultation and updating of the MPS. As the planner is solely responsible for creating, updating and issuing the MPS and weekly production plan, it may seem risky having one person manually assemble all the data into a three month production plan. At this point XYZ has no other affordable way of automatically formulating and updating a production schedule from the ERP system. Therefore it puts a lot of responsibility on the system. It encourages more communication and integration between departments. The level of integration depends on the willingness of its team members to collaborate and contribute. Since the system is of interpersonal nature, the communication distance is an important aspect along each arrow.

The distance between communication links in the overall chain may not have much significance on one order, but when dealing with several orders, it can affect the efficacy of overall production. When zeroing in on decision-making and problem-solving perspectives, it becomes obvious that communication builds and promotes coordination in the organizational chain. It is therefore important to understand this aspect to planning.

The author’s experience from XYZ is that some people are reluctant to communicate openly, waiting until something goes wrong before notifying relevant parties. Examples include quality problems, inability to deliver/pick-up goods from a supplier, and waiting until the planner “catches” that scheduled production steps are not completed on-time.

The benefit the MPS provides is an overall transparency to the entire process. Any one person can reference the list to see where pieces are in production. The transparency of data facilitate discussion within and between departments due to the foresight the formal scheduling gives, being stated directly on the weekly production update.

It has changed at a basic level the previous reactive nature of many production personnel, causing them to become more forward-looking by voluntarily giving more updates to each other, inferring a more coordinated way of organizing production. The author believes that over time the coordinated nature will automatically become the nature of production and planning. With a long history of previous method still fresh it is only human to expect some bumps before a smooth, continuous exchanging of information becomes everyday habit.

4.2.3 Creating the Master Production Schedule (MPS) – the organizational perspective

After reviewing the approach to production planning and control, the creation of the MPS at XYZ is explained along with the role it plays to aid in the delicate balancing of Wight's "priorities" and "capacity." Because the priorities are often reflected on the MPS and capacity incorporated into the schedules of the orders all parties of the firm can see a statement of production of all current planned orders, balancing the overall priorities and capacity of the firm. By its very nature of an master plan for all orders in the twelve week window it implies an organizational aspect. This interdependent encompassing aspect defines the organizational perspective analyzed.

With the process of planning the MPS in place, the next step was to create a medium to formalize the goals and objectives of the organization through a master plan, effectively creating a statement to production in the short to medium term horizon. The MPS was created based on the interdependent, encompassing organizational perspective, as a master production plan to produce all orders in the time period of twelve weeks.

As previously stated, the lead time for the average order is twelve weeks. It was found necessary to extend the planning window from four to twelve weeks. Many things have to be taken into account when planning a customer order at XYZ due to material procurement taking up to eight weeks and production between four and ten weeks. In addition to broadening the planning horizon, the following factors proved to be critical in applying to the MPS in order to recognize key information and thus, enabling better decision-making:

- Customer
- Material description
- Customer order quantity
- Parts on stock
- Parts ordered/in production
- Raw material delivery week
- Production process requirements such as incoming inspection, grinding, grinding external, gearing, gearing hand crafted, milling, roto-finishing, hardening, burnishing, polishing, coating, riveting, post processing, end inspections
- Delivery week
- Value
- Remarks/current status

At XYZ, since the creation of the MPS a list of orders with applicable information is exported weekly from SAP and the data is then imported into the MPS. Following that, a quick review of estimated production steps is compared with the current production schedule on the applicable machine and rescheduling of conflicts performed.

Events such as absent personnel can have an impact on production when there is a limited amount of staff for some positions – in some cases only one staff member. With the aid of this tool created, production personnel can at any given moment reference the MPS to see order information compared to stock and 'in production'-numbers. This enables independent decision-making in case the situation calls for it.

The properties of an MPS at XYZ

The MPS is a tangible tool allows production to concretely see the exchange of information between the department leaders within their respective swimlanes through facilitating discussion in relation to planned completion dates. This in turn, further impels the foremen and planner to be vigilant of any possible issues, and address them through prioritization and rescheduling.

FIGURE 7. Master Production Schedule (MPS)

Customer	Material Descripti	Open	Stock	i.Work	Déc	Insp	Grind	Gear	GearHa	Hard	Press	2 Gear	PP	Finsp	DelWk	Net value	Remarks
MMM	AW 1504	1982	1982		KW 45	KW 49	47-51					KW 13		KW 04	2014.14	2'754.98	Delivery
MMM	AW 1504	3018	0	5200	KW 28	KW 32	KW 33					36-37		KW 37	2014.37	1'341.00	déc
MMM	AW 1504	10000	0	10000	KW 45	KW 49	03-04					10-13		KW 13	2014.13	13'920.00	Tooling delay 1 wk
MMM	AW 1573	1500	2042		KW 36	KW 39	KW 40					KW 50		KW 42	2014.14	1'899.00	Delivery
MMM	AW 1573	624	0	650	KW 36	51-02	KW 02					KW 19		KW 19	2014.19	810.00	Very 2100
MMM	AW 1573	1500	0	1500	KW 39	51-02	KW 02					KW 19		KW 19	2014.19	2'188.80	
MMM	AW 1573	1500	0	1400	KW 09	KW 10	KW 11					KW 19		KW 20	2014.20	2'364.00	Verz 1400
MMM	AW 1573	2710	0	2700	KW 41	KW 02	KW 02					KW 14		KW 14	2014.14	3'121.00	Gearing 2700
MMM	AW 1574	5000	0	5000	KW 41	KW 02	KW 03					KW 15		KW 16	2014.16	5'760.00	Gearing 5000
MMM	AW 1574	5000	0	5000	KW 41	KW 06	03-04					KW 16		KW 17	2014.17	5'760.00	Gearing 5000
MMM	AW 1574	5000	0	4000	KW 41	KW 07	KW 08					KW 17		KW 18	2014.18	5'760.00	Grinding 4000
MMM	AW 1574	5000	0	10000	KW 06	KW 08	KW 09					KW 18		KW 20	2014.20	5'760.00	Inspection 10000
MMM	M 1051	3000	0	20000	KW 33	KW 35		KW 36		KW 37			09-10	KW 10	2014.14	900.00	Boring 19887
MMM	M 12401	2500	0	6400	06-07	07-08			07-08	KW 09				KW 19	2014.19	2'000.00	Gearing 6400
DMG	R 430221	10000	0		KW 11	KW 12		13-14		14-15				KW 16	2014.16	2'900.00	déc
DMG	R 430221	10000	0		KW 13	KW 14		15-17		KW 18				KW 19	2014.19	2'615.80	déc
DMG	R 430221	20980	0		KW 25	KW 26		27-33		KW 34				KW 35	2014.35	2'615.80	déc
MMM	S 1031	40000	0	31700	KW 45	KW 49		06-09		KW 10				KW 11	2014.11	9'216.00	Gearing 31700
MMM	S 1031	50000	0	50000									07-10	KW 13	2014.13	11'520.00	EP 9900 Ext.30000 / j
MMM	S 1031	30000	0	14000	KW 45	KW 49		10-12		KW 13				KW 14	2014.14	6'912.00	Gear 14000 M. 33

The figure above shows a simplified version of the MPS employed at XYZ. It depicts the most critical data and processes, highlighting crucial information to the team denoted by color or current status. By having a tool like this, the team is able to keep track of orders, see what orders are coming in the weeks ahead and recognize future conflicts to address. A crucial benefit realized is that it is a key reference for each department for planning in and between units. Everyone from incoming inspections to delivery personnel to management can reference the MPS to see current status on an order in question and rely on the information to mediate conflicts.

It can be a daunting task to manage having around three hundred parts in the planning horizon at any given moment, each having various production requirements. In order to overcome this complexity, it was decided to visually represent the production requirements through assembling a list of all parts in the twelve week period, scheduling them out across key production steps. This is illustrated across the top header row of the MPS graph shown above. Each column scheduled with a week number indicates the applicable production requirement. This makes it easy for personnel to plan and locate anticipated pieces. As the process steps are complete, the row is marked green. Colors are also used to indicate priority due to customer changes, delays or production issues. The remarks column at the right side enables the planner to detail current progress and write critical status updates for the team.

The MPS in practice – an example

With lead times upwards of three months and many orders to keep track of, any question from any department most likely involves reference to the MPS. Hence the planner benefits from having the MPS at hand. When walking to discuss order sequencing with the gearing foreman, another employee may ask a question about another order’s term or delay, which usually involves reference to the MPS to solve the issue.

From an organizational perspective, the MPS is a manifestation of the firm’s strategic and tactical goals, combined to realize a master plan of production. Therefore, it is a crucial tool to facilitate discussion and integrative planning within the organization.

FIGURE 8. A single order in the MPS

Customer	Material Description	Open	Stock	i.Work	Déc	Insp	Grind	Gear	GearHa	Hard	Press	2 Gear	PP	Finsp	DelWk	Net value	Remarks
DMG	R 430211	7130	0	28000	KW 45	KW 08		09-12		10-11				KW 12	2014.12	2'424.00	Ext. 14600 27.2 / Gear 13400

To understand how the tools used to coordinate production, a walk-through example of a single order shown above is presented. All the gross requirement data regarding customer, order quantity, stock levels and amount in production is on the left. Then starting after “i.Work” column, the MPS tracks the production progress through scheduling production requirements in weeks for all critical production steps. As the order progresses the completed steps are marked in green. Regarding the order above, we can see there are 28’000 pieces in production, 14’600 pieces at an external hardening supplier and the rest being geared. With more than enough pieces already in hardening, this communicates to all parties that the open 7130 pieces on the customer order should be ok for a week twelve delivery.

Maintaining the MPS at XYZ

The process designed for updating the MPS is modeled as follows:

Monday	Situation update involving manually updating what was delivered the previous week, performing a production update through additional orders that come into view by looking forward twelve weeks and then performing a shop walk-around to check each department’s production progress.
Tuesday	Completing situation update and releasing weekly production schedule
Wednesday	Production meeting, noting changes to priority and schedules
Thursday	Writing updates on the schedule to communicate to team members as necessary and for next week’s update. Check supplier deliveries and update on MPS and reschedule if needed
Friday	Planning new customer orders and entering them into the MPS

Unexpected changes are always updated continuously, but a complete MPS rescheduling is only rarely performed outside of the weekly update as this process is very laborious.

Because of the intensive nature of actualizing the production situation, the next aspect discussed between planning and management was establishing a rigid routine to control production and the MPS. That moves us to consider the decision-making perspective.

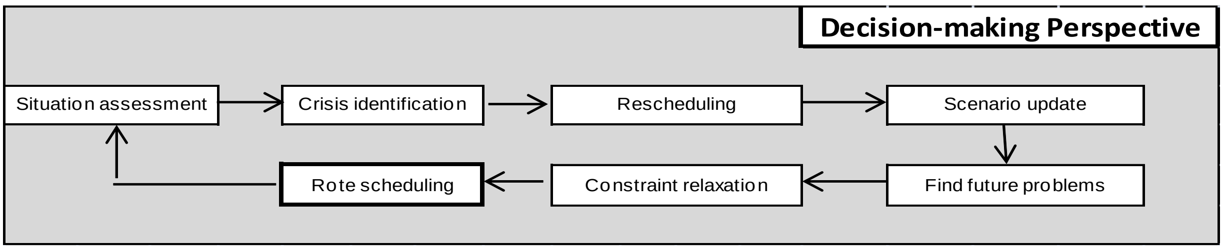
4.2.4 The 7-step routine – the decision-making perspective

After discussing the organizational perspective and examining the tool that helps to realize integrative planning within the organization, this paper will examine the decision-making perspective and look into a common routine to help a planner's decisions when planning and scheduling. The decision-making perspective refers to the system in place that facilitates good decision-making. Are there sufficient processes and tools in place to help with decision-making? Previously we can assume that due to the lack of a MPS and consistent method to plan, update and control production this perspective was not thought of. It is no surprise that a reactive situation resulted and jumping from one thing to another was resorted to. Additionally it will be shown how the MPS and integrative planning are used in execution.

The workflow of a planner; essential 7 steps

At the decision-making level, the figure x illustrates the key daily tasks a planner executes in order to maintain the production situation.

FIGURE 9. Decision-making perspective



The MPS and the 7-step routine in practice

This section shows how the MPS tool is used together with the 7-step routine for a few more orders with some scheduling challenges. The following is an actual example taken from our production situation.

In the course of the situation assessment included in the 7-step routine, planning recognized discrepancies to schedules below due to a tooling delay that the production informed of. After recognizing a crisis, planning and production met to discuss options to mediate the problem.

FIGURE 10. The MPS with an order containing a tooling delay

Customer	Material Description	Open	Stock	i.Work	Déc	Insp	Grind	Gear	GearHa	Hard	Press	2 Gear	PP	Finsp	DelWk	Net value	Remarks
MMM	AW 1504	1982	1982		KW 45	KW 49	47-51					KW 13		KW 04	2014.14	2'754.98	Delivery
MMM	AW 1504	3018	0	5200	KW 28	KW 32	KW 33					36-37		KW 37	2014.37	1'341.00	Déc
MMM	AW 1504	10000	0	10000	KW 45	KW 49	03-04					10-13		KW 11	2014.11	13'920.00	Tooling delay 1 wk
MMM	AW 1573	1500	2042		KW 36	KW 39	KW 40					KW 50		KW 42	2014.14	1'899.00	Delivery
MMM	AW 1573	624	0	650	KW 36	51-02	KW 02					KW 18		KW 18	2014.18	810.00	Very 2100
MMM	AW 1573	1500	0	1500	KW 39	51-02	KW 02					KW 18		KW 18	2014.18	2'188.80	
MMM	AW 1573	1500	0	1400	KW 09	KW 10	KW 11					KW 18		KW 18	2014.18	2'364.00	Verz 1400
MMM	AW 1573	2710	0	2700	KW 41	KW 02	KW 02					KW 13		KW 14	2014.14	3'121.00	Gearing 2700 / Resch.
MMM	AW 1574	5000	0	5000	KW 41	KW 02	KW 03					KW 14		KW 15	2014.15	5'760.00	Gearing 5000
MMM	AW 1574	5000	0	5000	KW 41	KW 06	03-04					KW 15		KW 16	2014.16	5'760.00	Gearing 5000
MMM	AW 1574	5000	0	4000	KW 41	KW 07	KW 08					KW 16		KW 17	2014.17	5'760.00	Grinding 4000
MMM	AW 1574	5000	0	10000	KW 06	KW 08	KW 09					KW 17		KW 20	2014.20	5'760.00	Inspection 10000

The problem was examined via the MPS, which offers an interface where the planning and production personnel can easily visualize the production situation. The highlighted order in red depicts a week delay in gearing production due to a tooling problem. Despite many other urgent orders, production did not have time to switch to another order. The setup time for a new part can take up to three days and switching from one order type to another would add an additional three day setup requirement to the time when the new tooling arrives.

The solution to the situation emerged in the sequence suggested by the 7-step routine. In this case it made sense to work with production and the customer to reschedule the affected orders in red and blue in figure 10. The red order will run into week thirteen, pushing all other orders back a week. It is the planner's responsibility to coordinate the changes and release a new schedule, so after expiring all options to try and maintain schedules behind the problematic order, the only option was to reschedule and inform the customer of the affected delays as illustrated below.

FIGURE 11. The MPS with rescheduled orders

Customer	Material Description	Open	Stock	i.Work	Déc	Insp	Grind	Gear	GearHa	Hard	Press	2 Gear	PP	Finsp	DelWk	Net value	Remarks
MMM	AW 1504	1982	1982		KW 45	KW 49	47-51					KW 13		KW 04	2014.14	2'754.98	Delivery
MMM	AW 1504	3018	0	5200	KW 28	KW 32	KW 33					36-37		KW 37	2014.37	1'341.00	déc
MMM	AW 1504	10000	0	10000	KW 45	KW 49	03-04					10-13		KW 13	2014.13	13'920.00	Tooling delay 1 wk
MMM	AW 1573	1500	2042		KW 36	KW 39	KW 40					KW 50		KW 42	2014.14	1'899.00	Delivery
MMM	AW 1573	624	0	650	KW 36	51-02	KW 02					KW 19		KW 19	2014.19	810.00	Very 2100
MMM	AW 1573	1500	0	1500	KW 39	51-02	KW 02					KW 19		KW 19	2014.19	2'188.80	
MMM	AW 1573	1500	0	1400	KW 09	KW 10	KW 11					KW 19		KW 20	2014.20	2'364.00	Verz 1400
MMM	AW 1573	2710	0	2700	KW 41	KW 02	KW 02					KW 14		KW 14	2014.14	3'121.00	Gearing 2700
MMM	AW 1574	5000	0	5000	KW 41	KW 02	KW 03					KW 15		KW 16	2014.16	5'760.00	Gearing 5000
MMM	AW 1574	5000	0	5000	KW 41	KW 06	03-04					KW 16		KW 17	2014.17	5'760.00	Gearing 5000
MMM	AW 1574	5000	0	4000	KW 41	KW 07	KW 08					KW 17		KW 18	2014.18	5'760.00	Grinding 4000
MMM	AW 1574	5000	0	10000	KW 06	KW 08	KW 09					KW 18		KW 20	2014.20	5'760.00	Inspection 10000

The delayed order decidedly remained red and the next order yellow due to the urgent production needs to ensure that rescheduling is maintained.

The example illustrates how a consistent routine can recognize and mediate scheduling conflicts from the decision-making perspective. The schedule start and completion dates of orders are examined and the current status of each order in production is traced in the MPS. When armed with a clear process and accurate production information, coping with conflict is a matter of a clearly established routine, leaving little room for error. However, the decision-making process isn't complete without some more sophisticated tools regarding machine capacity.

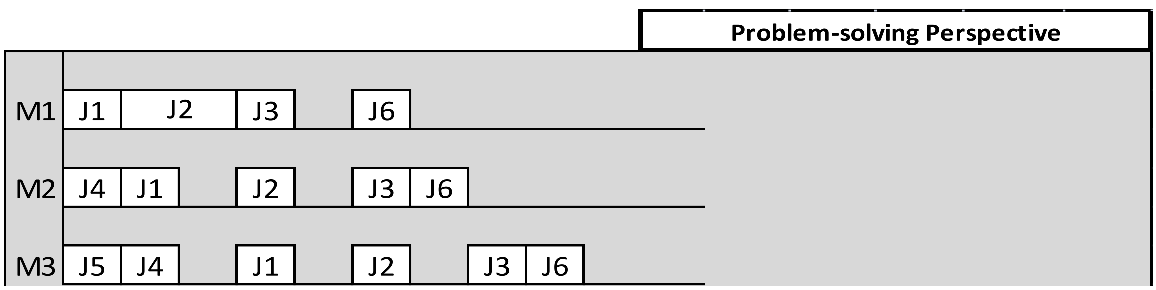
Ever since implementation of this routine into planning, most simple mistakes in production have been eliminated. Many times before simple mistakes happened such as forgetting to order material or forgetting to start production on time when material was ready. This created a bit of anger in production.

Of course there still are mistakes in planning, but they have more to do with improper scheduling due to incomplete or incorrect data regarding production and waiting times in SAP. This paper does not discuss this issue and reserved for topic for further study. Obviously, this has a negative impact on the total production situation and it is the author's opinion that data integrity be a high priority project over the next year. The main positive development on the decision-making front is the consistency and structure the routine gives to planning and control.

4.2.5 Capacity configuration and planning – the problem-solving perspective

With many pieces to plan in a three month window at XYZ, it is difficult to immediately see the impacts on future schedules due to production delays even when an MPS is employed. In a larger firm one would most likely find automated production software that is able to visually model the production situation, create a schedule repair suggestion and update production and delivery terms seemingly automatically. As part of the project to review machine scheduling options, the author met with a few companies in the group to review their sophisticated planning software. After realizing the expensive and complex nature, requiring substantial additional investment in cost and time, the planning software idea was dismissed by XYZ's management. The next sections show how XYZ resolved the question of how to configure and plan capacity optimally.

FIGURE 12. The problem-solving perspective



Key capacity constraints at XYZ

Since gearing is the most important department and a consistent bottleneck at XYZ, capacity levels of gearing are typically analyzed before adding an order to the MPS and confirming delivery to the customer. As a side note, XYZ is extremely dependent on the personnel running the gearing department: the gearing manager has the most knowledge for production requirements, with more that forty years of gearing experience, dealing with these same machine and pieces for most of that time.

The three critical things to take into account when planning an order are raw material terms (dec), gearing capacity / assigning machine to order and previous demand. In contrast, the three critical things to take into account when the order is in production are raw material delivery schedule, production status and any effectual change to schedules

At the time of planning an order the planner is dealing a lot with the gearing department and material suppliers. As the time to start production approaches, the planner is dealing with a lot more departments, controlling and coordinating status updates and priorities. Sometimes speaking with all employees within one day is necessary.

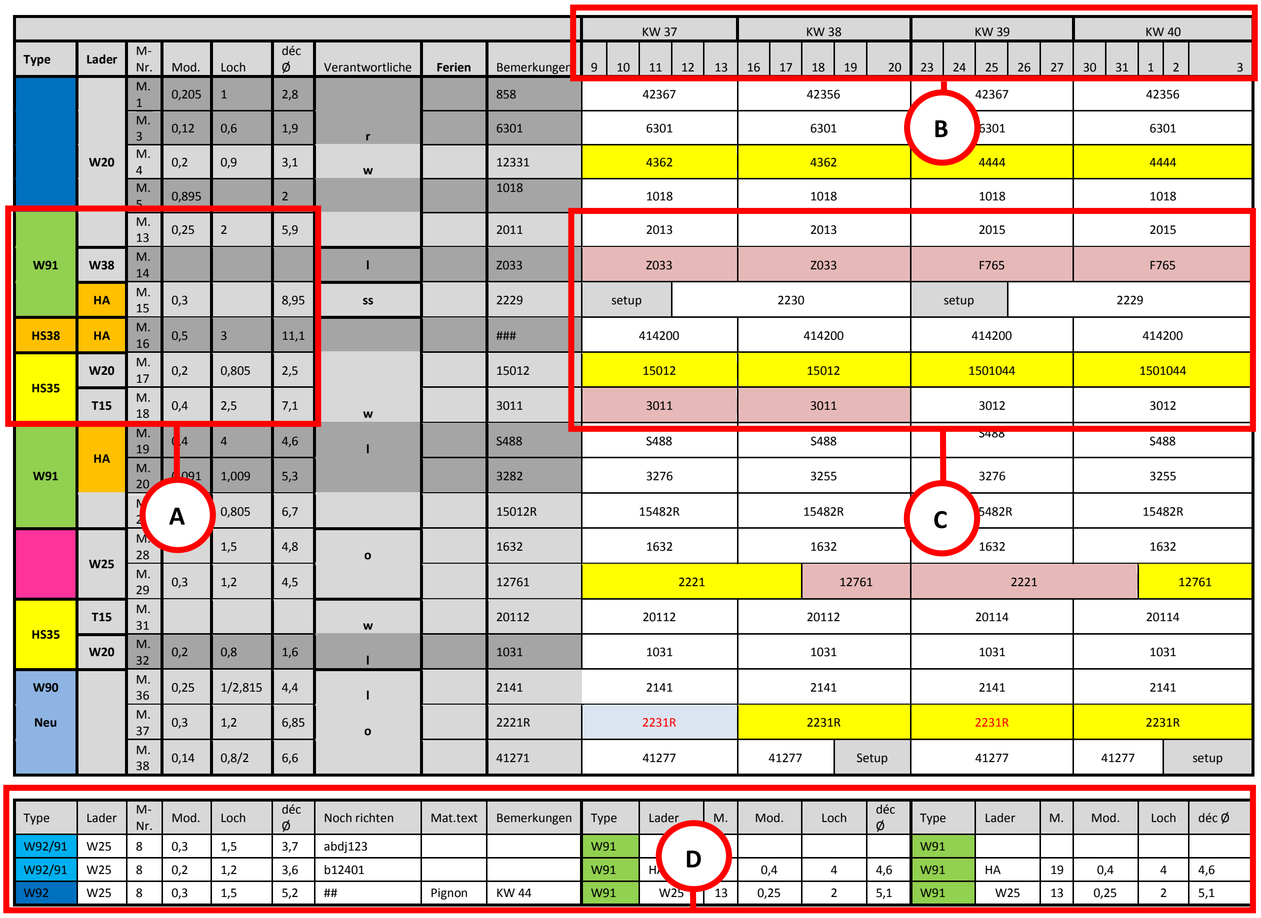
The questions of when to do things, how much to do, in what order to do them and on what machine are essentially discussed and answered by the planner and gearing manager before setting the production plan, adding the order to the MPS and confirming to the customer. With many machine possibilities for many pieces, there are an infinite amount of possibilities to optimally sequence and load each machine.

The first attempt to optimization: Gantt-charts as tools for capacity planning

A machine schedule built through incorporating the time element into planning is integral to maintaining a successful production plan. Thus, to make the job of the planner more effective, the idea was that a visual representation of each order from the MPS should be graphed in a manner that allows quick recognition. The concept of Gantt-charts was an obvious next step.

When a visual tool like the gearing Gantt chart is available, one can immediately recognize the effects on other orders to the right of the current order. This is not easily done with the MPS alone. The MPS is a great tool for determining the order requirements and allows a manageable overview of the process and current status, but to see for example how a broken tool on a machine for one week affects the other orders behind it, is helpful to have a machine schedule to see the impact through quick reference to part numbers behind. The MPS could not visualize this. (See figure 13 below)

FIGURE 13. Example of a machine scheduling chart (Gantt logic)



Type	Lader	M-Nr.	Mod.	Loch	déc Ø	Verantwortliche	Ferien	Bemerkungen	KW 37 (9 10 11 12 13)	KW 38 (16 17 18 19 20)	KW 39 (23 24 25 26 27)	KW 40 (30 31 1 2 3)
	W20	M. 1	0,205	1	2,8			858	42367	42356	42367	42356
		M. 3	0,12	0,6	1,9	r		6301	6301	6301	[illegible]	6301
		M. 4	0,2	0,9	3,1	w		12331	4362	4362	4444	4444
		M. 5	0,895		2			1018	1018	1018	1018	1018
W91		M. 13	0,25	2	5,9			2011	2013	2013	2015	2015
	W38	M. 14				l		Z033	Z033	Z033	F765	F765
	HA	M. 15	0,3		8,95	ss		2229	setup	2230	setup	2229
HS38	HA	M. 16	0,5	3	11,1			###	414200	414200	414200	414200
HS35	W20	M. 17	0,2	0,805	2,5			15012	15012	15012	1501044	1501044
	T15	M. 18	0,4	2,5	7,1	w		3011	3011	3011	3012	3012
W91	HA	M. 19	[illegible]4	4	4,6	l		S488	S488	S488	S488	S488
		M. 20	[illegible]091	1,009	5,3			3282	3276	3255	3276	3255
		M. [illegible]	[illegible]	0,805	6,7			15012R	15482R	15482R	[illegible]482R	15482R
	W25	M. 28	[illegible]	1,5	4,8	o		1632	1632	1632	1632	1632
		M. 29	0,3	1,2	4,5			12761	2221	12761	2221	12761
HS35	T15	M. 31				w		20112	20112	20112	20114	20114
	W20	M. 32	0,2	0,8	1,6	l		1031	1031	1031	1031	1031
W90		M. 36	0,25	1/2,815	4,4	l		2141	2141	2141	2141	2141
Neu		M. 37	0,3	1,2	6,85	o		2221R	2231R	2231R	2231R	2231R
		M. 38	0,14	0,8/2	6,6			41271	41277	41277 Setup	41277	41277 setup

Type	Lader	M-Nr.	Mod.	Loch	déc Ø	Noch richten	Mat.text	Bemerkungen	Type	Lader	M.	Mod.	Loch	déc Ø	Type	Lader	M.	Mod.	Loch	déc Ø
W92/91	W25	8	0,3	1,5	3,7	abdj123			W91						W91					
W92/91	W25	8	0,2	1,2	3,6	b12401			W91	H[illegible]	[illegible]	0,4	4	4,6	W91	HA	19	0,4	4	4,6
W92	W25	8	0,3	1,5	5,2	##	Pignon	KW 44	W91	W25	13	0,25	2	5,1	W91	W25	13	0,25	2	5,1

The machine scheduling graphed on a visual Gantt chart allows for quick recognition and schedule repair. The sooner the schedule repair, the fewer demands for urgent, disruptive setups due to lack of information. And with three hundred positions to keep track of, a scheduling mistake can and will happen.

While not illustrating the full complexity to the machine scheduling problem, figure 13 plots a few orders on a four week horizon.

A	Loader and machine type are listed on the left together with machine number and key article characteristics such as gearing module, outer and hole diameters, responsible party and current part on the machine. It is important to classify the loader type as some parts can only be run on a specific loader and machine. The gearing module, hole diameter and material diameter are classified in order to help optimally group similar parts that are not recognized at initial planning phase or due to schedule changes.
B	The planned start and completion dates are graphed over time - the days and months are scheduled out to ten weeks
C	Below the dates, the parts are scheduled over time as planned after consultation in the initial planning phase. Although in theory the data should be updated continuously, it is not feasible in practice due to the manual nature of the process.
D	Below are articles sorted according to machine type along with their respective characteristics to help with optimized grouping when sequencing

The figure doesn’t fully credit the utility of having a complete overview of all planned orders over twelve weeks, but it is grasps the concept of scheduling orders over time to get a simplified capacity configuration and allows a visualization of machine scheduling based on the MPS.

Because of the manual nature of assembling, graphing and updating the machine schedule and the sheer amount of work that is needed to maintain the machine scheduling Gantt chart, XYZ had to reject the idea of using them. Even though maintaining the machine schedule in this fashion proved to be unrealistic in practice, the idea created an improvised capacity planning system for the firm. From this the idea to utilize the SAP capacity planning tool was born.

A feasible solution: capacity planning aided by SAP

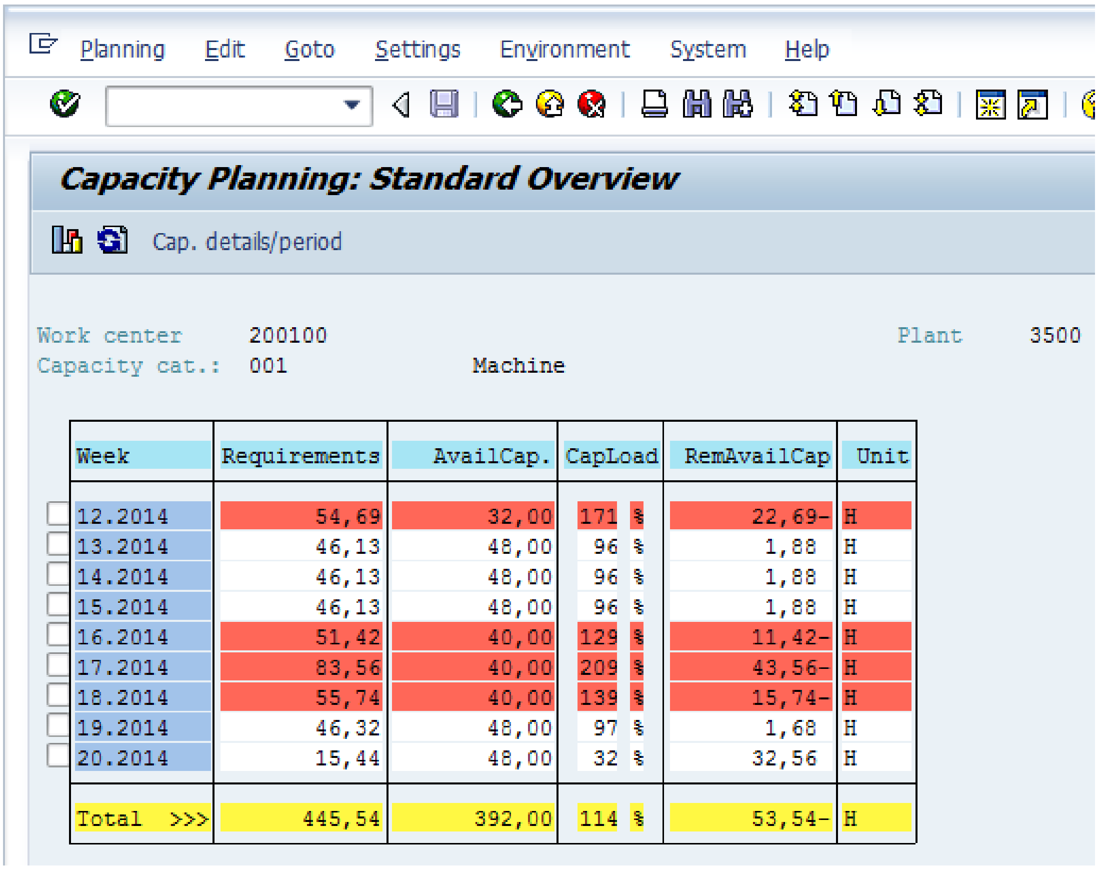
The system that XYZ ended up employing is based on the ERP system's capacity planning tool, which collects current production order status and future planned order information for every open production order scheduled on the applicable machine - these planned orders have already been assigned and scheduled to a machine in the initial phases of planning. Previous inquiry about integrating SAP capacity planning to XYZ's planning system was dismissed by three representatives of XYZ's holding company due to the complex nature of the capacity planning function in SAP.

The author continued to inquire to XYZ management and the same personnel at the holding company, specifically demanding a capacity configuration machine scheduling tool, abandoning the infinite loading (unlimited machine loading logic) and adopting a finite (limited machine loading logic). After all, if we want to improve our planning we must accurately reflect our true machine capacity and in turn, our confirmations to our customers.

After many discussions and pushing for a solution to our problem, the efforts paid out after XYZ management found a solution with the holding company's IT department and incorporated SAP capacity planning, creating a more sophisticated machine scheduling with a more automatic nature due to the linkage within the ERP system.

The capacity tool in SAP is easier to maintain as the information regarding the sales order delivery dates and production order status is already maintained. This eliminates most of the manual upkeep of the machine schedule. The additional benefit to using the capacity planning in SAP is that the previous production time data must be updated to more accurately reflect actual production times and in turn, longer term capacity levels. With time, this system should improve and the capacity information better reflect shop conditions. Since XYZ has only just over a year of experience with the new ERP system after retiring the more paper-based system previously used, it is likely that there are improvements that can yet be realized.

FIGURE 14. Capacity planning tool in SAP



Week	Requirements	AvailCap.	CapLoad	RemAvailCap	Unit
12.2014	54,69	32,00	171 %	22,69-	H
13.2014	46,13	48,00	96 %	1,88	H
14.2014	46,13	48,00	96 %	1,88	H
15.2014	46,13	48,00	96 %	1,88	H
16.2014	51,42	40,00	129 %	11,42-	H
17.2014	83,56	40,00	209 %	43,56-	H
18.2014	55,74	40,00	139 %	15,74-	H
19.2014	46,32	48,00	97 %	1,68	H
20.2014	15,44	48,00	32 %	32,56	H
Total >>>	445,54	392,00	114 %	53,54-	H

The screen shot illustrates a machine's capacity per week based on the scheduling data in SAP. By adjusting the production order, the data in the capacity module changes accordingly by moving the gearing schedule and then calculating the amount of gearing hours in each week. The weeks highlighted in red depict a scheduling of over 100%. When reviewing machine schedules and noting consecutive weeks overscheduled due to delays, one can adjust the start dates of orders as necessary. This requires referencing the MPS and contacting the applicable foreman or customer as needed.

The capacity tool allows the personnel at XYZ to see a five month planning window, essentially showing all orders that may have been confirmed six or more months in advance. This enables XYZ to recognize and work around the scheduling. Previously this ability did not exist and occasionally some orders were forgotten about until material arrived or the customer contacted XYZ.

A drawback to SAP capacity planning is that it lacks the easy visual aspect the manually created machine schedules illustrated in the previous section. This challenge has been addressed by requiring the gearing manager to create a generic machine schedule with order sequencing for each machine, but without the time element. Previously this was completed at a more basic level, so the enhancements allow a more transparent representation that is easy to use and combine with the MPS and SAP capacity planning tool. All in all, consulting the gearing manager, who schedules the machines and sequences the orders while the planner ensures that the schedule matches the MPS requirements, has ultimately improved the overall planning situation.

Summarizing the path that XYZ traveled to optimize its capacity planning, the company first opted for an approach in which personnel manually analyzes previous order history and current demand, assigning every part a specific machine and grouping similar parts when possible. Assigning every part a specific machine allowed XYZ's personnel to visually see the capacity levels five months out– essentially most open orders – where previously the estimate for available capacity was a best guess. The idea to assign every part a machine was born after creating a visual Gantt chart, plotting out each order to a machine and incorporating the time element into planning. It enabled a more accurate view of upcoming orders and allowed the planner to recognize the effects of delays, and reschedule orders in a more proactive fashion. However, this method proved to be too laborious, but it made the organization aware of what it needs to plan capacity efficiently. Consequently, the planning tool of SAP was discovered and employed together with selected more manual process steps to achieve a working solution for capacity planning.

5 CONCLUSIONS

As we have reviewed, manufacturing organizations comprise complex systems to combine resources in order to deliver goods to their customers. There can be many ways to coordinate these resources developed differently between organizations and individuals within the systems. The coordination of these resources is an interesting subject and can have ultimate implications to a firm's success or failure.

This study has examined the progress a Swiss manufacturer has achieved in attaining a more formalized planning system in order to improve the coordination of its production. Through the study to improve XYZ's planning system we have reviewed a basic approach and concepts of production planning, Slack et al. (2010), Guinery and MacCarthy (2005) and Herrmann (2006), examined Viera et al. (2003) framework for rescheduling, borrowed McKay and Buzacott (2000) 7-step routine; and realized the ever-present reality of production systems reliance on the human element of decision-making with the help of (McKay and Wiers, 2004).

Initially, the firm lacked a cohesive way of coordinating resources. Often schedules and time frames were arbitrary in nature, changing daily at times. As a result planning was very reactive, often jumping from one issue to the next. Originally the planning window for production was four weeks, but due to reactive nature of production and planning the company was largely only able to represent its current production situation. Many times orders were approved based on a mechanical twelve week lead time. It was no surprise that orders were often late and under-delivered.

Central to this research was:

How could the production planning and coordination at XYZ be improved?

In order to answer the central question, key findings were:

1. A basic planning system to improve coordination was established
2. a production profile was created
3. three perspectives manifested through tools to improve the planning system

5.1 Key findings – a basic planning system to improve coordination was established

Considering the key findings above, XYZ now has a basic planning system as a foundation for the firm. Organizational, communicational and interactive perspectives have been considered and built into the solutions presented. Additionally, tools to formalize the production planning system have been created and help to realize the gap between management objectives and real-time operational challenges.

5.1.1 A production profile was created

After setting the background for planning an overall production profile was created, with the help of McKay and Wiers (2004) production profile survey, in order to get a basis for understanding where the production system was currently at. The profile was analyzed in terms of:

- Information
- Predictability
- Recovery Options and Flexibility
- Goals, Objectives and Constraints
- Control Structure and Environmental Factors

In accordance with McKay and Wiers' interpretation of our profile, we found that we have a difficult job to fix the bad situation we had. Planning and scheduling can work, but no tight production sequencing is possible. Although we had a bad situation, it was normal for most manufacturing systems.

After finding the lack of information and a coordinated way of assembling information, an understanding of the importance of information and the planning process related to information exchange and communication links needed to be developed.

In addition, the predictability of the production situation was not great. Deviations to plans were normal and allotted schedule times to production steps were not kept. As a result personnel were not sure which scheduled step would be kept and which exceeded. There were minimal recovery options with a low level of flexibility, adding more difficulty to the profile.

With a lack of consistent goals, objectives and control structure, one could not be surprised of the sometimes chaotic, reactive nature of production. With official, unofficial and interchanging goals stated by management at times, a clear system with consistent routines to planning seemed necessary. Also, with additional ad hoc dispatching sometimes deviating to plan it became evident that decisions could not be made independently, but must involve others and multiple systems. This brings us to the next finding of considering the three perspectives to planning.

5.1.2 Three perspectives manifested through tools to improve planning

With the help of Herrmann (2010) we were able to analyze the planning system based on the organizational, decision-making and problem-solving perspectives within a manufacturing system.

Organizational perspective – the MPS

With initial personal observations and the production profile indicating a lack of an organized method of combining resources, it was clear that individual and organization perspectives needed to be analyzed. While it is obvious that each individual had a clear responsibility to their job, the interaction – organizational perspective – was not given due credit. With a complexity of resources in a manufacturing system the organizational interaction and communication are a basis for a healthy system.

The MPS is a manifestation of the consideration of this perspective. By its very nature it involves assembling diverse information through communication and consulting multiple systems. This has been a positive step for XYZ to realize this important aspect and its impact on the system.

After an understanding of that aspect, through continuous discussions with management and employees, a tool was needed to assemble information in an effective way to accurately report production information and facilitate collaboration.

The MPS serves as a tool to realize this important communication and coordination aspect. It assembles information from all perspectives, from custom demand and supply requirements, to actual procurement and production steps and its timing in order to meet supply with demand, delivering on time. It is a formal statement to all parties involved. As we can see, along with Slack et al. (2010) and Vieira (2006), the MPS is the most important tool for a manufacturing firm.

The MPS has improved the transparency of status data, communication between departments and coordination of resources; ultimately contributing to the overall improvement of the planning system.

Decision-making perspective – the 7-step routine

With the reactive and sometimes chaotic production situation, the decision-making perspective needed further examination. Referring to Wright (1984) priority and capacity problems that manufacturing firms commonly face – what to produce, when and how much are relevant points to consider when scheduling production.

We are reminded by Slack et al. (2010) and Vieira (2006) that the MPS is the most important tool for a manufacturer. As it is the planner's responsibility to create and update the MPS, this is where the most weight should be placed on configuring what, when and how to schedule orders to produce. At the same time being aware that production seldom goes as planned, it is equally important to be current with production, following the Vieira et al. (2003) rescheduling framework . However, this involves a continuous or regular method to assess, recognize and relax production constraints.

In order to consider this perspective into XYZ planning, the McKay and Buzacott (2000) seven-step routine was adopted. A consistent and formalized method to production scheduling and control is necessary to minimize the risk of fatigue or forgetting to consider unintended consequences of a decision. Where previously, planning lacked the proper tool to even notice future impacts for example on a machine re-sequencing, now armed with an MPS, machine sequencing and capacity configuration tool and a specific controlling routine, planning has a structure in place to update, adjust and reconfirm current and impacted orders. This has helped to bring planning more forward-looking and structured in order to facilitate good decision-making.

The structured seven-step routine has specifically improved the accuracy of production status data, reduced simple planning mistakes and contributed to the improvement of the overall planning situation.

Problem-solving perspective – machine scheduling and capacity configuration

The previous planning situation didn't involve a machine scheduling perspective and as we know was quite reactive to many developments, be it customer, management or production. Many ad hoc decisions were made based on partial information and with an incomplete current production awareness, much less a four week awareness (previously four-week planning window), planning could not properly cope with planning production with twelve week and greater lead times.

The loading and sequencing of machines had little to no thought from planning in a manufacturing firm that needed to know its capacity in order to develop robust production plans to deliver on-time. Without a formalized method to develop an understanding of its capacity, therefore its production capability, XYZ direly needed a capacity configuration tool.

After developing a manually work intensive version of a capacity configuration tool modeled after a Gantt chart, incorporating the time element into planning, XYZ understood its importance to schedule orders over time. The development of a tool to visually depict how many orders can be produced on each machine was crucial for XYZ to understand that mechanically scheduling and confirming all arriving orders based on a generic twelve week lead time didn't reflect the firm's true production capacity; and in turn created a chaotic environment for planning – where almost every machine was always over-scheduled and unnecessary rescheduling a requirement as a result.

After this realization we searched for a more sophisticated capacity tool to incorporate with SAP in order to properly reflect our true capacity, giving more accurate production plans and confirmations to our customers. After discussing with other managers in the group about capacity planning tools, we had no solutions for XYZ. Finally, after many discussions with XYZ management, we pressed our holding company to integrate capacity planning directly within our new ERP system.

As a result we currently have a mixed solution where, based on the initial work-intensive Gantt chart, a scaled down version is used only as a sequencing tool, while the SAP capacity configuration more accurately calculates the actual machine capacities from the sequencing provided by the scaled down sequencing tool.

The mixed-solution to capacity configuration has helped to bring relevance to the importance of machine sequencing and reflecting more accurate machine schedules, developing an understanding of how important machine scheduling and capacity configuration is for a manufacturing firm. As gearing is the most important and consistently constrained department, this has been a crucial revelation to the firm and has had a positive impact to improving the planning system.

In doing so, we have realized there needs to be further work on data integrity within the article and production planning data to more accurately reflect production times. In addition, we have recognized that additional wait time for all articles have to be calculated and incorporated into the data to better reflect the production situation. This paper doesn't discuss these issues but it is deemed appropriate topics for further study.

In sum, the three perspectives considered have had an impact on the firm's overall planning system, formalizing it through developing processes and tools and sparked a curiosity to solving the firm's machine scheduling problem, leading to further inquiry in calculating the aggregate capacity of the firm. Aggregate capacity is another topic not discussed in this paper but deemed appropriate for further study.

5.1.3 Topics for further study

Over the course of conducting this research topics for further study have surfaced. Issues such as:

1. ERP data integrity
    a. Article routing accuracy
    b. Including wait time into routings
    c. Article costing calculations (not related to topics in this paper, but firm relevant)
2. Aggregate capacity
    a. Optimized resource configuration for current articles
        - Article cataloged per demand, historical production, machine and article characteristics
        - Optimal machine to personnel ratio configuration
3. Supply chain integration (80+% customers in group / 60% suppliers in group)
    a. Long-term customer forecasts
    b. Planning integration
4. Obtaining a sophisticated production planning software integrating concepts of this paper

5. Quantitative analysis of the manufacturing firm after a history of stable production

With basics in place the firm could proceed further into updating ERP data to maintain data integrity. Currently there are data discrepancies in article routing production times and not reflecting important waiting time realities of the production situation. This is having an impact on capacity configuration and cost controlling and unnecessary probing from management that is reading inaccurate reporting from the SAP data. Crucial is obtaining the most accurate data for capacity configuration, as the more accurate the data is the more accurate the MPS and machine scheduling can reflect the actual production situation. In turn, this would have a great impact on Key Performance Indicators (KPIs) that we suppliers are reviewed on.

After updating crucial production data in the SAP, it is important to analyze previous production history to configure the firm's aggregate capacity over the one year time horizon. By establishing aggregate capacity awareness, the firm can optimally plan the order mix of longer term contracts to small varying orders. Equally related would be a cataloging of all articles base on order and production history, along with machine and part characteristics, in order to properly find the right resource mix for the demand mix. The author's opinion is that XYZ could find a more sophisticated planning software to analyze this and finding optimal machine sequencing using sophisticated mathematics. But this is an optimization question and therefore should be deferred until XYZ has production basics underway and a bit of history of stable production.

Also, for the future after a stabilized situation the firm could employ quantitative strategies to further address optimization issues, taking the next step towards a world-class manufacturer Before getting too much into quantitative optimization issues, due to the nature of the small firm's multi-tasking in many roles it is the author's opinion to run with a basic system for at least one year to drive the basic system home before adding yet more changes to an already unstable manufacturing system.

A more suitable theme, yet complicated for small firm, would be supply chain integration. A large effort has been underway to further integrate the planning up and downstream of XYZ. With one key customer and one key supplier consisting of 60+% of total sales and purchases, the supply chain could benefit from focused integration. Although not addressed in this paper, a great challenge for XYZ planning is that our largest key customer doesn't provide firm demand forecasts and as a result often employs a very reactive strategy of short lead time orders of smaller order types, creating a production problem for XYZ, not being able to deliver on time.

In addition, because of the great percentage of our total portfolio going to one key customer, decisions are weighted in the interest of the customer, sometimes pushing other customer orders in delay and ultimately adding to a reactive production problem.

The author's opinion is that further integration is the only method to solve this problem. While now XYZ exhibits a basic planning system previously absent and contributing to the reactive production problem, the large customer's actions overwhelm any attempts at a world-class manufacturing system. It is thus equally important to direct sufficient efforts to integrate planning systems and demand a longer term forecast is followed.

5.2 Reliability and validity

Despite all intentions of this research to be objective and complete in solving the improvement of the planning system at XYZ there are always limitations. One simply cannot cover all things necessary to completely analyze and present a solution including all factors due attention to this problem. Many variables are at play within the manufacturing organization. Some factors technical and mechanical related production knowledge, market and supply chain related were not given credit due to limitations of time and inability to look so far holistically.

Other subjective factors are at play with qualitative research involving the researcher’s personal opinions, being involved directly in the research, the nature of the informal methods to the research alongside work and the possibility for the author’s unintentional dismissal of an otherwise crucial aspect.

In case of any additional unintentional discredit, oversight or misunderstandings to the information collected and presented throughout this research are solely the author’s mistake. Any and all information and results presented are only intended to present the best solution to improving the planning system at XYZ.

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APPENDICES

Appendix 1. Production profile survey

TABLE 1. McKay and Wiers, “Supplement for chapter one – production control profile,” *Practical Production Control* (2004)

1	Unusual or unexpected situations around the plant are consciously looked for and provides early warning signs for potential problems.	*1*	*2*	**3**	*4*	*5*	*6*	*7*
		Never						**Always**
2	Unusual or unexpected feedback from fellow workers is consciously looked for and provides early warning signs for potential problems.	*1*	*2*	**3**	*4*	*5*	*6*	*7*
		Never						**Always**
3	Unexpected products are made - before they were expected to be made or by mistake.	*1*	*2*	*3*	**4**	*5*	*6*	*7*
		Never						**Always**
4	Unexpected quantities of a product is made – either too much or too little.	*1*	*2*	*3*	*4*	**5**	*6*	*7*
		Never						**Always**
5	Unexpected resources (tooling, material, fixtures, machines, people) are used – the wrong one is used.	*1*	**2**	*3*	*4*	*5*	*6*	*7*
		Never						**Always**
6	Unexpected quantities (tooling, material, fixtures, machines, people) are used – too much or too little.	*1*	*2*	*3*	**4**	*5*	*6*	*7*
		Never						**Always**
7	Machine operators pick the next job to do from a queue of work in front of the machine or cell.	*1*	*2*	**3**	*4*	*5*	*6*	*7*
		Never						**Always**
8	Key material that is damaged or misused cannot be easily obtained and replenished from the vendor (or upstream process).	*1*	*2*	*3*	*4*	*5*	**6**	*7*
		Never						**Always**
9	Common material is used in multiple products, usage in one can affect the production of others.	*1*	**2**	*3*	*4*	*5*	*6*	*7*
		None						**All**
10	Stock or inventory counts for required parts or	*1*	*2*	*3*	**4**	*5*	*6*	*7*

	subcomponents are validated – parts were sought and not immediately found.	**Never**						**Always**
11	Stock or inventory counts are found to be significantly wrong – too high or too low.	1	2	3	**4**	5	6	7
		Never						**Always**
12	Parts thought to exist are not found and a special production run is made to replenish the stock.	1	**2**	3	4	5	6	7
		Never						**Always**
13	When a material or part shortage occurs, significant portions of the work force or plant are left idle.	1	**2**	3	4	5	6	7
		Never						**Always**
14	The time to setup a part (machine, line, or cell) is not predictable and cannot be relied upon.	1	2	3	4	5	6	**7**
		Never						**Always**
15	The time to qualify a part is not predictable and cannot be relied upon.	1	2	3	4	**5**	6	7
		Never						**Always**
16	The time to run a part (or batch) is not predictable and cannot be relied upon.	1	2	3	4	**5**	6	7
		Never						**Always**
17	The various tools and test mechanisms are not available or not ready when the machine operator needs them.	1	2	3	4	**5**	6	7
		Never						**Always**
18	Supporting personnel are not available or not ready when the machine operator needs them.	1	2	**3**	**4**	5	6	7
		Never						**Always**
19	The workforce has people or crews that need to be watched and special planning done for – not everyone is trained to the same level or is at the same level of competency.	1	2	3	4	5	6	**7**
		Never						**Always**
20	When something goes wrong on one line or machine, the problem can affect other machines or resources.	1	2	3	4	**5**	6	7
		Never						**Always**
21	When something goes wrong on one line or machine, the workers accidentally amplify the damage through their recovery actions.	1	2	3	**4**	5	6	7
		Never						**Always**
22	A large part of the start of day (shift) or morning	1	2	3	**4**	5	6	7

	routine concentrates on getting information about the current status of the factory floor – machines, people, material.	**Never**						**Always**
23	At the start of day (shift) or morning, the workforce is basically on pause until the morning's decisions are made – they just do not come in through the door, go to their workstations and continue with what was on the machine.	*1*	**2**	*3*	*4*	*5*	*6*	*7*
		Never						**Always**
24	A large part of what was planned yesterday morning for the day did not happen as expected and what we were planning for today is dramatically different than what we expected yesterday morning.	*1*	*2*	*3*	**4**	*5*	*6*	*7*
		Never						**Always**
25	Work – machine combinations are very sophisticated and it is possible to easily overlook some constraints so that infeasible schedules are created – it is not possible to build the part on the machine specified.	*1*	*2*	*3*	**4**	*5*	*6*	*7*
		Never						**Always**
26	Setup work is started in anticipation of material or parts arriving – not yet in hand.	*1*	*2*	*3*	**4**	*5*	*6*	*7*
		Never						**Always**
27	Schedules and plans (or executed work sequences) are criticized for leaving people or resources idle, or having too much overtime.	*1*	*2*	*3*	**4**	*5*	*6*	*7*
		Never						**Always**
28	Schedules and plans (or executed work sequences) are criticized for having too much or too little raw, in process, or finished inventory.	*1*	**2**	*3*	*4*	*5*	*6*	*7*
		Never						**Always**
29	Schedules and plans use secondary information often not found in the materials master or bill of material or routing file.	*1*	**2**	*3*	*4*	*5*	*6*	*7*
		Never						**Always**
30	Key data about the current status is obtained through person-to-person contact (phone or email or fax.	*1*	*2*	*3*	*4*	*5*	**6**	*7*
		Never						**Always**
31	Data is not taken for granted and key information is checked or validated.	*1*	*2*	*3*	*4*	*5*	**6**	*7*
		Never						**Always**
32	Through an informal network, data is sought from	*1*	**2**	*3*	*4*	*5*	*6*	*7*

	vendors and customers about key events or situations may affect production requirements and options.	**Never** **Always**
33	Objectives and goals vary by the day, week, month.	*1* *2* *3* *4* *5* **6** *7* **Never** **Always**
34	Objectives are a mix of official and unofficial statements.	*1* *2* *3* *4* *5* **6** *7* **Never** **Always**
35	Number One priorities make up at least 20-50% of production.	*1* *2* *3* *4* **5** *6* *7* **Never** **Always**
36	Constraints change – what options exist and what is allowed.	*1* *2* *3* **4** *5* *6* *7* **Never** **Daily**
37	Management and Supervision change or modify the plan without consultation or without negotiation or without discussion.	*1* *2* *3* *4* **5** *6* *7* **Never** **Always**
38	Time does not exist for determining the best decision or for examining several options and understanding the impacts.	*1* *2* *3* *4* *5* **6** *7* **Never** **Always**
39	Numbers and estimates for processing times, setups and expected results are optimistic.	*1* *2* *3* *4* *5* **6** 7 **Never** **Always**