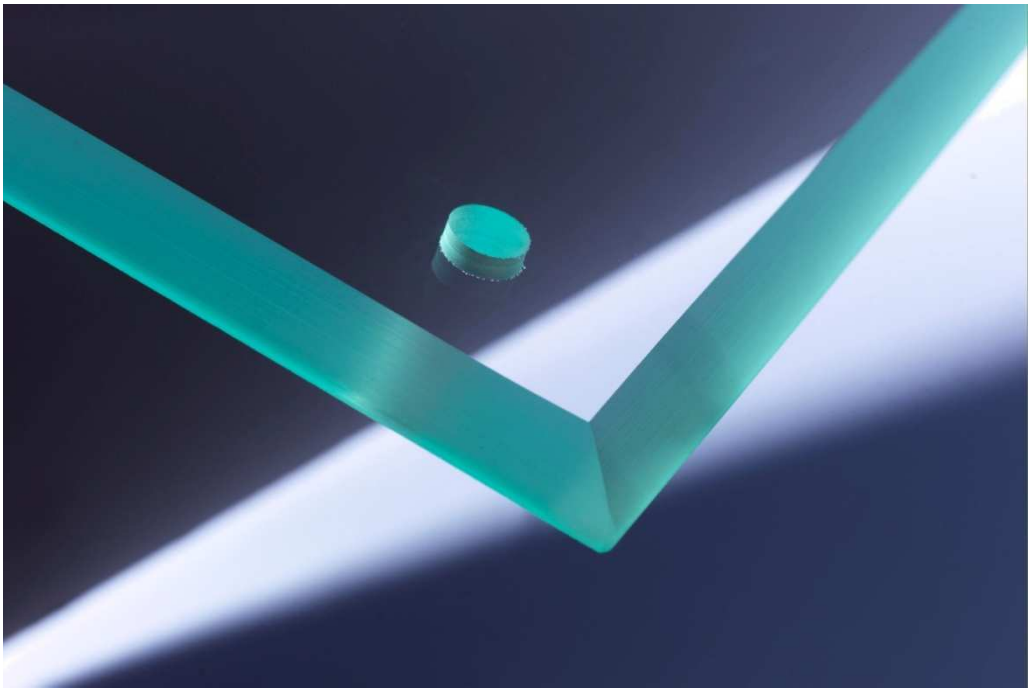
Structuring the production planning

at

Schott Industrial Glass Ltd.



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University of Groningen

SCHOTT
glass made of ideas

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Schott Industrial Glass Ltd.

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Management Summary

SIG is a flat glass manufacturer located in the Northeast of Great Britain and processes glass in five production steps on customer specification. Most of the orders are processed in a flow shop type environment. Products include hob tops, oven doors and control panels. In-between the five production steps (Cutting, Grinding, Drilling, Printing and Toughening) large amounts of work in progress (WIP) are located. This causes long lead-times, a lack of overview and an uncontrollable planning environment.

The reason for this research was to improve the production planning at Schott Industrial Glass. As this was a very broad objective, a narrower goal needed to be formulated. After several weeks of analyzing the company, its processes and problems, it became apparent that the production planning lacked structure. The uncontrolled levels of WIP, the unrestricted release of orders onto the shop floor and the impossibility to establish accurate lead-times led to the following goal:

Analyse, evaluate, and redesign if necessary, SIG's production planning and shop floor control systems.

As SIG is one of several flat glass companies controlled by Schott, the project was pulled to a higher level: production planning had to be investigated on the business unit level. The focus of the primary project was on SIG though.

In order to measure if the goal has been achieved, a set of objectives and attributes has been formulated (Table 1).

SIG Objectives	SIG Attributes
Reduce total factory WIP with 50%	Pull instead of push production
Reduce average production lead-time with 4 days	Decrease departmental boundaries.
Maintain current delivery adherence (95%)	Increase decentralized planning decisions
	Stabilise capacity usage (reduce need for overtime)

Table 1 Objectives and attributes

In order to reach this goal, a study of the available theoretical literature on production planning has been performed. Several theoretical concepts were found that could help to structure the production planning at SIG. A selection procedure led to the shop floor control system: POLCA and the production planning system: Workload Control (WLC). These theoretical concepts were then adapted to the characteristics of SIG. This resulted in a future state, separated into three aggregate levels:

The first aggregate level focuses on establishing the necessary high level linked concepts. An improved control over the flow of orders is proposed, based on the concept of Workload Control and the high level planning concepts as they are required in any production planning system.

The second aggregate level focuses more on the detailed working of WLC. It gives a clear overview of what kind of information is necessary on each planning level and when an order is allowed to flow to the next more detailed planning level. WLC proposes several pools of work that restrict the flow of work onto the shop floor. By adjusting the parameters, more or less orders are allowed onto the shop floor, changing the capacity loading of the different machines. Key in the WLC concept is the separation of authorization between the creation and release of orders. By giving the authority to release orders onto the shop floor only to the production planner, the loading of the shop floor will be stabilised. The logistic manager has more insight into the long term loading of the plant and is able to pull orders forward, postpone orders, or to change the availability of secondary resources such as labour. On each planning level there are different variables that can be adjusted within the boundaries of this function, making the planning structure more controlled and stable.

Once orders reach the shop floor, WLC assumes the orders are processed without problems and delays. Due to the nature of the products processed on the shop floor, the many routings, the variation in cycle times and the unstable availability of machine and labour resources at SIG, the assumption made by WLC becomes invalid. A different type of shop floor control mechanism is necessary to pull products through the factory.

This brings us to the last aggregate zoom. With the help of a type of Kanban system called POLCA, machines are restricted from producing orders if the next process step already has too much work waiting . Work is pulled through the factory based on need, only restricted by the availability of the different resources. In a POLCA controlled shop floor, work flows from A to B to C, while 'POLCA cards' flow only between cells A-B or B-C. If an upstream machine (e.g. C) is not processing orders due to breakdown or a slower cycle time, cards will not be returned to the previous cell. This automatically stops the previous machine(s) from building more WIP for a cell that cannot process the orders. The supplying machine can then either make work for another cell or be switched off. This process limits the build-up of WIP in the factory, will stabilize lead-time and improve visual management.

POLCA cells have been created based on lay-out and productivity (if one machine in a cell does not run, the entire cell is stopped). The loops covering the various cells are populated with a number of cards, based on the intensity of the routing. A detailed description has been given on how to create the necessary 'loops' between the various machines and how to set the number of cards in the loops.

It is proposed that the primary focus of the various improvement steps is on the implementation of POLCA. Once POLCA is accepted by the employees on the shop floor and the WIP levels are under control, the focus should shift to the introduction of WLC. Limiting and structuring the flow of production orders to the shop floor will further stabilize the production process. If both systems are working satisfactory, more mathematical systems can be introduced to further optimize the capacity utilization of the shop floor.

Once the future state had been defined, the first two of three aggregate levels were adapted to create a gap analysis template. This analysis was used to identify the functional requirements of the different flat glass companies. The analysis revealed that several of the other factories require parts of the solution drafted for SIG. Due to time restrictions this has not been investigated further.

This research finished with an overview of the current state of implementation, several of the associated problems and future steps required to improve the planning procedures. After several weeks of implementation it appears that POLCA and WLC are still the right way forward and have already reduced WIP with an average of 10%. Achieving the remaining 40% WIP reduction is possible once the remaining implementation steps are set. This will require full management support, a lot of effort and should not be taken lightly though.

It can be concluded that the goal of this research has been achieved. Problems have been found in the production planning and shop floor control systems. A redesign has been proposed and implemented. And although the initial results are not massive, the planning structure provided and the continued focus on the shop floor have resulted in improvements and will do so in the future.

Introduction

After five months of intensive work at Schott Industrial Glass (SIG), I have concluded the last part of my study Technology Management. In this period I investigated the production planning structure at SIG.

Working at SIG has been very interesting. Not only did I do what any student dreams of, I was able to combine this with a fantastic period abroad. Being able to actually implement a relatively new production and shop floor control system has given me a lot of insights into the functioning of a ‘real’ company. Moving away from study books and testing a theory in practice is very rewarding. To experience working and living in a different culture is also very exciting. Not only do you have to adapt theoretical work to a real live situation, cultural differences make for interesting situations.

I worked with great pleasure at SIG and I want to thank all my future colleagues for their time and effort. Each and everybody contributed to my research in their own way. I especially want to thank my primary supervisor Peter Dekker for the insightful discussions we had and for sharing his experience in the field of logistics management. Keith Sowden, my secondary supervisor, helped me understand the ins and outs of SIG and has supported me during many discussions and the implementation of my proposal. Thank you. Most of this work could not have been done without the support of Viv Whitaker, who gave me a home away from home, many thanks.

With regard to my educators I want to thank Jannes Slomp for his support and the critical notes that helped me focus and cross the dots on my thesis. His personal touch and patience while working through the endless stream of ‘final drafts’ has greatly helped me. Thanks also to J. Riezebos, my secondary supervisor and his insights into POLCA.

Ewout J. Verweij

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Some used abbreviations:

KPI	=	Key Performance Indicators
WIP	=	Work in Progress
PPC	=	Production planning and shop floor control (system)
SIG	=	Schott Industrial Glass
WLC	=	Workload Control
POLCA	=	Paired-cell overlapping loops of cards with authorization

1 General introduction

This research focuses on the selection and introduction of a production planning and control system for Schott Industrial Glass Ltd. A short introduction is given to the industrial group (1.1), the company (1.3), its products (1.4) and the main production process (1.5).

1.1 SCHOTT AG

SCHOTT Industrial Glass is part of the SCHOTT AG Company, a multinational technology based group focused on the production of materials, components and systems that can improve the way people live and work. SCHOTT's main markets are household appliances, optics, electronics, pharmaceutical industries, automotive as well as solar energy. SCHOTT has production plants and sales offices located throughout the world. The company can be divided in three main business segments: Precision Materials, Optical Industry and Home Appliances (Figure 1-1).

The SCHOTT concern is part of a foundation and is not privately or publically owned. The headquarters are in Mainz, Germany. The foundation owns 98 companies worldwide including 48 production plants, employing 20.000 people. SCHOTT has an average annual sales volume of two billion Euros.

SCHOTT's core values are: accountability, market-driven innovation, technological expertise, integrity, reliability and entrepreneurship, whilst also focusing on its social and environmental responsibility. The main SCHOTT objective is to contribute to the success of its customers.

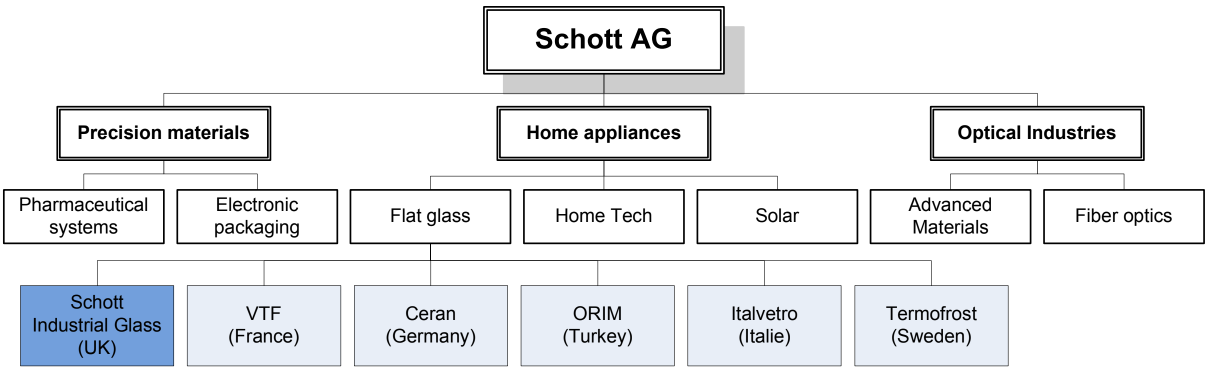


Figure 1-1 The Schott corporate structure

1.2 Home appliances: Flat glass group

The flat glass group is part of the home appliances business segment. The flat glass group consists of 16 production plants situated across the world. Flat glass is used mainly for windows, cooking plates and shop freezer doors, but can also be used for heat intense products like oven-doors, fire places and cooking appliances. The production processes of the different companies are comparable; the process from raw material to end product follows similar steps as described in paragraph 1.5. Although comparable, each production company has its own customers, its own specialties, software systems and production planning and control systems.

1.3 Schott Industrial Glass Ltd.

The research for this master thesis has been done at SCHOTT Industrial Glass (SIG). SIG is located in the north of the United Kingdom, in the village of Newton Aycliffe. The company was founded in 1980 by SCHOTT, has a production plant surface of 17.000m2 and has 180 employees. At SIG, glass between 3 and 12 mm thick can be processed. Most products are flat, but products can also be bent through a heating process. SIG produces for two markets: The UK market takes up 65% of production, the remaining 35% is exported worldwide. The UK market is characterized by high variety and low volume demand. The export market is more all-round: high product variety combined with a demand for low to medium volumes.

1.3.1 Company characteristics

SIG is set up as a large volume factory. The value of the products produced is not high; on average a panel costs less than five GBP. The added value of the product is somewhat higher: The aesthetic value of a glass panel is of some value for the end customer, making the glass panel more 'valuable.' SIG currently has between a 100 and 150 active customers. The 8 biggest customers create 80% of the production volume. The first 12 customers create 80% of the company's net value.

Competition in the United Kingdom is limited to three direct competitors. Worldwide SIG has many competitors, including other SCHOTT flat glass companies.

1.3.2 Recent changes

Almost two years ago the company was on the edge of a complete closure. As part of a last chance, several changes were initiated. A new general manager has been assigned, a Lean Manufacturing program has been initiated and several other projects were started. A new corporate mission statement has also been introduced by the General Manager in 2008:

We have to be able to produce every product out of every niche market on our machines.

Without any batch size restriction

This mission statement will have some impact on the company. If the mission statement can be achieved by sales, SIG will have to handle more customers and orders, of varying batch sizes. The value of the products processed might also go up. A customer will, on average, pay more for fewer products processed.

1.4 Products

SIG produces 2300 different products yearly. These products are grouped in 29 different product groups: oven doors, control panels, glass doors, cooker hoods, etc. Some of the products are depicted in Figure 1-2. From left to right: A detail of a glass panel, a hop top and a warm plate, a glass fireplace and finally some oven doors and an oven control panel.

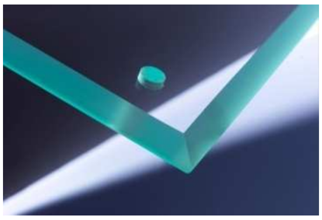



Figure 1-2 Types of products

1.5 Primary production process

The primary production process is depicted in Figure 1-3. Raw material consists of big sheets of glass, so called ‘jumbos’. These jumbos are cut down from three by six meters to the required size. In general, an order can be processed in three ways. The fast line can process a batch of products in a continuous flow within a few hours. The different machines in the fast line are linked with automatic conveyor belts. On average, 10% of all orders are processed on the fast line. The fast line can only process products of a limited size and complexity. The remaining 90% of all orders are processed in a typical flow shop. This 90% can be split up in two groups, the difference being that some products require parts to be assembled to the panels. All products move from one functional department to the next. A short description of the departments is given in Table 1-1. Between all process steps, products are placed in a Work in Progress (WIP) area. The period products remain in this buffer depends on a variety of factors and will be discussed later. After most production steps, the panels are washed and cleaned. This is done to remove rest material and to detect if products are scratched. The components to be attached to the glass panels at assembly are produced by the customer or by an external party. After assembly, the products are packed and shipped.

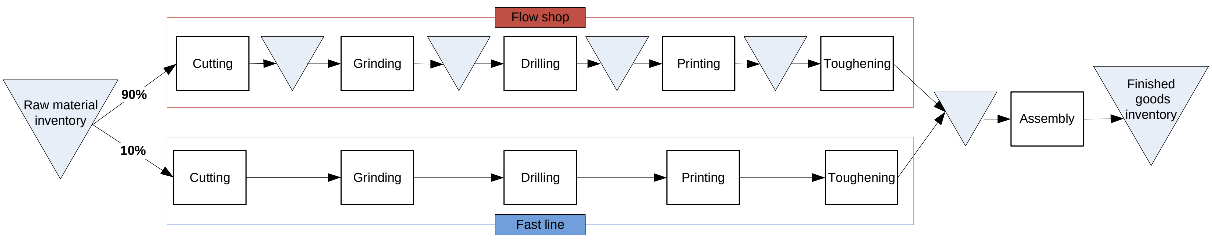


Figure 1-3 Primary Production process

Department	Explanation	Extra input
Cutting	Jumbos are cut to the requested panel size. A panel is the name of the semi-finished glass material processed in the factory.	Cutting program
Grinding	The edges of the cut glass are given a profile, customer dependent. The corners are 'rounded', sharp edges removed if required.	Grinding programs, jigs and templates
Drilling	Most panels are drilled. Hole sizes and location are customer dependent.	Drilling program, drills
Printing	Most panels are printed. Any colour or print is possible. If more than four colours are required, or a print on both sides, a batch of panels will be routed through printing twice.	Screens, printing programs
Toughening	Glass is heated and then cooled fast. This creates surface tension making the glass strong and more heat resistant.	Jigs
Assembly	Some orders require materials to be attached to the glass. E.g. gluing components or attaching parts through soldering	Components

Table 1-1 Production steps

At some of the production steps, extra information, jigs, printing screens, programs and materials are required, as can be seen in the third column of Table 1-2. Most added materials or programs are customer specific and are created by the department work preparation.

1.6 Information Technology: SAP

SIG makes use of the Enterprise Resource Planning (ERP) program: SAP. SAP is an advanced manufacturing resource planning (MRP) tool. ERP combines MRP functionalities like material requirement, availability of machine and human capacity and integrates these with financial information.

SAP is a modular software program, which is able to control and integrate various production information and control systems. SIG uses SAP for controlling and storing the following information flows:

- Order information
- Bill of material
- Routing information
- Production rates
- Sales and customer information
- Resource capacity (personnel / machines)
- Pre- and post cost calculations

A large SAP upgrade is planned for January 2010. This upgrade will replace the current SAP R/3 system with SAP Progress. Schott flat glass companies that currently do not have SAP will receive SAP Progress, standardizing the information structure across the Schott Corporation.

A general problem with SAP is that the system does not have a proper capacity planning or finite resource planning tool, making the system impractical for detailed shop floor planning.

1.7 Customer decoupling point

Every product processed at SIG is customized and therefore made-to-order. Changes between two orders of a customer can be subtle, but do require attention. Five types of orders can be identified. Each type of order requires a certain amount of attention and control (Table 1-2). 82% of all orders are reruns and therefore require little attention. The other 18% either require new screens for printing, new jigs for bending or drilling or some adjustments to one of the required computer programs.

Type of order	Explanation	Percentage of orders
Normal Order	An order that has been processed before	82%
Sample	A new order, small batch quantity, examples for the customer	7%
Straight into production	A new order, no previous sample, customer liable for success of production run	3%
First run after sample	The first production run after an order sample	4%
Change to a normal order	An order that has been processed before, with some minor changes	4%

Table 1-2 Types of customer orders

The influence of the customer does not strictly vary with the type of order though. Currently, the customer decoupling point changes with the type of order processed and the forecast provided by the customer. Some customers provide forecasts and reorder certain products on a regular basis (normal orders). For these customers, products can be made-to-stock. Most customers do not provide forecasts or reorder on a regular basis, making the average customer decoupling point before the first production step.

2 Research approach

The why and how of this master thesis will be described in this chapter. First the why: an introduction to how this research was started and how I got involved. This is followed by the how: a problem statement and some methodology to structure the research.

2.1 Problem introduction

SIG has and is going through several transformations in recent years. As any West-European production company, SIG is losing sales to low wage countries like Poland, Turkey and the People's Republic of China. In an attempt to improve the overall effectiveness of the factory, several projects in key areas were initiated. Concern was raised in the logistics department about the seemingly high levels of WIP, the inflexibility of the production planning system and the capacity loading of the machines on a day to day basis. Due to time restrictions and the complexity of the problem, a good overview of the actual instrumental problems could not be formed. Pressure from the general manager and an external SAP/logistics advisor led to the formulation of a master thesis research project.

During the first analyses it became apparent that a second project, initiated at the flat glass business segment level, had several overlapping elements with the originally formulated project. A meeting between the logistics managers of the different flat glass companies became the focal point of a standardization project. One of the main focus points of this standardization project is to standardize the PPC structures of the different Schott flat glass factories. In an attempt to make production orders interchangeable between factories without affecting customer satisfaction, all processes, quality levels and lead-times in the different factories must be standardized. The standardization project led to an adjusted research focus.

2.2 Primary Problem statement

The problem statement can be summarized into the next few points:

- Identify the problems with the current production planning and shop floor control procedures at SIG.
- Identify and select a suitable and sustainable PPC system.
- Provide an improvement trajectory and initiate the first steps if possible.
- Standardise the approach to the evaluation of the PPC system, so it can be used in other factories.

Several boundaries restrict the research:

- Any chosen solution has to be compatible with SAP (R/3 and Progress) when need be.

- The solutions cannot include any physical movement of the machines, in particular the furnaces. Furthermore, a long disruption of production is not acceptable.
- A solution should be practical and not require intensive training or a major disruption to the processes or personnel on the shop floor.
- Money is no issue: if a solution requires a high investment that guarantees to earn its money back, this is no problem.
- The research and the initial implementation steps should be completed in five months.

2.3 Goal

The problem statements led to the following goal:

Analyse, evaluate, and redesign if necessary, SIG' production planning and shop floor control systems.

The secondary goal of this research is to standardize the approach used to analyse and evaluate the PPC system of SIG in such a way that it can be used by the other flat glass companies.

2.4 Research methodology

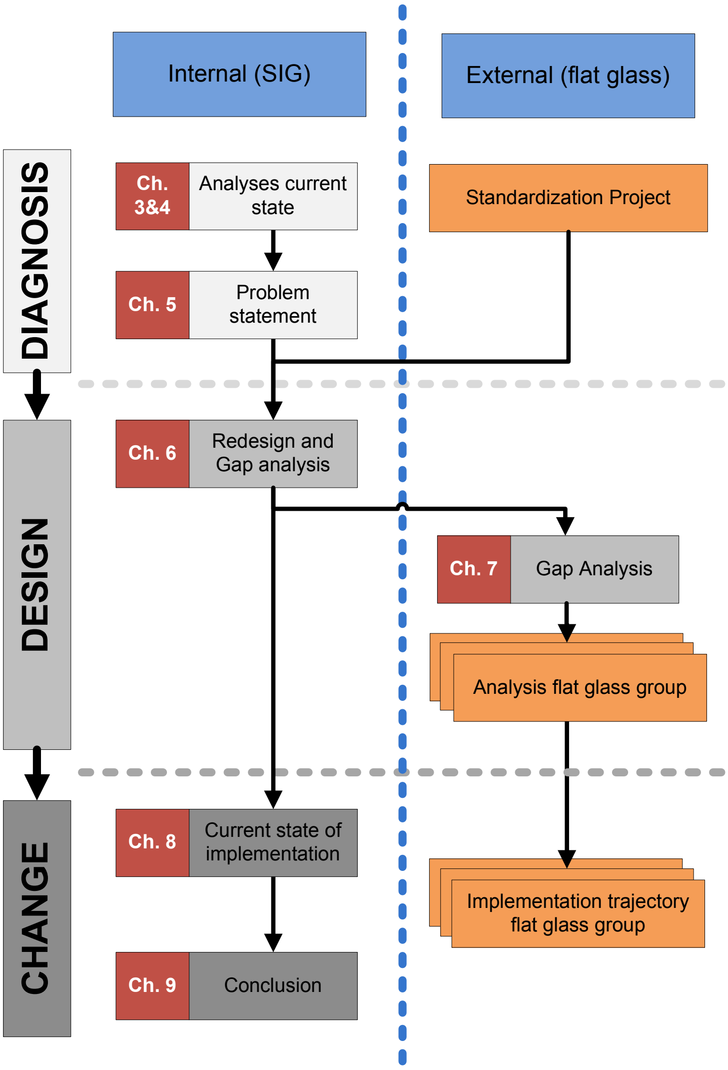
According to Checkland and Holwell (1998), any decent research should consist of three elements: First a framework of ideas (F) in which the knowledge that has been found through research is expressed. This framework is encapsulated in a methodology (M), the second element. This methodology entails all methods, tools and techniques needed to translate the 'area of concern' to the framework of ideas. The area of concern (A) is the third element and this can be seen as the real problem of interest. The order in which these elements are defined is not strict (Verweij, 2008).

2.4.1 Methodology (M)

The methodology used is adapted from the course 'Ontwerpen van Bedrijfskundige Systemen' as proposed by W. Prins (Sheets OBS 2007). This methodology includes a framework, and will be described in the following subparagraph.

2.4.2 Framework (F)

Diagnosis, design and change are the three main phases of this research. Each phase consists of several sub phases that correspond to the chapters in this thesis. A graphic overview is given in Figure 2-1. The phases can be found vertically on the left, the chapter numbers are coloured red. Horizontally on the top level, two research areas have been defined: 1) Internally: SIG and 2) Externally: the flat glass group. These two areas concern the focus of my research and the interaction with the different flat glass companies. The first phase (Diagnosis) consists of analyzing the company characteristics, the current production planning and shop floor control system and determining the instrumental problems. This is then followed by a problem statement which includes a description of the problem and a proposal for a redesigning.



The second phase (Design) begins with a review of the available literature, leading to a redesigning or 'future state' of SIG' PPC system. SIG' current PPC system will be compared to PPC systems found in the literature. The functional gaps between the current state and the future state are input for the redesigning and implementation of a new PPC system at SIG.

The creation of a future state and the gap analyses will be done for SIG first. The gap analysis will then be standardized and sent to the different flat glass companies. The results of this gap analysis are input for the management of the flat glass group and will not be discussed further.

Figure 2-1 Research model

In the third phase (change) a structured implementation trajectory will be proposed for SIG. Some initial implementation steps will be made and evaluated.

2.4.3 Area of concern (A)

The area of concern will be defined in chapter 5. The focus of this research is on the production planning of SIG and it is expected that problems will be found in this area.

3 Company characteristics

In this chapter the main characteristics of Schott Industrial Glass and in specific the production planning and shop floor control procedures (PPC) will be analyzed. Any solution presented in this thesis will be based on a theoretical model. To be able to fit this solution in with the company, a good understanding of the company characteristics is necessary: adjustments to the literature based solution can be made.

A thorough analysis of the company is necessary. Several attempts to improve the production process have been undertaken in the past years. According to the principles of chaos theory, small changes in a system's state do not inevitably lead to small-scale consequences (Jackson, 2000). A parallel can be made to production processes. The state of a system and the complex behaviour it exhibits could have been caused by seemingly unimportant decisions or behaviour in the system's past. Current behaviour and performance is therefore based on the interaction of events set off in the past. Unravelling the interaction of the elements in the system and identifying current 'routine behaviour', correct or false, requires an understanding of all product-, production- and customer characteristics.

The focus of this research is on production planning and will be covered in chapter 4. Before the different company characteristics are described, it is important to fully grasp the process from customer order to end-product. An introduction to the current PPC processes is given in paragraph 3.1. The rest of this chapter is structured similar to the route an order is processed: starting at the customer, the customer characteristics are discussed in paragraph 3.2. The order itself is discussed secondly: paragraph 3.3 explains the different product characteristics. After an analysis of the production process and its characteristics in paragraph 3.4, several operational characteristics will be given in paragraph 3.5. Three Key Performance Indicators (KPI's) will be discussed in paragraph 3.6, resulting finally in a conclusion (paragraph 3.7) that will compare the KPI's to the operational characteristics.

3.1 Current Production planning and control processes

In Figure 3-1 an overview of the current production planning and control processes is given using the prism method. This method is a way to visualize the flow of materials and information between different units. The prism method gives an overview of the interaction between the following elements: company functions, information flow, physical flow, and the information system (Borgstede, 2005). Moreover, it helps to find the in- and outputs of a production unit. Based on the 'black box' theory (De Leeuw, 2000), a function can be analyzed on different aggregated levels. Knowing exactly what happens inside a black box might not be possible or necessary. Opening and investigating a black box may cause an overflow of information, which can become difficult to comprehend. Problems, the general structure and functionalities of the black box become difficult to see. Looking from a higher aggregated level to a complicated process can help to see the inputs, the outputs and the variables that can be controlled.

In this prism table (Figure 3-1), the thick black boxes can be seen as the different planning functions at SIG. Each of these functions creates an output. An output is always on the same horizontal line (left or right) as the function it originates from. These outputs can be inputs for other functions. Inputs are therefore vertical (bottom up or top down).

The prism overview shows the stages a production order will go through. A customer [1] will place a normal order [2], an EDI order [3] or a rush order [3]. The order planners [4] create manual forecasts (VSF) [6] and input the normal orders into SAP [6]. All orders [3+6] are given the status 'planned order'. These planned orders are input for the weekly capacity planning [8]. Some due date adjustments might be made [9], but most orders will just be accepted and released to the day to day planning [11]. The day to day planning will create a sequenced production plan [12] that is released to the shop floor [17]. The shop floor will process the order, creating the finished goods [13] that will be sent to the customer. The shop floor creates scrap [18], but will mostly return information to the higher planning levels, in the form of several KPI's [14] and the current shop floor status [16].

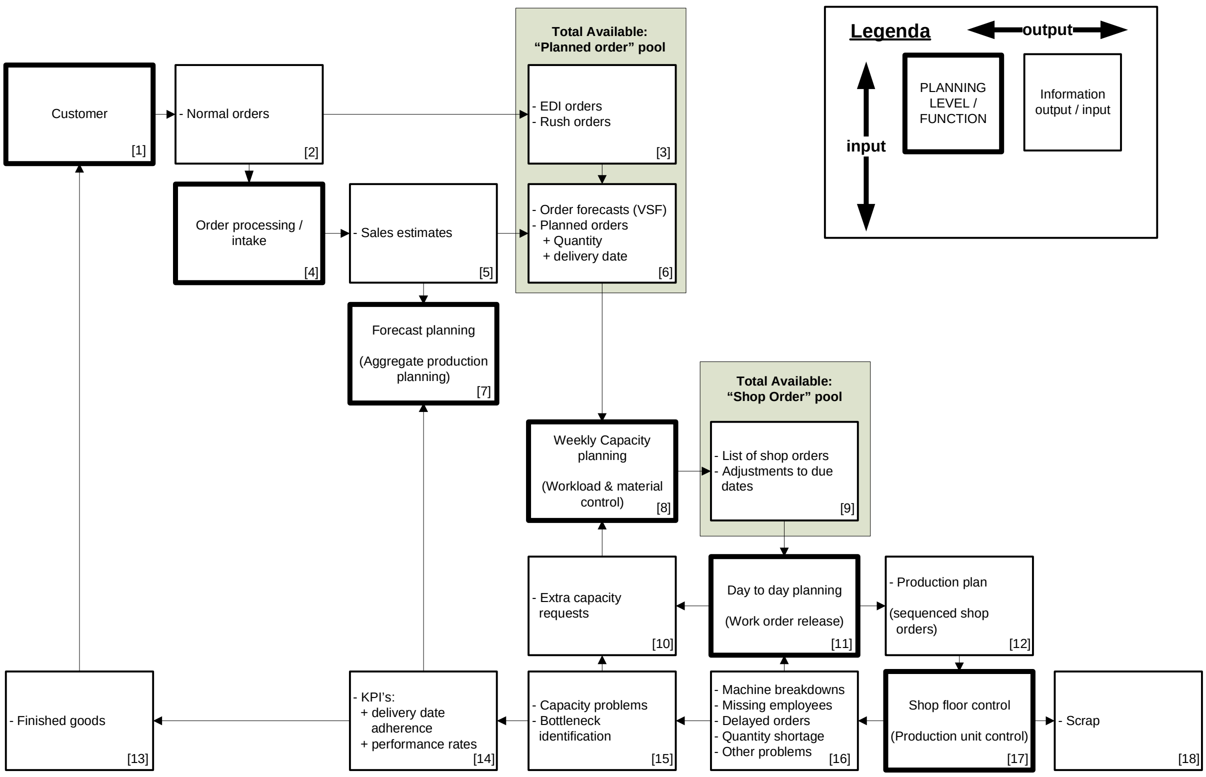


Figure 3-1 Current functioning of SIG

Once per month, the forecast planning is made [7], based on sales estimates [5] and historical sales patterns. This function is not related to other production planning functions. It is depicted in Figure 3-1 because according to Bertrand, Wortmann and Wijngaard (1998) this function should, in some form, be integrated in any production organization. The different planning functions (between brackets in the black lined boxes) will be discussed thoroughly in chapter 4.

3.2 Customer characteristics

Sales trend, batch sizes, shipping rules, forecast predictions, stock rules and other customer behaviour are analysed.

3.2.1 Sales trend

Figure 3-2 gives an overview of the current sales trend. Several of the customers are in the process of outsourcing their parts production and/or assembly to low-wage countries like the Peoples Republic of China, Turkey and the Czech Republic. The second biggest customer will stop buying products in December 2008, causing an 18% loss in processed volume. In an attempt to attract new customers and increase production volume, all incoming order requests are accepted if economically feasible. This includes orders that need to be finished within normal accepted lead-time, causing a lot of disturbance in the planning process.

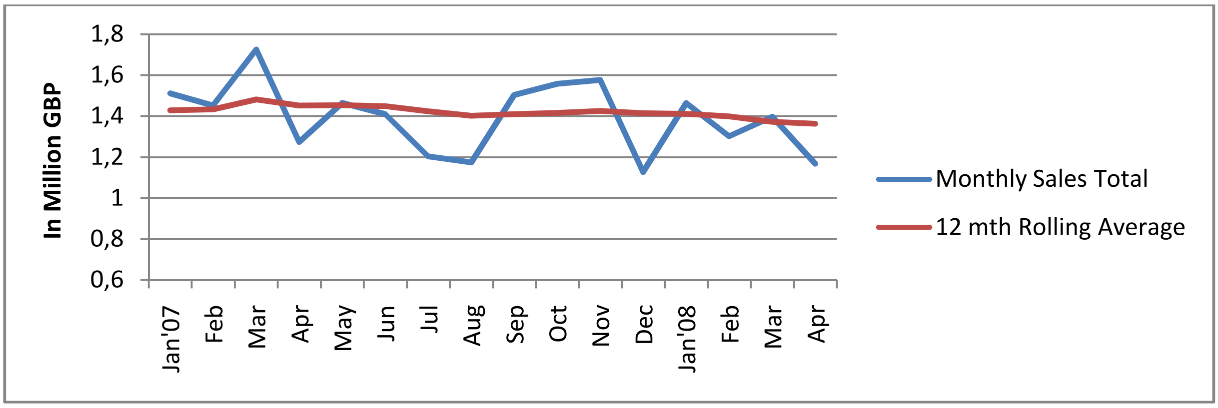


Figure 3-2 Sales history

3.2.2 Batch size

Orders of any batch size are accepted. In general the following quantities are processed (Table 3-1).

Quantity	% of orders
1-72	25%
1-172	50%
1-418	75%
1-4665	100%

Some of the forecasted orders are nested and processed as one batch. This is done only with fast running orders as customer demand is erratic. The average batch size is not large, especially as the shop floor of SIG is set up for large volumes.

Table 3-1 Quantity per order

3.2.3 Customer order behaviour

The common 80/20 'rule' is slightly different for SIG: the top 8 customers make up 80% of the sales volume, representing 71% of the net sales value. The top 12 customers represent 80% of the net value earned, making up 82% of the production volume.

Due to various reasons, customers are not very restricted in ordering their products. Most customers have been allowed to order without due-date restrictions or forecasts. Customer behaviour has been captured in Table 3-3. The columns have been split into several groups. An explanation can be found in Table 3-2.

Group	Explanation
Customer forecast	Only few customers give some forecast. Three customers provide EDI forecast. A small percentage of customers send forecasts per email or fax (manual forecast). SIG creates forecasts for some of its customers and only for products that are bought frequently (VSF). In total, 11 customers give some forecast. Reliability of this forecast is limited; many forecasted orders are withdrawn or adjusted, making forecasts very unreliable.
Firm Customer orders	Firm orders are confirmations of the forecasted orders or new orders that have to be produced as soon as possible. For most of the customers that give manual orders, no forecast can be made. The buying behaviour is too erratic.
Customer call off	Most of the customers that give forecast and are supplied weekly or even daily, use call-off lists. Call-off lists are the detailed requirements of the customer. A customer can for example confirm a quantity of 100 in a certain week, calling off 20 on Monday, 10 on Tuesday, etc.
Customer behaviour	Some agreements are made with customers to restrict their behaviour and to stabilize the production process. A lead-time agreement has been made with most customers. Orders within this minimum lead-time will result in added costs. This also applies to the ordered quantity and the delivery days; any deviation will cost extra money. If possible, orders will be nested (e.g.:10+10=20). Some other rules are in place: Stock agreements are made with customers: if possible any over produced quantity is sent to the customer. With some of the new customers agreements are made regarding obsolete products in stock. If a customer makes a firm order but doesn't call the products off, he will be charged for the products.

Table 3-2 Customer Characteristics

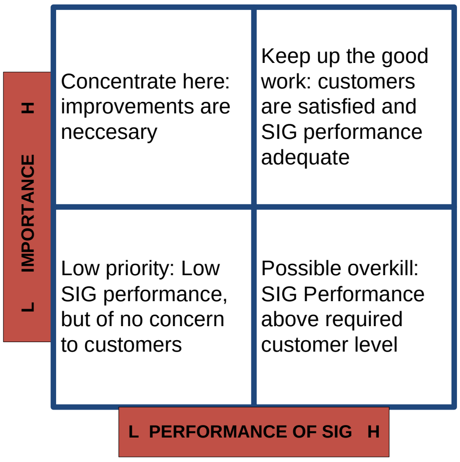
From Table 3-3 it can be concluded that a lot of customers behave stereotypically: unstructured and unpredictable. The effects of this behaviour on planning and production stability can be guessed. The customer can interfere with planning right up to the last moment: last minute quantity or design changes are accepted if still possible. Very troubling is the resulting behaviour: To be able to meet customer demand, orders are started based on expected or forecasted demand and get stranded halfway through the process due to missing details like shapes, prints or hole sizes. An order is then rushed through the rest of the process to meet shipping dates or call-off lists.

Customer Name	Customer Sales		Customer forecast				Firm Customer orders		Customer call off		Customer behaviour							
	% Sales Qty.	% Sales value	EDI Fore-cast	Manual Forecast	VSF	Forecast reliability	EDI Orders	Manual Orders	EDI Call off	Manual Call off	Min. Lead-time in working days	Over produced	Delivery Days	Delivery dates	Min. order quantity	Qty. Nesting	Stock liability	Production dates
Glen Dimplex Cooking Limited	36%	23%	No	Yes	Yes	Changing Reliability	No	Yes	No	Yes	5	No overs	Daily Except Wednesday	Daily	Some	Some	No	Weekly
Rangemaster	7%	16%	No	Yes	Yes	Reliable	No	No	No	Yes	5	No overs	Weekly - Tuesday	Weekly	Some	Some	10 Weeks	Monthly
Electrolux Home Products (oper) Uk	18%	11%	Yes	No	No	Changing Reliability	Yes	No	No	No	10	No overs	Daily Except Wednesday	Daily	Some	Some	Yes	Lot for Lot
Spinflo Ltd	4%	5%	No	Yes	Yes	Unknown	No	Yes	No	Yes	0	Up to 10% over	Fortnightly - Mondyas	Fortnightly	Some	Some	No	4 Weeks
Fulgor Elettrodomestici Spa	3%	4%	No	No	Yes	Unknown	No	Yes	No	No	15 Max	Up to 5% over	Weekly - Tuesdays	Weekly	Some	Some	No	Lot for Lot
Asko Kodinkone	3%	4%	No	No	Yes	Unknown	No	Yes	No	No	15	Up to 10% over	Weekly - Thursdays	Weekly	Some	Some	No	Lot for Lot
H. V. Skan Ltd	0%	4%	No	No	No	Unknown	No	Yes	No	No	15	No overs	Weekly - Tuesday	Weekly	Some	Some	No	Lot for Lot
Electrolux Schwanden Ltd	4%	4%	No	Yes	Yes	Changing Reliability	No	No	No	Yes	10	Up to 10% over	Weekly - Fridays	Weekly	Some	Some	No	Lot for Lot
Amica Wronki Sa	2%	4%	Yes	No	No	Changing Reliability	Yes	No	Yes	No	15	Up to 10% over	Weekly - Thursdays	Weekly	Some	Some	No	Lot for Lot
Whirlpool Sweden Ab	4%	3%	No	Yes	No	Unknown	No	Yes	No	Yes	15	Up to 10% over	Weekly - Thursdays	Weekly	Some	Some	No	4 Weeks
Schott New Zealand Pty. Ltd.	2%	3%	No	No	No	Unknown	No	Yes	No	Yes	15	Up to 10% over	Weekly - Fridays	Weekly	Some	Some	No	Lot for Lot
Indesit Company Uk Limited	0%	3%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Thursday	Fortnightly	Some	Some	No	Monthly
Magnet Ltd	2%	2%	No	No	No	Unknown	No	Yes	No	No	15	No overs	Weekly - Triday	Weekly	No	250	No	4 Weeks
Bitech Engineering	1%	2%	No	No	No	Unknown	No	Yes	No	No	20	Any fired qty	Weekly - Anyday	Weekly	Some	Some	No	Lot for Lot
Defy Appliances (pty) Limited	3%	2%	No	No	Yes	Unknown	No	Yes	No	No	20	Up to 10% over	Weekly - Wednesdays	Weekly	Some	Some	No	Lot for Lot
Levens Cooking & Baking Systems Bv	0%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Weekly - Tuesday	Weekly	Some	Some	No	Lot for Lot
Energy Products Bv	1%	1%	No	No	No	Unknown	No	Yes	No	No	20	No overs	Weekly - Tuesday	Weekly	Some	Some	No	Lot for Lot
Doehler & Gerweck Entwicklungs-und	1%	1%	No	No	No	Unknown	No	Yes	No	No	20 Min	Any fired qty	Weekly - Tuesdays	Weekly	Some	Some	No	Lot for Lot
Suncrest Surrounds Ltd	0%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Weekly - Tuesday	Weekly	Some	Some	No	Weekly
Philips Lighting	0%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Wednesday	Fortnightly	Some	Some	No	Lot for Lot
Neff Gmbh	1%	1%	Yes	No	No	Unknown	Yes	No	Yes	No	15	Up to 10% over	Weekly - Triday	Weekly	Some	Some	10 Weeks	4 Weeks
Electrolux Home Products	1%	1%	No	No	No	Unknown	No	Yes	No	No	15	Unknown	Fortnightly - Frida	Fortnightly	Some	Some	No	Lot for Lot
Intergas Verwarming B.v.	1%	1%	No	No	No	Unknown	No	Yes	No	Yes	15	Up to 10% over	Weekly - Tuesdays	Weekly	Some	Some	No	Lot for Lot
Schott Vtf Sas	0%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Weekly - Tuesdays	Weekly	Some	Some	No	Lot for Lot
Fabriweld Tubular Steel Prod Ltd	0%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Thursday	Fortnightly	Some	Some	No	Weekly
Schott Australia Pty. Ltd.	1%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Monthly - Thursdays	Monthly	Some	Some	No	Lot for Lot
Beha Fabrikker A/s	0%	1%	No	No	No	Unknown	No	Yes	No	No	20 Min	Up to 10% over	Monthly - Thursdays	Monthly	Some	Some	No	Lot for Lot
Panasonic Manufacturing U.k. Ltd	2%	1%	No	Yes	No	Very Reliable	No	No	No	Yes	15	Up to 10% over	Monthly - Usually NDL	Monthly	Some	Some	No	Lot for Lot
Cramer Sr S.r.o.	0%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Weekly - Tuesday	Weekly	Some	Some	No	Lot for Lot
Amalgamated Appliances	0%	1%	No	No	No	Unknown	No	Yes	No	No	20 Min	Unknown	Monthly - Wednesdays	Monthly	Some	Some	No	Weekly
Dekker Zevenhuizen B.v.	0%	1%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Weekly - Tuesdays	Weekly	Some	Some	No	Lot for Lot
Astracast Plc	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Any fired qty	Fortnightly Friday	Fortnightly	Some	Some	No	Lot for Lot
Mfi Financial Services	0%	0%	No	No	No	Reliable	No	Yes	No	No	15	No overs	Fortnightly - Thursday	Fortnightly	Some	Some	24 Weeks	Lot for Lot
Guangdong Whirlpool Elec. Appl. Ltd	0%	0%	No	No	No	Not Reliable	No	Yes	No	No	20 Min	Up to 10% over	Monthly - Mondays	Monthly	Some	Some	No	Lot for Lot
Gaggenau Industries	0%	0%	No	Yes	No	Changing Reliability	No	Yes	No	Yes	60	Up to 10% over	Monthly - Fridays	Monthly	Some	Some	No	Lot for Lot
Crs Electronics Ltd	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Thursday	Fortnightly	Some	Some	No	Lot for Lot
Porter Lancastrian Ltd	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Friday Ev	Fortnightly	Some	Some	No	Lot for Lot
Flamerite Fires Ltd	0%	0%	No	No	No	Unknown	No	Yes	No	No	10	Up to 10% over	Fortnightly - Tuesday	Fortnightly	Some	Some	No	Lot for Lot
Doeco B.v.	0%	0%	No	No	No	Unknown	No	Yes	No	No	20	No overs	Monthly - Tuesdays	Monthly	Some	Some	No	Lot for Lot
Merrychef Limited	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Unknown	Fortnightly - Thursday	Fortnightly	Some	Some	No	Lot for Lot
Ceramaspeed Limited	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Tuesday	Fortnightly	Some	Some	No	Weekly
Moores Furniture Group Limited	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Unknown	Fortnightly - Friday	Fortnightly	Some	Some	No	Lot for Lot
Trace Machining	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Thursday	Fortnightly	Some	Some	No	Lot for Lot
Schott Italvetro S.p.a.	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Unknown	Monthly - Tuesdays	Monthly	Some	Some	No	Lot for Lot
Ab Electrolux	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Any fired qty	Monthly - Thursdays	Monthly	Some	Some	No	Lot for Lot
E & R Moffat Limited	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Fortnightly - Wednesday Even	Fortnightly	Some	Some	No	Lot for Lot
Gsm Primographic Ltd	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Up to 10% over	Monthly - Usually NDL	Monthly	Some	Some	No	Monthly
Applikon Analytical B.v.	0%	0%	No	No	No	Unknown	No	Yes	No	No	15	Unknown	Monthly - Tuesdays	Monthly	Some	Some	No	Lot for Lot

Table 3-3 Customer Characteristics

3.2.4 Performance Importance matrix

One of the customer characteristics that is not quantifiable is the reason why customers buy products at SIG. As identified in the customer characteristics table (Table 3-3), customer behaviour is unstructured and its effect on planning problematic.



With the help of a performance-importance matrix (PIM), the competitive position of a company can be charted. A PIM helps to identify a firm's competitive position in the market, to identify improvement opportunities and can help to guide strategic planning efforts (Garver, 2002). An explanation of the PIM is given in Figure 3-3.

Figure 3-3 PIM explanation (Duke and Mount, 1996)

Based on inputs from the sales department, the following overview can be given: Figure 3-4. Customers appreciate the ability of SIG to deliver products on time. They also appreciate the customer service and the flexibility in accepting changes to orders.

Although SIG' products are slightly more expensive than competitors, the price/quality ratio is often of little importance to customers. Only the large volume customers are outsourcing to the low-wage countries. The price/quality ratio is compensated by the flexibility of SIG in its ability to accept last minute changes to planned orders. This can be seen as the added value that SIG offers. Not being able to make last minute changes will seriously hinder SIG's strategic position. The effects of this behaviour on planning has to be taken into account. Although current customers accept the given lead-time, new customers demand shorter lead-time.

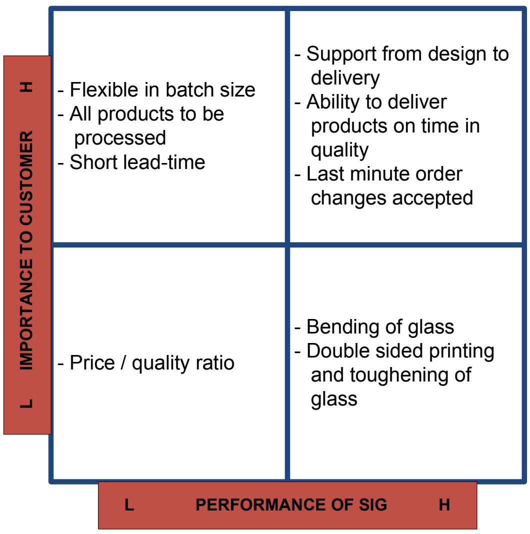


Figure 3-4 Performance importance matrix

3.3 Product characteristics

Products processed by SIG are discrete. Each panel requires individual attention. Panels are of a specific size, thickness and form, as specified by the customer. Material must be handled with great care; a scratched panel cannot be used again. Panels are transported by specific conveyor belts or on pallets protected with jiffy foam. Some material is more expensive than others. This also depends on the order quantity. The more efficient jumbos can be used, the cheaper.

% of total quantity processed	End products
1-25%	15
1-50%	72
1-75%	248
1-100%	2358

A total of 2358 different products are currently processed regularly, following a total of 256 different routings through the factory. As can be seen in Table 3-4, 15 end products make up a quarter of all material processed in the factory.

Table 3-4 Number of end products

3.4 Production characteristics

In paragraph 1.5 the primary production process has been explained. This paragraph will go into some more detail and will highlight several important characteristics of the production.

3.4.1 Machine reliability

Many of the machines currently in use by SIG have been in use for several years. The machines have a high variety in the level of automation and operating difficulty. Some machines are fully integrated CNC stations, some are manually controlled and have no automation. Several of the machines are interchangeable and can perform similar tasks. Production rates, downtime and machine loading vary per machine centre. Due to a lack of investments in the machines in the last few years and a walkout of the complete engineering department in September 2007, many of the machines experience technical problems and have high downtime percentages. Two new engineers are solving the main problems and root downtime causes, but the old machine park and backlog of problems will take time to clear. A preventive maintenance and six sigma project have also just started in an attempt to improve the liability of the machine park. Reasons and length of downtime vary; a problem in one of the furnaces causes a downtime starting at several hours, due to a cooling down and warming up period. In Table 3-5 a breakdown of the main reasons for downtime are given. As can be seen, 42% of the downtime is caused by faulty machines. A more detailed overview of downtime per machine is given in Table 3-7.

Reasons for Machine downtime	Hours down	Percentage/ Total
Machine faulty	1821	42%
Missing staff	1965	45%
Missing tool	319	7%
Material problems	180	4%
Transport problems	34	1%
No work	38	1%

Table 3-5 Downtime per reason (Based on a three month survey: January-March 2008)

3.4.2 Production flow analysis

Based on six months of data, an overview is created showing the most linked machines on the shop floor. An attempt has been made to find the most popular routes through the factory, but this did not reveal any significant results. The intensity of the various routings is given in Figure 3-5. As can be seen, this is not a very clear overview. No easy grouping or standard routings can be created.

FROM \ TO	GL4	GL3	HF1	R6&8	CPC	WA	R5	R7&11	INTMC	PL6	SCH	PL3	ILD	VF	HT	B2	IPL	BF	PL4	PL9	R1&2	CL1
CL1	360	231	9	151	8	3	37	35	19	6	1		9	6	4	1	3		2		2	
GL3			19		108	111			1	20	36	4	1	2	4	11	1		1			3
IPL			492									2						10				
INTMC			46		32	1			26	11	1	27	2	2	11	1	8	11	13	28		
PL6			230									128		10				12				3
WA			14		77				6	47	1	10										
PL4			289															4				
R5			5		45				10	22	2	1	1	5	5		2	1	4		3	
CPC			56			26			5	237		11		14		2	4	4	2			2
SCH			42							26		1					130	8	136	1		
GL4			159		1				4	11	103	6	172		39		59	1	91	20		
PL9			43						6									4				
R7&11			15						10		17	4	5		7		6	4	25	3	9	
B2	5	19	3	3	2	10	7	29	46				1					1		1	6	
ILD			105							2							285		76			
R6&8			54		1				1	1	93		93		26		12		12		7	
PL3			35							2				75				2		2		
HT			39			1			2	6							36		61	7	2	
R1&2			7						6	1	1	2			16		2		4	2	2	
HF1										4		8							8	3		
VF						11																
BF																						

Figure 3-5 From-to linkages

3.4.3 Machine grouping

Group	Grouped machines
CL	**C**utting line **1** + cutting m/c 3
B2	**B**ottero **2**, C/M 2+4, Horizontal cutting bench, SCT,Tempax SC
GL 4	**G**rinding **l**ine **4**
GL 3	**G**rinding **l**ine **3**
R6&8	**R**otary grinding m/c **6 + 8**
INTMC	Rotary grinding m/c 9+10+12+ waterjet (**Intermacs**)
R7&11	**R**otary grinding m/c **7 + 11**
R1&2	**R**otary grinding m/c **1 + 2**
R5	**R**otary grinding m/c **5**
WA	**W**heel **A**rris m/c
ILD	**In**line **D**rilling m/c 12
SCH	Drilling m/c 15 (**Sch**iatti)
CPC	Janbac 1, 3, 4, 5, 8, 9 (**C**ontrol **P**anel **C**entre)
HT	Janbac 10, 11, 14 (**H**ob**t**ops)
IPL	Printing line 1.1/1.2/1.3/1.4 (**IPL**)
PL 4	**P**rinting line **4**.1/4.2
PL 6	**P**rinting line **6**.1/6.2/6.3
PL 3	**P**rinting line **3** (Argon)+ SIAS+Hand printing bench
PL 9	**P**rinting line **9**
HF 1	**H**orizontal **F**urnace **1**
VF	**V**ertical **f**urnace
BF	**B**ending **F**urnace

Machines are currently grouped based on function, but departments are spread across the factory. E.g.: The department grinding consists of the functions rotary- and straight edge grinding, both located in different places in the factory. Rare occasions excepted, material flows from one department to the next without revisiting previous process steps. Within a department, a job will be assigned to a specific machine. Except for the fast line, machines are not linked by conveyor belts.

Table 3-6 Machine grouping

Due to the length of the four furnaces (2 of which are 100metres long) and the location of the fast line, the interdepartmental movement of products is sometimes up to 10 min. The furnaces separate the shop floor into several small areas, connected by one long pathway. The flow of products does not follow this pathway and often traverses back and forth through the factory. A production flow analysis (Nicholas, 1998) has been performed but did not reveal clear 'popular' routings (see also paragraph 3.4.2). Several of the machines have been grouped based on characteristics (Table 3-6). Machines perform similar tasks, but are not 100% interchangeable. Some machines that have been grouped perform similar functions, only scale and specifics are different. For example: the hand cut bench is grouped with a fully automated cutting machine. Fast line machines have been excluded.

INPUT																						
MACHINGROUPNAME:	**CL 1**	**B2**	**GL4**	**GL3**	**R6&8**	**INTMC**	**R7&11**	**R1&2**	**R5**	**WA**	**ILD**	**SCH**	**CPC**	**HT**	**IPL**	**PL4**	**PL6**	**PL3**	**PL9**	**VF**	**HF1**	**BF**
No. of machines in grouping	2	1	1	1	2	4	2	2	1	1	1	1	6	3	1	1	1	1	1	1	1	1
Total hours of work processed by machine group 01.01.08 - 25.03.08	1311	877	705	363	1046	3227	502	293	486	430	711	438	2691	859	780	**335**	**419**	**340**	**571**	**1179**	**268**	**523**
Downtime	18	0	350	219	452	651	239	311	185	25	181	119	964	501	236	63	50	55	137	30	3	43
Setup time	139	93	181	126	150	249	141	34	129	3	222	143	209	105	208	158	165	47	79	143	23	138
LOADING TOTAL PLANT CAPACITY																						
Total plant capacity	2.520	1.680	1.680	1.680	3.360	6.720	3.360	3.360	1.680	1.680	1.680	1.680	10.080	5.040	1.680	1.680	1.680	1.680	1.680	1.680	1.680	1.680
Idle time	1.052	710	444	973	1.712	2.593	2.478	2.722	881	1.223	566	981	6.216	3.575	455	1.124	1.047	1.238	893	328	1.385	976
Loading %	52%	52%	42%	22%	31%	48%	15%	9%	29%	26%	42%	26%	27%	17%	46%	20%	25%	20%	34%	70%	16%	31%
LOADING 3 SHIFT CAPACITY																						
3 shift capacity	1.800	1.200	1.200	1.200	2.400	4.800	2.400	2.400	1.200	1.200	1.200	1.200	7.200	3.600	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
Idle time	332	230	-36	493	752	673	1.518	1.762	401	743	86	501	3.336	2.135	-25	644	567	758	413	-152	905	496
Loading %	73%	73%	59%	30%	44%	67%	21%	12%	40%	36%	59%	36%	37%	24%	65%	28%	35%	28%	48%	98%	22%	44%
LOADING 2 SHIFT CAPACITY																						
2 shift capacity	1.200	800	800	800	1.600	3.200	1.600	1.600	800	800	800	800	4.800	2.400	800	800	800	800	800	800	800	800
Idle time	-268	-170	-436	93	-48	-927	718	962	1	343	-314	101	936	935	-425	244	167	358	13	-552	505	96
Loading %	100%+!!	100%+!!	88%	45%	65%	100%+!!	31%	18%	61%	54%	89%	55%	56%	36%	98%	42%	52%	42%	71%	100%+!!	34%	65%

* all in hours

Table 3-7 Capacity Loading

Table 3-7 gives an overview of the factory loading in the period of 1 January to 25 March 2008. The machine groupings are based on Table 3-6. Several machines in a group functioned only a few hours in the monitored period. To compensate, these machines have been excluded from the analysis. As no information is available about the exact total number of hours the machines ran during the monitored period, three scenarios have been created: a 2 shift loading overview, a 3 shift overview and a total plant capacity overview. From this overview it can be seen that machine capacity is no issue. Shifts can be added to compensate for a busy period.

3.4.4 Setup time

Setup time varies per machine. Some of the machines require tooling and jigs to operate. The time required to set up a jig or specific tool varies between 5 min to two hours, the bending furnace being the exception with setup times varying from 10 min to 24 hours. The availability of jigs is normally not a problem. Table 3-5 shows 7 percent downtime due to missing tools, most of these can be explained by external factors such as slow supply of needed drawings or missing details from customers.

There is a high variation in the setup times per machine. Based on the machine grouping given in paragraph 3.4.3, an analysis of the setup time has been made (Table 3-8). E.g.: most setups at Horizontal Furnace 1 are less than 5 minutes (92%). In general, the faster a line turns green, the lower the average setup time is. The length of a setup is sequence dependent, but no data exist on the exact length of the actual versus planned setup time.

Grouped Machines		Proc	Count of setups	Setup time									
				5 min	10 min	15 min	20 min	30 min	40 min	50 min	1 hour	2 hour	2 hs<
CL1	Cutting line 1 + cutting m/c 3	1450	939	36%	88%	99%	99%	100%	100%	100%	100%	100%	100%
B2	Bottero 2, cutting 2+4, HCB, SCT, Tempax	970	325	12%	47%	72%	72%	95%	97%	100%	100%	100%	100%
GL1	Grinding line 1 (Fastline)	600	265	22%	52%	95%	95%	96%	97%	98%	98%	100%	100%
GL4	Grinding line 4	886	720	24%	31%	88%	88%	92%	95%	98%	98%	100%	100%
GL3	Grinding line 3	489	386	12%	43%	73%	73%	85%	93%	95%	97%	100%	100%
R6&8	Rotary grinding m/c 6 + 8	1196	425	18%	47%	67%	67%	83%	86%	91%	97%	99%	100%
INTMC	Rotary grinding m/c 9 + 10 + 12 + waterjet	3476	231	6%	7%	8%	8%	19%	28%	45%	70%	95%	100%
R7&11	Rotary grinding m/c 7 + 11	643	145	11%	15%	20%	20%	31%	38%	46%	61%	92%	100%
R1&2	Rotary grinding m/c 1 +2	328	36	6%	6%	6%	6%	6%	15%	44%	65%	97%	100%
R5	Rotary grinding m/c 5	614	182	26%	45%	47%	47%	57%	66%	69%	75%	94%	100%
WA	Wheel Arris m/c	433	31	97%	100%	100%	100%	100%	100%	100%	100%	100%	100%
ILD	Drilling m/c 12 (Inline)	933	533	27%	34%	35%	35%	71%	73%	81%	99%	100%	100%
SCH	Drilling m/c 15 (Schiatti)	580	357	21%	32%	55%	55%	65%	86%	92%	96%	100%	100%
CPC	07 Janbac 1, 3, 4, 5, 8, 9	2900	402	13%	25%	30%	30%	39%	75%	87%	95%	99%	100%
HT	Janbac 10, 11, 14	964	199	16%	21%	25%	25%	64%	75%	79%	90%	98%	100%
IPL	Printing line 1.1/1.2/1.3/1.4 (IPL)	988	699	28%	38%	63%	63%	97%	99%	100%	100%	100%	100%
PL4	Printing line 4.1/4.2	493	494	9%	16%	69%	69%	88%	95%	98%	100%	100%	100%
PL6	Printing line 6.1/6.2/6.3	584	543	18%	40%	62%	62%	97%	99%	99%	100%	100%	100%
PL3	Printing line 3 (Argon)+ SIAS+HPB	387	195	9%	58%	94%	94%	99%	100%	100%	100%	100%	100%
PL9	Printing line 8.1/8.2 + 9 simas	650	225	12%	16%	56%	56%	84%	97%	98%	99%	100%	100%
HF1	Horizontal Furnace 1	1322	2833	92%	98%	100%	100%	100%	100%	100%	100%	100%	100%
HF2	Horizontal Furnace 2	669	636	97%	99%	100%	100%	100%	100%	100%	100%	100%	100%
VF	Vertical furnace	292	319	78%	94%	100%	100%	100%	100%	100%	100%	100%	100%
BF	Horizontal Furnace 4 (Bending)	661	76	13%	17%	29%	29%	35%	36%	40%	48%	72%	100%

Table 3-8 Setup time

The variation in setup time gives an indication of the flexibility of the company (Slack, 1987). SIG was setup as a high volume, large batch factory. The creation of the fast line was the summit of this idea. Long setup causes changeover inflexibility and a lot of non-added value. A value stream map revealed that value is added only 0,5% of the time an order is being processed.

3.4.5 Transportation

The internal transport of material is done with pallets and lift trucks. Material handlers transport the pallets, on request of the operators. External transport is outsourced to a freight company. Some orders are pulled forwards to meet truck departure dates. This process of pulling orders forward causes problems at machines centres: Orders in process are stopped to allow 'truck' orders to be finished in time, causing setup inefficiencies.

3.4.6 Customization

A company either makes products to stock (MTS) or to customer order (MTO). Stevenson, Hendry and Kingsman (2005) use a classification system that gives a refined indication of the level of customization of a company (Figure 3-6). MTS still stands for make-to-stock, but MTO has been split up in 'RBC' and 'VMC', creating a sharper classification of production companies. RBC stands for 'Repeat Business Customers' and VMC for 'Versatile Manufacturing Companies.' The difference being the difference in variety and volume of processed orders. In paragraph 1.5 SIG was classified as a Make-to-order company. Based on Figure 3-6, the average batch size and the variety in orders, SIG can be classified as an RBC. Most orders are repeats (Table 1-2) and the batch sizes are small to medium (Table 3-1).

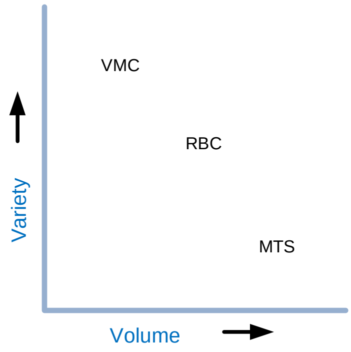


Figure 3-6 **Classification model based on volume versus variety**

3.5 Operational characteristics

This paragraph will go into the details of several operational characteristics of SIG. Wielen, Slomp and Heere (1995) identified four typical operational characteristics: order size restrictions (3.5.1), order process dependent restrictions (3.5.2), workload restrictions (3.5.3) and capacity restrictions (3.5.4). Other sources use different characteristics that give some more detail on operational performance. These characteristics include lead-time, delivery performance, quality and flexibility, all discussed in paragraph 3.6.

3.5.1 Order size restrictions

The new mission statement (paragraph 1.3.2) states that any batch size must be accepted if economically feasible. From Table 3-4 it can be deducted that current batch sizes are not big, especially for a high volume factory. Currently, setup time can be up to a third of all available machine time (Table 3-7: capacity loading).

The factory has a no-batch-splitting rule, causing long batch waiting times. According to Hopp and Spearman (2000), an optimal batch size will minimize the batch cycle time. A no batch-splitting rule can cause long cycle times, especially if the setup times are short.

In recent months, the order managers have started using minimum batch size restrictions for some of the products. If a product is difficult to produce (high scrap rates) or setup time is an issue, the customer is forced to buy larger quantities. This rule is not in direct conflict with the new mission statement: smaller sizes are accepted at a higher cost.

3.5.2 Order process dependant restrictions

Department	Setup grouping
Cutting	1. Product type
	2. Glass type
	3. Material thickness
Grinding	1. Material thickness
	2. Panel shape
	3. Panel size
Drilling	1. Hole size
	2. Number of holes
	3. Panel shape
	4. Drilling program
Printing	1. Panel size
	2. Ink colour
	3. Customer
	4. Material thickness
Toughening (bending only)	1. Bending shape
Toughening (flat furnace)	1. Material thickness

Table 3-9 Grouping options per department

The order in which materials are processed is quite strict. After toughening, no cutting or drilling is possible. Improved setup efficiency can be achieved. Per department, different forms of 'optimal' grouping rules can be found (Table 3-9). One or all grouping rules are applied if possible. Optimisation is done per department only and is based on the available orders and due dates. Orders with approaching due dates will be prioritised, disregarding optimal optimisation options, resulting in sub optimisation. There are no order process dependent restrictions.

3.5.3 Workload restrictions

Currently the shop floor is not fully loaded (Table 3-7). On average, most machines stay under 50% loading if the factory would work 24/7. Due to the order-push-approach currently in work in the factory, machines always appear to be fully loaded. Currently, no workload restricting function is in place at SIG. Sudden build-ups of work due to increased demand or downtime can cause long throughput time. One of the first and longest standing 'rules' in the history of production, is Little's law: Work in Progress = Lead time x Throughput rate (Hopp and Spearman, 2000). Raised WIP levels with steady throughput rate will cause lead-time increases.

An analysis of the WIP on the shop floor has given some insight in the apparently 'fully loaded' shop floor. The WIP levels have been recorded for several weeks. High variations in the WIP levels can occur between two consecutive days, as can be seen in the second column of Table 3-10. The last column indicates that, on average, the level of WIP in a department cannot be cleared during that day. This means that the amount of work that enters that department, combined with the backlog, is more than a work centre can process at any given day. This is not a bad thing per se, but as can be seen in the fore last column, a large percentage of WIP never gets cleared. This shows that WIP levels are too high in general.

Department	Maximum recorded difference in WIP between two days	Average difference in WIP between two days	Average WIP level	Minimum recorded WIP level	Average % of WIP not cleared.
Cutting	7913	1038	2162	168	52%
Grinding	8612	2924	29042	18813	90%
Drilling	16185	3512	37085	18679	91%
Printing	11288	3470	22578	10706	85%
Toughening	14687	5896	21571	8085	73%
Assembly	3398	793	26867	742	97%
Finished goods	38688	6357	296709	21251	98%

Table 3-10 WIP calculations

3.5.4 Capacity restrictions

Capacity can be restricted by either the availability and speed of machines or the availability of personnel. Machine capacity has already been discussed, leaving labour capacity.

Exact figures concerning capacity restrictions due to a lack of labour or skills are unknown. General comments indicate that the factory has enough labour; but skills for specific machines are a problem. Missing skills is the biggest reason for machine downtime (Table 3-5). Based on qualitative information, several complex machines have only one or two experienced operators. Adding capacity through overtime is therefore limited. The 'normal' machines have plenty of capable operators, making overtime and extra shifts possible. It can be concluded that shifting personnel around when machines are supposed to run is not always possible as the availability of the right skills at the right time is problematic.

Currently employees are on flexible labour contracts, personnel are asked to work if work is available. If necessary, employees can work overtime. Shifting from a two to three or three to four shift is possible, but has to be planned ahead a few weeks. Further investigation into the labour cross-functionality is outside the scope of this research.

3.6 KPI's

Many performance indicators are recognized in literature (Nicholas 1998). Only a few of these are monitored by SIG. WIP has been covered in paragraph 3.5.3. Lead-time, delivery performance and quality will be covered in the following subparagraphs.

3.6.1 Lead-time

Due to the many different routings and the varying machines an order visits, any averaged lead-time will give a distorted view. The three main product routing 'options' and their corresponding lead-times are given in Table 3-11. Fast line products are processed in one day, but often some rework or missing material causes delays: Orders are halted in dispatch until all material is available, resulting in a longer than one day lead-time.

Routing	Average lead-time
Assembly products	15 working days
Fast line products	5 working days
Normal flow-shop orders	9 working days

Table 3-11 Average lead-time per routing

3.6.2 Delivery performance

Delivery performance (Figure 3-7) has been growing in recent months. Currently, delivery performance is averaging around 95%. When comparing the delivery reliability with the realized sales, a trend can be seen. Although not a 1:1 relation, the lower average volume processed has caused an improvement in the delivery reliability. If demand would go up, delivery reliability would drop and WIP levels will rise.

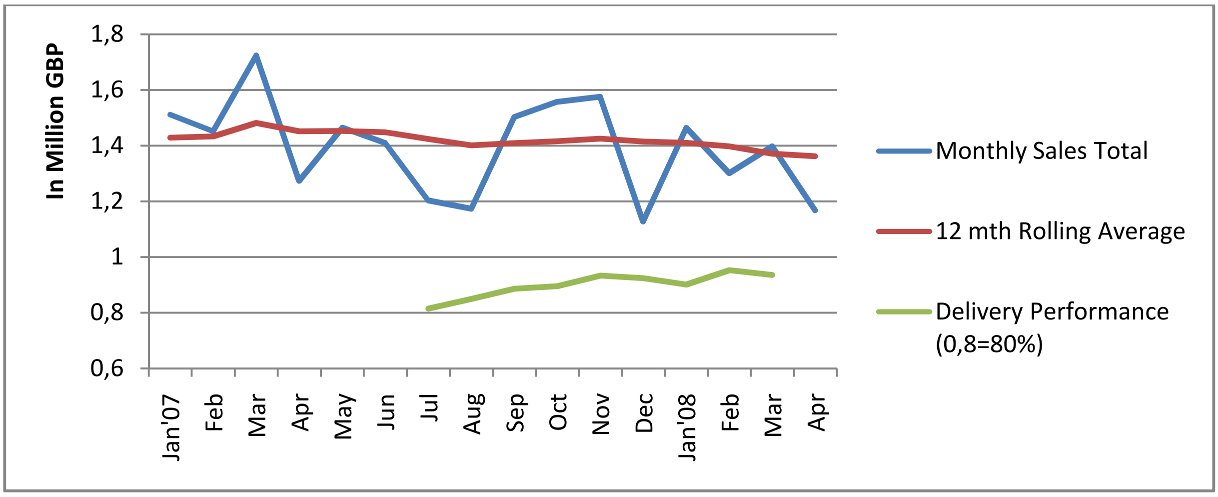


Figure 3-7 Delivery performance and sales volume

3.6.3 Quality

The definition of quality can be split into internal and external quality. Internal quality can be measured with scrap rates and rework percentages (Hopp and Spearman, 2000). External quality is measured in customer complaints and customer satisfaction.

Internally, 14% of all panels processed are scrapped. One of the characteristics of the glass processing industry is a high scrap percentage. Corrections cannot be made, and a fixed percentage is known to be lost in the initial start up of any machine. Scrap percentages are currently too high though. 10% is an acceptable level and has been achieved in the past. A lot of problems arise due to a lack of experienced personnel. Fifteen external complaints are received each month, with varying reasons. A total of 17.500 GBP is incurred monthly due to internal and external quality problems. This accounts for 1% of all revenue and excludes further indirect costs. External complaints are avoidable and should be picked up by internal quality checks.

3.7 Conclusion

SIG is losing sales to low wage countries. With an 18% drop in demand expected in the coming few months, efficiency is key. Several problems have to be tackled to improve performance. The many hours downtime, high levels of WIP and the scrap percentages have to be reduced. Some of the causes of these problems can be found in the departmental sub-optimization, the lack of employee training and the high WIP levels itself. SIG will need to focus and manage that what its customers appreciate: delivery reliability, fast lead-time and small batch sizes. Less scrap means less rework and less rush orders to complete production orders. Quality is essential.

Chapter 4 will go into the details of production planning. The causes and consequences of the above described problems on the production planning will be discussed.

4 Production planning

Chapter 3 introduced the factors that need to be controlled: the flow of orders, the unpredictable customer behaviour and the various problems on the shop floor. All these factors need to be taken into account whilst planning the shop floor. How this is done is discussed in this chapter.

In order to analyze the current planning procedures at SIG, a structured approach is followed. This approach and some definitions are first introduced (4.1), followed by the analysis per planning level (4.2-4.6). To confirm if the current planning procedures are successful, a performance benchmark has been made (4.7). A conclusion is found in the last paragraph.

4.1 Theory: Production planning and control

Production planning and control is a contraction of two definitions: 'logistical control' and 'production planning.' According to Bertrand et al. (1998), logistics control combines material management and production control. Logistics control is the *'control of the availability and use of materials and capacity resources in time, quantity and place'.* Material management is a term used for a multitude of functions including control of the material flow, quality management and the ordering of raw material.

Production planning can be defined as the allocation and coordination of capacity resources between and over different production departments. In most organizations, three levels of production planning can be identified: A strategic level, a tactical level and an operational level (Table 4-1). The focus of this research is purely on the operational level. Its functionalities and interactions are given in Figure 4-1. This framework is based on the production planning and material control framework created by Bertrand et al. (1998). Figure 4-1 also integrates some slight adjustments made by Wielen et al. (1995). The five elements in Figure 4-1 are explained in Table 4-2.

Planning level	Function	Period
Strategic level	Strategic planning, sales growth predictions	1 year and up
Tactical level	Order forecast, high level capacity planning	6 to 12 months
Operational level	Detail planning, workload control, optimization of production, capacity smoothing and shop floor control.	One day to 6 months

Table 4-1 Planning levels

The elements from Figure 4-1 can also be found in Figure 3-1. To understand the links between the different planning levels as they occur at SIG, please refer to Figure 3-1 on page 19. Wielen et al. (1995) state that the details of each planning level are situation dependent. Starting in paragraph 4.2 and on, the different functions and unique SIG characteristics will be explained using the functions from Figure 4-1 as a structure. SAP is the main software program in use by SIG. As explained in paragraph 2.2, any solution presented must be compatible with SAP. An explanation of the interaction of each planning level with SAP is therefore included, as well as the current problems and restrictions experienced with SAP at each level.

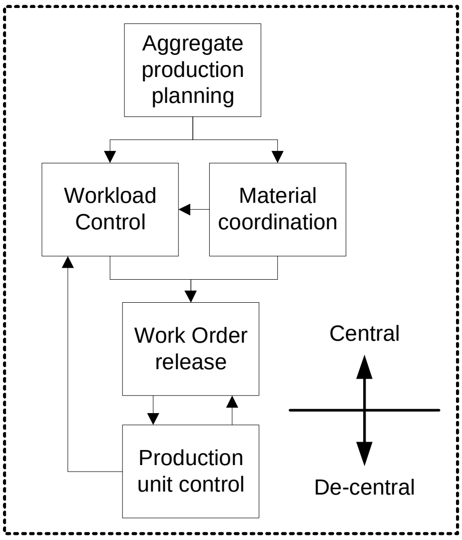


Figure 4-1 Production planning framework.

Definition	Theoretical explanation
Aggregate production planning	This level performs the long term order planning and the capacity to be used. This is a rolling plan, performed once monthly. Agreements on various KPI's like min/max stock levels, WIP, maximum lead time are made on this level. Made to stock / made to order agreements are also made on this level.
Material coordination	This task is performed partly by sales and partly by production planning. Sales will submit lead times and price quotations to the customer, based on suggestions from planning. These suggestions are based on the current and future loading of the factory and the characteristics of the order book.
Workload Control	This function has a strong link with material coordination. Workload control analysis incoming order-requests and provides delivery dates to the material coordination function. Confirmed orders are planned, looking at required throughput time and delivery date. If capacity problems arise, adjustments are made or extra capacity planned.
Work order release	On this level, orders are released to the shop floor, based on the available capacity (workload control) and the requested orders (material coordination). Last minute adjustments are made, based on the current shop floor situation.
Production unit control	The order processing on the shop floor is controlled by the foremen in the different production units. Orders are processed based on internal delivery dates. Order processing optimization is possible with the available WIP and within set boundaries. Problems, extra capacity requests and information are fed back to the levels above.

Table 4-2 Explanation of framework definitions (Slomp and Ruël, 2001), (Wielen et al.1995)

4.2 SIG: Aggregate planning

Long term planning is done once monthly, looking three months into the future. SIG refers to this long term planning as forecast planning. Based on expected sales, it can be seen if the coming months will be busy. As this is based on sales predictions, the loading of the different machines is not planned. No breakdown into product families or customer orders is done. If a period will be busy, personnel will be asked to work extra shifts, or temporal personnel can be attracted. No changes in the list of accepted planned orders are made. Based on the expected machine loading, it can be decided to switch furnaces off for specific days. One tries to keep the furnaces occupied 100% of the time, in order to optimize energy and labour usage.

As described in paragraph 3.2.3, some stock agreements are made with customers and some order forecasting is done. Currently, delivery reliability is the only high level KPI measured and controlled. WIP is measured but not acted upon. No maximum lead-time is set, although one strives to limit it to 3 weeks (non assembly products) or 6 weeks (assembly products).

4.2.1 SAP integration

SAP is only used to download an overview of the planned orders for the coming period. These data are processed in Microsoft Excel to give an overview of the capacity loading of the factory.

4.2.2 Problems

- As can be seen in Figure 3-1, the aggregate planning is not linked to any future planned orders. Information on this level is used only for sales purposes and has no link with the other planning levels. A forecasted busy period may only cause problems in one or two specific weeks. Adding capacity or pulling orders forward is therefore not done. So although problems are foreseen, no corrective actions are made. SIG deals with capacity problems in the workload control level, which is sometimes too late for corrective actions.
- No breakdown of required capacity per customer order or product group is done. Temporal bottlenecks can therefore suddenly appear. This causes WIP to build up and orders to be delayed, while the rest of the factory performs normal.

4.3 SIG: Material coordination

The sales department makes first contact with new customers. After the initial contact, the order planners take over the customer contact. Order requests are quoted a lead-time, set standard to 3 or 6 weeks (Assembly orders). As mentioned in paragraph 3.2.3, no structured approach to accepting, planning and balancing orders with the available capacity is possible. Some fast moving products are made to stock, but in general customers confirm orders only days before the promised due date. This causes orders to be started based on approaching due dates, only to be stopped again half way through the production process. Orders might not have been confirmed, the quantity processed so far was incorrect or art work is not available. Some customers also require and receive a lead time less than is possible with the available capacity, creating rush orders. Quality problems, rework and missing quantity create lead time problems for current and future orders.

The material coordination function is performed once weekly, looking a month into the future. This meeting is done production planning internally only; no sales, order planners or sample coordinators are present. Rush orders are accepted on a day to day basis, depending on customer importance and available capacity.

4.3.1 SAP integration

All orders are input into SAP, which will calculate production quantities and give production start dates. Only the route that processes products the fastest is currently stored in SAP, no alternative routings are stored. New orders will be calculated and details entered into the system. If an order is accepted, it will become a planned order. Planned orders become shop orders if the order planner thinks the order should be started (standard three or six weeks before the due date). This is based purely on approaching due dates and lead-time calculations by SAP.

4.3.2 Problems

- Lead-time estimations are fixed at three or six weeks (assembly products). Estimations are not based on the actual loading of the factory. Rush orders from important customers are always accepted, creating planning and capacity problems.
- Late confirmation of orders causes a lot of problems. The customer demands delivery reliability and short lead-times, without providing correct forecasts. All adding to the nervousness of the system.
- The planning of skills is difficult, causing a lot of downtime and thus longer lead-times and WIP pileups.
- As SAP has no shop floor scheduling function, the SAP proposed start date is always too close to the delivery date. The given three or six weeks lead-time is based on experience and is much more correct. SAP start dates are always ignored.

4.4 SIG: Workload control

Workload control is strongly linked with the material coordination function. In fact, both functions are integrated into one. The same weekly meeting that is used for the ‘material coordination’ function also looks at the capacity loading of the factory. SIG refers to this meeting as the capacity planning meeting. Bottleneck problems are identified and some capacity smoothing will take place. If capacity is available on a machine, work from a busier period can be pulled forward, smoothing the capacity loading, but increasing the WIP and finished goods inventory. This is done on a daily basis looking one week ahead only. Creating extra capacity by putting on extra shifts is possible but expensive as it is always a last minute decision.

4.4.1 SAP integration

As any proper MRP system, SAP does not take capacity loading into account. Shop orders released by order planners will appear on the planner's production list. A Microsoft Excel macro uses the required capacity of the planned shop order to create a capacity loading overview of the coming few weeks. This macro gives a crude overview of the current available production capacity, the required capacity and the factory loading. Based on this overview, the capacity usage will be smoothed by changing due dates, triggering the production planners to pull jobs forward.

4.4.2 Problems

- All shop orders will be processed as soon as capacity is available at the first production step. Throughput time and WIP at machines downstream are not taken into account, creating an uncontrolled situation.
- This behaviour can create sudden bottlenecks in the factory, creating pileups of WIP. No maximum WIP- or throughput time rules are currently in place.
- Meeting delivery dates is of vital importance and material is pulled through the production process focused on this goal. This process can create a 'snowball' effect: work pushed out will have to be rushed through later, creating lead-time and delivery problems.

4.5 SIG: Order release

The release of orders onto the shop floor is done by one of the two production planners. SAP will automatically place released jobs on the production planning. The planners will sequence the jobs, based on experience and some basic grouping rules. The effects of starting an order on the cutting bench and the effects this might have on downstream machines cannot be foreseen. Capacity problems might arise days later at the furnaces, based on decisions made at cutting. Orders are currently pushed onto the shop floor, dictated by the speed of the grinding machines (second process step). In general, jobs are cut just before a grinding machine will finish his current job. Jobs are sequenced and released to the shop floor based roughly on the grouping rules described in Table 3-9. All departments are optimised centrally based on the work available in their inbound WIP area. Updated production lists are issued to all team leaders once daily.

4.5.1 SAP integration

SAP is used to generate the production plans used on the shop floor. Information from the shop floor about processed jobs, finished jobs, produced quantities and unplanned downtime is downloaded from SAP. This information is used to update the production plans and to signal problems. The machine throughput rates stored in SAP are on average 10-30% incorrect, making accurate planning difficult. The production planners use SAP to see if all additional material (screens, jigs, tools, cutting programs) required by production are available.

4.5.2 Problems

- Optimization is done centrally and with the available WIP only. Most bottlenecks are downstream from cutting and grinding. Order sequencing is disrupted by rush or simply late orders and samples, creating long (partly unnecessary) setup times at machines.
- The release of orders is uncontrolled. Any order with an approaching due date is pushed onto the shop floor.
- Operators do not stop processing jobs even if upstream machines are full. No signal from upstream stations will indicate faulty machines or an overloaded production situation.

4.6 SIG: Production unit control

SIG currently has 9 production units and these production units are controlled following a strict hierarchical structure, as can be seen in Figure 4-2.

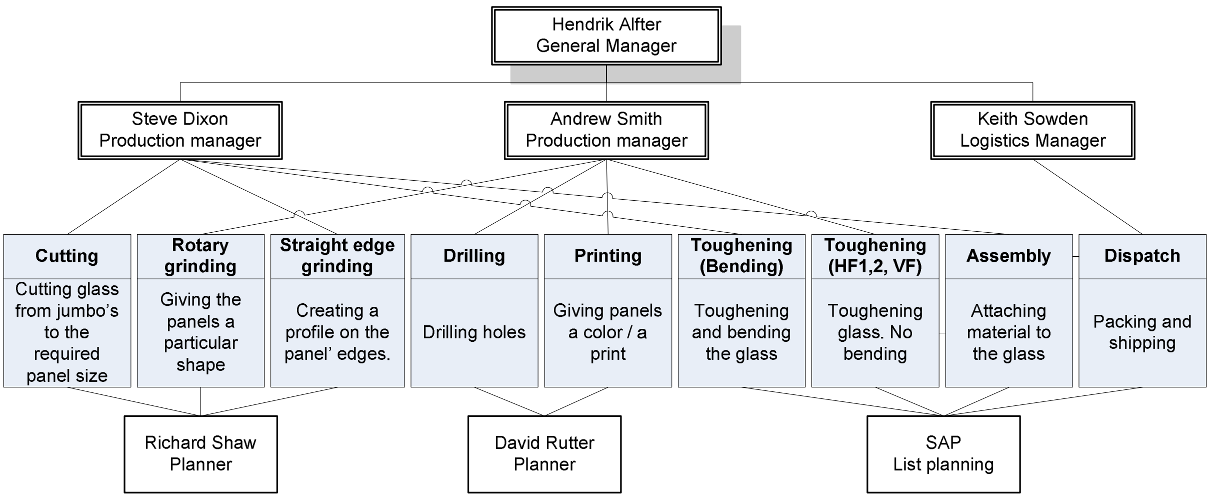


Figure 4-2 Departments and control

As can be seen from Figure 4-2, the furnaces, assembly and dispatch are not planned. Orders arriving in these departments are processed based on due dates provided by SAP. Processed jobs will be moved to a storage rack near the next process step if possible. A job is accompanied by a specification card, holding all relevant information for that job.

4.6.1 SAP integration

SAP is used at this stage only for feeding back data to higher planning levels. Confirmations, throughput rates, set up time, etc. are entered into SAP at the end of an operator's shift. Confirmations show the order progress through the factory. Information in SAP is always several hours old.

4.6.2 Problems

- Pileups of WIP take up a lot of factory floor space, causing problems like untraceable material, quality problems and invisible obsolete WIP.
- Information received from the shop floor by higher planning levels is not or cannot be acted upon. Capacity problems are not recognized until very late in the planning process (day to day planning) and requests for extra capacity on short notice are difficult.
- Not planning the downstream processes can create problems. Work is processed at these stations based on due date. WIP can pile up uncontrollably in these departments.
- Wrong throughput rates, delays in feedback of information, no information about alternative routings cause problems and high WIP on the shop floor in case of machine breakdowns.
- Departmentalized finite planning creates sub optimal finite planning on plant level.

4.7 Benchmark

Establishing if the above described characteristics are really problematic is inherently hard to achieve. Some problems might not be real problems at all, even if common sense would indicate otherwise. A benchmark of key company characteristics with four of the other flat glass factories has resulted in the following overview (Table 4-3). Customers and orders vary per company, but the production processes and products are similar. Although some margin should be taken into account, comparisons can be made. Based on the provided information, several conclusions can be drawn:

- When comparing the delivery reliability and average customer lead-time of SIG with ORIM, SIG's lead-time is, on average, a week too long. Taking into account that SIG currently is not using much of its available capacity, the lead-time should even be shorter.
- The production lead-time is also quite long. Products remain an average of 9 days in the production process at SIG, compared to 3 days at ORIM and 5 days at VTF. Both factories process more volume but require less production time if compared to SIG.
- The lack of machine reliability, downtime due to missing skills and the forecast reliability make planning more difficult at SIG, causing some of the previously discussed problems.

- The WIP levels at SIG are very high compared to VTF and Italvetro. VTF processes 3,5 times the volume of products as SIG, while their WIP level is at the same level as SIG. Italvetro has 40% less WIP compared to SIG.
- A similar statement can be made about the finished goods stock. Although the finished goods stock at VTF is 5 times higher than SIG, this comes down to only 4 days of WIP.

			SIG		ITALVETRO		VTF		ORIM	
Level	**What**	**Factor**	**SIG quantified example**	**High-Low**	**ITA quantified example**	**High-Low**	**VTF quantified example**	**High-Low**	**ORIM quantified example**	**High-Low**
Customer characteristics	orders	Product variation	2358 different products	High	2646 different products	High	About 6000 active items	10	9317 different products	High
		Batch size variation	Batch size: 1-4500. Average=172.	High	Batch size 5-9000.Average HT=150,CP=200,OD=400,ID=700,LIDS=200	High	In average 600 pcs	10	1-45000, average : 541	High
		Lead-time variation	3 week lead-time promise	High	3 to 4 wk for customer without forecast. 1to 2 wk for customer with forecast (binding or not)	Med-High	In average 5 weeks	10	2 week lead time avarage	High
		Forecast reliability	2 EDI customers	Low	9 customer with forecast (75% of turnover	Low	6 EDI customers	8	4 Edi Customers, 5 Others	High
		Rush orders	Not many	Medium	Not many	Medium	A few	2	Internal Customers %10	Medium
	Type of order	Order - uniqueness	25% orders =not normal run (733/2933)	Medium	??		About 2,8 %	2		
	Due date	Variability		Medium		Medium	A few	2	Quantity and date	Medium
		Flexibility	Except all if possible	High		Medium	???????		Only for some customers	High
	Customers	renew rate	Limited new customers	low	Limited new customers	low	Limited new customers	2	Limited	Low
		Top 10 value	13 customers = 80 % value	High	Top5= 60%, Top10=80%	High	9 customers = 80 % value	10	15 customers=%80 value	High
Production Characteristics	Setup time	Variation	average: 5 min - 2 hours	High	5min-2hours	High	average: 5 min - 45 min	10	Average : 5 Min - 2hours(in Bolu)	High
	Setup Grouping	Possible	4 mm / 5 mm etc	Medium	yes based on glass type, thickness , type of grinding, dimension of holes,	Medium	techical spec. : thickness, corner, glass etc...	10	depends on process	High
		Factory optimization	No, only per department	Low	??		Departments + Global factory	10	depends on process and methot	High
	Processing time	Length variation	Quantity dependent	High	Quantity dependent	High	Quantity	10	Quantity depended	High
	Machine breakdown	Occurrence	Often. Some up to 20% of time	High	sometimes, up to 8-10%	Medium	1,70%	3	Changes Bolu, Ckoy	High
	Emergency Rerouting	Occurrence	Due to many breakdowns only	Medium	Mainly due to lack of labour or breakdown	Medium		5	Breakdowns,feedback from production	
	Lack of labour	Quantity	Flexible	Low				5	not Flexible	Low
		Skills	About 600 manhours / month	High			On going traning sessions	5	24 Hours, 25 days	High
	Stock	WIP Level	170.000 panels = 10 days of WIP	High	6days production	High	WIP = 160 000 Euros =	5		
		Finished goods level	180.000 panels = 18 days of WIP	High	4days production	Medium	Finished goods : 1 000 000 Euros	8		
	Scrap	Percentage	14%	low	about 12%	Medium	12%	7		High
	Delivery	Reliability	90-98%	High	70% ontime deliveries, 2,5days average delay	low	70 - 75 %	10	98%	High
	Missing material	Percentage	Unclear, up to 5%	High	Unclear, about 1-2%	low	Replenishment due to missing quantity <= 2%	2	only washing	
	Production lead time	variation	9 days average	High	9 working days average	High	In average 5 days	10	3 days avarage	High
	Capacity	Smoothing possible	Sometimes	medium	Sometimes	Medium	Not possible due to the high workload	2	All time	High
		Availability - flexibility	Extra shifts possible.	high	Extratime on Saturday (1 shift) or continuos production on weekend (with 1wk notice to union)	medium	Less flexibility - high workload	10	4 shifts	High
	Bottleneck	Bottleneck - occurrence	Some machines	Medium	Some machines	medium	Furnace	10	Some Machines (printing, tempering)	High

Table 4-3 Flat glass benchmark

No adjustments have been made to Table 4-3. Some information is missing as these haven’t been completed by the companies. The columns ‘high-low’ indicate if the company perceives the variable in the previous column as a high or low indicator. E.g. SIG has a three week lead-time and think this is too long.

4.8 Conclusion

The analysis of the company revealed a lot of information, characteristics and problems. Some of the bigger problems are interrelated and cause many of the shop floor problems. Several small problems also contribute, but are of less importance for this research. The main problems and their interrelation are given in this paragraph.

Planning functions

When comparing the planning functions in Figure 3-1 with Figure 4-1, some differences can be seen. Most elements in Figure 4-1 are linked and interacting, providing useful information for the different planning levels. These links provide information top-down or feedback from the shop floor up to the different management levels. At SIG some of these links are missing or not fully working. If a problem is recognized on the shop floor, it is often too late to minimize or counter the problem. This is especially apparent at the forecast- and weekly capacity planning level. Limiting the loading of work centres is only done on a very high level. Levelling capacity on a weekly or daily basis is difficult. The effects of rush orders or new orders that are planned between capacity planning meetings can cause unforeseen capacity problems and WIP build ups. Pulling work forward to level out capacity is done only sparsely.

Lack of structure

Restricting the release of orders to a next planning level or onto the shop floor is not structured. All planned orders appear on the production plan if the due date approaches. Again, no capacity control is done, resulting in high WIP levels that cannot be cleared (Table 3-10). This approach of pushing work onto the shop floor creates floating bottlenecks and seemingly busy work centres, whilst the overall factory capacity is underused (Table 3-7). The departmental optimization done by the planners actually causes plant-wide sub-optimization. Machines are not stopped if the next department has enough WIP. The lack of cross-functionality is also a major issue: a lot of downtime is caused by missing skills. A downstream machine could be understaffed and overloaded, whilst a supplying department is overstaffed and running at full capacity, supplying even more WIP.

Lack of communication

Machine downtime causes longer lead-times and more orders being rushed through after reparation. Due to a lack of interdepartmental communications, operators in stations upstream do not stop processing jobs if a machine downstream is down. The physical separation of supplying and receiving machines does not help. Any production plan is based on information that is confirmed into SAP once every 8 hours. Any changes in the plan due to problems are communicated verbally. Using alternative routings to get orders through is not recorded in SAP. Production rates of the alternative machine are not linked to the actual order, causing problems in post calculation.

Contributing to the problem of long lead-times and setup inefficiency at bottleneck machines is the grouping optimization in the first departments: cutting and grinding. The optimal order in which orders are processed at a downstream bottleneck is disrupted by the optimization at the first station. Once jobs filter through to bottlenecks, the 'optimal' order jobs could be processed in, is disrupted by rush orders and delivery performance adherence.

More issues

Comparing the actual required hours of work and the total production lead time per order, value is added 0,5% of the time an order is being 'processed'. Reducing lead-time or limiting the time work is on the shop floor (WIP) will cause an increased percentage of value added time, will reduce the amount of money tied down in the factory and will allow more efficient production in general. Reducing WIP is only possible if the planning and production systems are more reliable and problems can be dealt with. Most of the basic planning elements are in place at SIG, but structuring the interaction of the elements and limiting the release of orders to a next stage is required. Once the planning framework is improved, 'smaller' problems like skill allocation and obsolete stock can be tackled. Any improvements have to be able to deal with the company characteristics. Customers buy products at SIG because of the last minute changes and the high delivery reliability. The many products, routings and varying batch sizes make for a complex planning puzzle. Adding to the complexity are the many hours of downtime and long setups. Knowing that these variables will not be solved with planning improvements, they will have to be taken into account: slack and variety has to be planned for. The more variety accepted, though, the more the performance of a production system degrades (Hopp and Spearman, 2000).

From the comparison made in paragraph 4.7 and other elements in this chapter, it can be concluded that the average WIP is too high. A reduction of 50% would be feasible if compared to the other flat glass companies. WIP is directly linked with lead-time. A WIP reduction will therefore lead to shorter lead-times. It is expected that an average lead-time reduction of 4 days should be achievable. Lower WIP will reduce the amount of money tied down in the factory. Shorter lead-times and less WIP will also make the factory more flexible. Especially the reduction of WIP will improve visibility on the shop floor and will make other problems and bottlenecks more recognisable.

This almost concludes the diagnosis phase of this research. How the various problems will be dealt with will be discussed in the following part of this research, the design phase. The diagnosis phase will conclude with a problem statement, to be found in the next chapter.

5 Problem Statement

This research was initiated to improve the production planning at SIG. During the analysis phase of this research, a standardization project had already been initiated on the business unit level. It became apparent that both projects were entangled and it has therefore been chosen to include part of the standardization project in the research.

Having identified the main problems in chapter 3 and 4, changes should be made to improve the PPC systems at SIG. With regard to the boundaries set in paragraph 2.2 and the unchangeable characteristics of the products processed, the focus of improvement is on the customers and the PPC framework. Regulating or restricting customer behaviour can be done limited only. As stated clearly by the mission statement, all orders should be accepted. This includes orders that cause disruptions to the stability of the production and planning processes. The PPC should be robust and flexible enough to deal with any variability caused by customers.

Based on the problems found in the previous chapter, several improvements will be proposed, starting in the next chapter. The first step is the selection of an appropriate PPC system and the associated future state of the production planning (chapter 0). Once the improvements for SIG have been identified, a gap analysis is performed per planning level (also chapter 0). This is done to identify the functionality gaps between the current and proposed future state of the production planning.

This gap analysis is then standardized and used to chart the functionality gaps between the current state and the future state of each flat glass factory involved in the standardization project (chapter 7).

The proposed redesign options will be modular. Once the gap analyses are returned from the various companies, the required improvements per factory are known. Factories will then be able to pick one or several of the improvements proposed for SIG and implement them (see Figure 2-1, page 17, for a procedural overview).

Solutions will be prepared and (partly) implemented for SIG only. Analyses and implementation requests by other flat glass companies will not be discussed, as this is outside the scope of this research.

6 Redesign and gap analysis

In this chapter, a redesign of the production planning and shop floor control systems will be proposed. To improve the current situation, a structured approach is used that takes all controllable factors and variables into account. As stated by Riezebos (2001), (re)designing a production system often goes hand in hand with changing the planning system. Improving the material flow on the shop floor (production system) will lead to changes in the way planning is performed and vice versa.

Radically improving, or innovating a process can be achieved by following several steps as proposed by Davenport (1993). Davenport proposed a six step approach to execute process innovations (Figure 6-1). After having identified the processes that require improvement, change enablers are to be found. A process vision is set that will focus the improvement project and will set clear targets. Finally, the current processes are analysed and new processes developed. All steps should be done, in order to achieve a (successful) implementation. The thirst and fourth step of Figure 6-1 have been completed respectively in chapter 2 and 3-4. In this chapter, the remaining three steps will be completed. Finding potential change levers, or improvements, for the PPC system and selecting a preferred theoretical model will be explained in paragraph 6.1. Setting the vision and the corresponding improvement objectives is done in paragraph 6.2. Based on the objectives and the selected model, a future state design is introduced in three aggregate levels (paragraph 6.3 to 6.6). Per aggregate level, the future state is compared to SIG' current PPC system. Required functional improvements will be found.

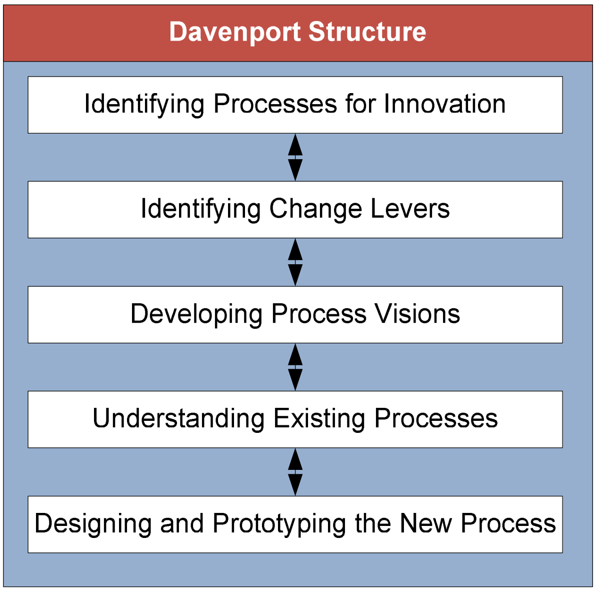
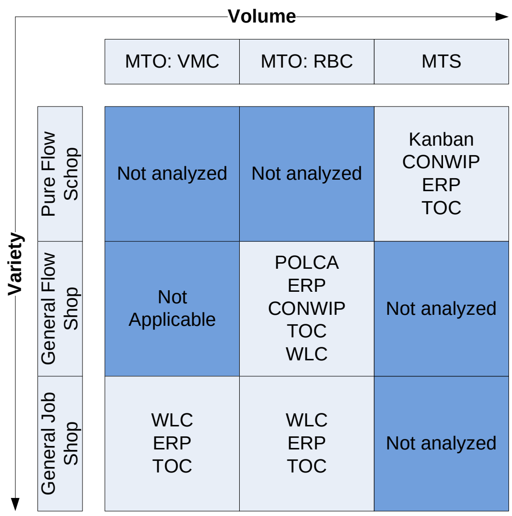


Figure 6-1 Process innovations steps

6.1 PPC selection

6.1.1 Requirements

The analysis of the planning procedures at SIG revealed a planning approach with a limited structured approach. It was apparent that a more structured PPC system will improve the planning functionalities on each level. In the literature, several PPC concepts can be found. To select the correct PPC for a company, a selection matrix was introduced by Stevenson et al. (2005) and integrated by Verweij (2008), resulting in Figure 6-2. In paragraph 3.4.1 and 3.4.6 SIG has been classified as a RBC / general flow shop based on the high variety in processed orders and the low – medium volume of the batches. From Figure 6-2 it can be concluded that five PPC concepts are fit for SIG, namely; TOC = Theory of Constraints, WLC = Workload Control, CONWIP = CONstant Work In Progress, ERP = Enterprise Resource Planning and POLCA= Paired-cell Overlapping Loops of Cards with Authorization (The various PPC's will be explained in the next paragraph).



The first concept can be excluded from further review based on the fact that SIG already has a type of ERP system: SAP. SAP can perform many functions, but planning the shop floor in detail is not its strength (refer to paragraph 1.6 for SAP functionalities). SAP does offer several big benefits and its functions have to be integrated with the selected planning solution. Choosing between the remaining PPC's requires a deeper analysis with more variables.

Figure 6-2 PPC selection matrix

6.1.2 PPC: Short introduction

The different PPC concepts will not be explained in-depth. For a good explanation of the different PPC's, please refer to the article of Stevenson et al. (2005).

6.1.2.1 POLCA

POLCA is a type of KANBAN system that uses 'POLCA-cards' to authorize production on the shop floor. POLCA combines elements of push and pull production. Material is pulled through the factory based on available capacity. Once a job has been processed at a work centre, the POLCA-card attached to the specification card will be returned to the previous machine, authorizing the production of the next order. If capacity, material and the authorization in the form of the POLCA card are all available at this upstream work-centre, the next released planned order will be processed. In one loop (two connected work centres), no more jobs can be processed or waiting than allowed by the number of cards. Restricting the number of cards restricts the level of WIP. POLCA requires a high level MRP system to coordinate the release of orders on to the shop floor.

6.1.2.2 Workload Control

WLC is designed especially for the MTO industry. It uses pools (waiting rooms) of orders, making the shop floor independent of the incoming order stream. The flow of orders from one planning level to the next is stabilized through release mechanisms that allow only a maximum number of jobs or WIP to the next planning level or onto the shop floor. A maximum level of capacity loading is set, either per department or per machine. As long as an order to be released does not exceed the preset capacity loading level, an order is released to the shop floor. Orders can furthermore be shuffled within the various order pools to make decentralized optimization possible. WLC does not control the flow of orders from machine to machine. After an order has been released to the shop floor, dispatching rules control the progress of jobs on the shop floor. A dispatch rule can be: First-in-first-out, shortest processing time first, etc. WLC does not control an order at the shop floor level, it assumes the dispatching rules are sufficient for the order to be processed efficiently (Land and Gaalman, 1996).

6.1.2.3 Theory of Constraints

TOC concentrates on keeping bottlenecks occupied. The factory works in the speed dictated by the bottlenecks. The theory also includes several management theories, but the main focus of TOC is on optimizing the use of bottlenecks and scheduling the rest of the factory accordingly.

6.1.2.4 CONstant Work In Progress

CONWIP is a shop floor control system that stabilizes the number of jobs on the shop floor. Every job processed on the shop floor is given a card. Once a job is processed completely, the card is sent back to the first station, allowing a new job to be started. CONWIP does not look at the loading of individual workstations, but limits the loading of the shop floor to a preset maximum WIP level.

6.1.3 Selection

In reviewing the four above PPC's, several common variables can be found. The first three important factors: volume-, routing- and product variety can be grouped into 'volume' variety and product/routing 'variety', covering the many types of production environments (Amaro, Hendry, Kingsman (1999). These variables are covered in the selection matrix from Stevenson et al. (2005) (Figure 6-2). A PPC needs to be selected that provides an improved planning structure for all planning levels.

In Table 6-1, the remaining four PPC's are compared on their ability to structurally improve the different planning levels. The third row of Table 6-1 holds the requirements of SIG with regard to the new PPC. Solutions will need to work on the six identified planning levels.

An additional column has been added for another important variable: the workload balancing capacity of the identified PPC's. Not all of the PPC's are able to balance the workload across the different machines on the shop floor. The current uncontrolled push system in place at SIG has to be improved. A PPC that balances capacity is therefore imperative.

	Workload balancing capability			Planning levels					
	Yes	No		Aggregate control	Workload control	Material control	Order release	Detail planning	Shop floor control
SIG (required)	X			X	X	X	X	X	X
CONWIP		X[1]			X		X		X
POLCA	X				X		X		X
Workload Control	X			X	X	X	X		
TOC	X[2]						[3]	X	

Table 6-1 **PPC selection table. An X represents 'can do'.**

Comparing the remaining four PPC's to SIG's requirements, it is clear that no 'one' solution can be chosen. TOC is the second PPC to be excluded. Although good in keeping bottlenecks occupied optimally, TOC is less capable in the planning and control of the 'material control' and 'aggregate production' planning levels (Stevenson et al. 2005). Floating bottlenecks are also problematic, making TOC not an ideal PPC for SIG. Unlike TOC, WLC improves performance on most planning levels. The drawback of WLC is that once orders are released to the shop floor, WLC does not control the physical flow of orders very well. It does not stop bottlenecks from overloading or give signals to stations upstream if a machine is broken down. WLC uses 'simple' rule like FIFO and assumes these rules are sufficient. In real life, problems affect the planning, making FIFO not robust enough against WIP build ups. Neither WLC nor TOC are very good in controlling the flow of work from machine to machine. POLCA and CONWIP do have these functionalities, but both need a high level MRP system to control and plan on the higher 'aggregate level' and 'material flow level.'

A combination of WLC with either POLCA or CONWIP would make improvements possible on all required planning levels. In theory, WLC structures the release of orders between each planning level right up unto the shop floor level. On this last level it would have to give control to a shop floor control system. Choosing between CONWIP and POLCA, POLCA then becomes the preferred shop floor control system. CONWIP makes use of one 'loop' covering all departments and stations, no loops between individual machines are in place. In contrast with POLCA, CONWIP does not balance the workload across the individual stations and therefore does not protect bottlenecks (Germs and Riezebos, 2008). A combination of WLC and POLCA is therefore chosen to be implemented at SIG.

[1] Germs and Riezebos (2008)
[2] Stevenson et al. (2005)
[3] Stevenson et al. (2005)

Both WLC and POLCA have specific requirements and before a full scale implementation, it is imperative that a detailed analysis of the literature and the situation at SIG is made.

6.2 Process Visions and objectives

Now that the enablers of change have been found (POLCA and WLC), it is necessary to define what the future state of the production planning should incorporate. The future process state is embodied in a process vision. A process vision is formulated in line with the corporate strategy. A process vision incorporates several measurable objectives and attributes, necessary to measure the adherence of the future system state with the proposed process vision. Objectives are quantifiable, whilst attributes are more soft and qualitative. An example of an attribute is 'break down departmental barriers'.

In line with the corporate mission (paragraph 1.3.2), a future state of the PPC system should be able to cope with any type of order. Accepting an order is possible only if it can be planned for within the required due date and if a marginal profit can be made. To know if planning the order is feasible, the exact throughput time, the current and future capacity loading and the costs associated with the order need to be known. If for example an order can be made on time with two hours of overtime, the benefits should outweigh the extra costs. If these extra costs cannot be claimed from the customer, a later due date must be accepted by the customer or the order declined. These variables depend on a wide range of factors, including labour costs, production rates, current WIP, etc. In order to make the right decision with regards to a new order, insight in the variables and the underlying factors is required. The production planning needs to be controllable, reliable and adjustable. The production planning needs to know the variables it can influence, to be able to accept or decline a new order. They also need to know what the effects of adjusting one variable are on the remainder of the current planning and shop floor status. This leads us to the process vision:

"In the future PPC state, the production planner needs to be in total control of the variables that affect the production planning and shop floor."

In this vision, the shop floor is seen as a black box. How an order is processed on the shop floor is not important. It is important though to know how to affect this black box. For example: Limiting the level of WIP on the shop floor should lead to shorter throughput time. Or: adding more capacity leads to a reduction of lead-time.

This process vision for SIG is translated into objectives and attributes that can be used to measure the success of the process vision. The objectives and attributes are given in Table 6-2. These objectives are based on the conclusions made in paragraph 4.8. POLCA and WLC are the change enablers that will help to achieve these objectives.

SIG Objectives	SIG Attributes
Reduce total factory WIP with 50%	Pull instead of push production
Reduce average production lead-time with 4 days	Decrease departmental boundaries.
Maintain current delivery adherence (95%)	Increase decentralized planning decisions
	Stabilize capacity usage (reduce need for overtime)

Table 6-2 Process vision objectives and attributes

6.3 Creating the future state

Now that the process vision and the change levers have been established, the future state of the PPC system can be presented. This future state will be based mainly on the principles of WLC and POLCA. To create a good overview of the proposed future state, three aggregate zooms will be given. First a high level overview of the general flow of orders through the future production planning process is given. This is done with the help of a prism table, all explained in paragraph -. The next step is to give a more detailed overview, zooming in on the area most 'affected' by Workload Control (paragraph 6.5). The third step goes one aggregation level deeper and will look at the shop floor planning level and POLCA (paragraph 6.6).

Each paragraph will begin with a detailed explanation of the future state. After the explanation the current situation at SIG will be compared to the future state. Changes required to achieve the future state will be given.

6.3.1 Boundaries

- Beginning January 2009, all flat glass companies will receive or upgrade to SAP Progress. The gap analysis therefore has to focus on the interaction between the functionalities offered by SAP and the requirements needed by the companies.
- SAP is a MRP package that has proven to be efficient in handling information flows such as material requests, machine routing, the bill of material and information about printing screens, jigs and templates. It is unnecessary to take these information flows into account.

6.4 Future state I: General overview

For the future state of the production planning to work properly, the required planning elements introduced in paragraph 4.1 must be integrated into the current production planning and control processes of SIG. See Figure 6-3 for a recap of the interaction of the planning elements.

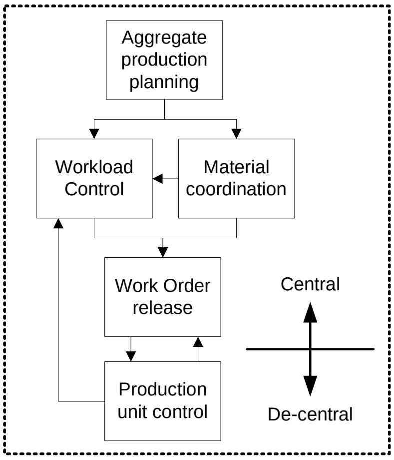


Figure 6-3 This is a copy of Figure 4-1: Production planning framework.

The first high level overview is given in a prism model, similar to the one explained in paragraph 3.1. All required planning elements are integrated in this prism framework (Figure 6-4). This prism overview is the improved future version of the current planning processes, as has been depicted in Figure 3-1. A description of the overview:

Starting in the top left corner [1], a customer creates orders [2]. Based on these customer orders SAP can create planned orders [3], expecting sales in the near future. All received orders are processed by a SAP run. The SAP run will label the received orders 'Planned order' [3] and add a scrap percentage to the required customer quantity. All planned orders in SAP will enter the so named 'planned order pool' (waiting room) of orders [4]. Some customer behavior can be forecasted [6]. This is done by the order planners [5] based on historic data. Forecasted orders also become planned orders.

Based on the available orders in the 'planned order pool' [4] a capacity planning activity takes place [9]. This is a rolling process and can be seen as the aggregate production planning function (see for an explanation: Table 4-2). Every week the capacity loading of the coming three weeks is analyzed. Orders are postponed or pulled forward to smooth the capacity loading. The amount of orders to be processed in the coming weeks [4] is matched to the available capacity [9&10].

Orders that need to be processed in the coming three weeks receive a status change, going from 'planned order' to 'unreleased shop order' [10] and enter another pool. This pool of 'unreleased shop orders' [11] is input for the weekly planning [13]. The weekly planning concurs with the combined 'material coordination' and 'workload control' function (see: Table 4-2). The weekly planning will plan only with the orders made available [11]. If an order is selected from the pool [11] and will be processed in the coming four shifts, another SAP status change is made. The selected 'unreleased shop order' will change to a 'released shop order' [14], entering the last pool [15]. The next step is the day to day planning (Work order release function, Table 4-2) performed by the planners [16]. The planners will sequence orders to optimize the factory loading and minimize setup time. Their output is a production plan which basically is an order processing priority list [17].

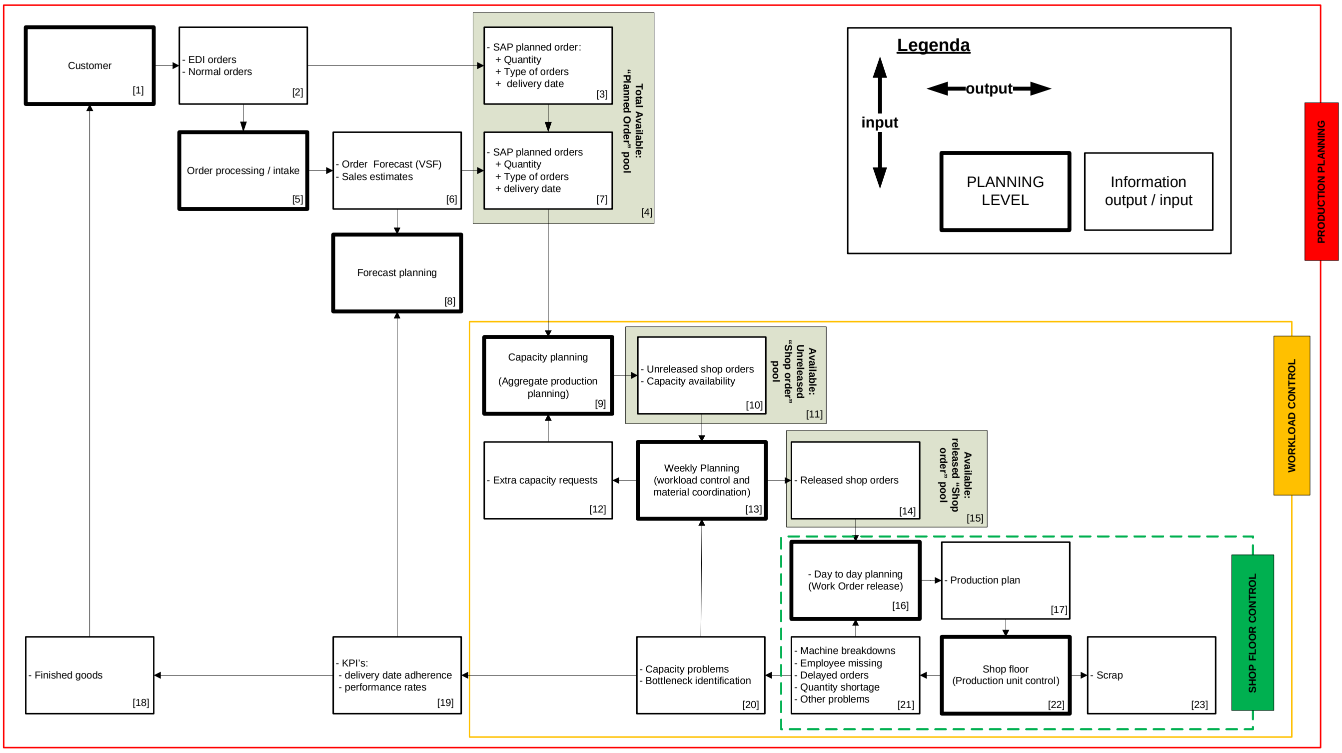


Figure 6-4 **Production Planning structure**

The last step is the actual processing of raw material to finished goods on the shop floor [22]. The machine operators receive a production plan from the planners. Re-sequencing these orders can be done limited only, as the list of available orders is limited too. The output of the shop floor consists of material in the form of scrap [23], finished goods [18], information in the form of KPI's [19] and feedback necessary for the daily planning [20&21].

Most of the processes described above can be described as 'workload control'. At several moments in time the planned orders and shop orders are analyzed and filtered. This filtering system controls the maximum inflow of orders into the next level. E.g.: After selecting a maximum workload level, the planners will not allow more orders onto the shop floor than it can handle capacity wise. The planners again will only see a list of 'released Shop Orders' [15]. The planners are shielded from an overflow of shop orders and only take into account those orders with an approaching due date. When possible, the shop floor will process the orders without requiring extra input from the planners. The pull shop floor system POLCA will control the flow of orders from one machine centre to the next. At the machines, the operators have only some degree of freedom: if no list of priorities is given by the planners and only a 'to do today' list is given, the operator can optimize by minimizing setup time with the physically available orders.

6.4.1 Changes required to achieve future state

In order to make the above described processes work, several changes need to be made to the current processes (SIG). As all of these changes will happen within the yellow enclosed area (Workload Control), the changes will be discussed in paragraph 6.5. But before the next aggregated level is discussed, several elements that have influenced the proposed model need to be addressed.

6.4.2 Influence: Socio-technical design principles

The success of the implemented production planning system depends on the acceptance of its end user: the planners. Not taking socio-technical elements into account when developing a technical system will ensure failure. Most of the above described processes require the interaction of humans with a (technical) planning system. Cherns (1987) gives several socio-technical design principles that help to create a feasible production control system (Table 6-3). While designing the processes in paragraph - and 6.5, several socio-technical aspects have been taken into account.

Socio-technical Design principles	Explanation
Compatibility	The design of the production system should be compatible with the design objective.
Minimal critical specification	No more should be specified than is essential. That what is essential, should be specified.
Variance control	Employees have to be able to adjust and control the variables that they are responsible for. The control should not cross organizational boundaries.
Boundary location	Sharing information, knowledge and learning should not be bound by departmental barriers.
Information flow	Information for action should be directed first to those whose task it is to act.
Power and authority	The person or department responsible for a certain task should have enough resources, tools and authority to perform the task.
The multi-functional principle	If the environmental demands vary, it then becomes more adaptive and less wasteful for each element to possess more than one function.
Support congruence	Support systems should reinforce behavior the organization needs. (training, conflict resolution, etc).
Transitional organization	Those designing a system should implement the design.
Incompletion	No design is complete. The end of an implementation is the beginning of the next.

Table 6-3 Socio-technical design principles (adapted from Slomp and Ruël 2001)

The proposed future state and the concept of Workload Control in general, are based on the idea of variance control. A machine operator does not need to know what order he has to produce next week. The operator is only interested in the next order he needs to process, the quantity and the order specifications. Giving him information about delayed orders is in violation with another design principle: information flow. A similar argument can be raised with concern to the production planners. Planners only need to know those orders that should be processed within the coming few shifts. An order of which the raw material is unavailable or has a due date weeks out, should not be visible for the planners. The long term overview should only be visible for those who can influence it: logistic managers and long term capacity planners.

The second major cornerstone of the future state is focused on the minimal critical specification guideline. The gap analysis is only concerned with the most essential decisions per planning level. It is not possible to discuss and chart every function performed at each planning level. Only the core functions as discussed in paragraph 4.1 are taken into account.

6.4.3 Influence: Controlling / controlled

In the theories provided by De Leeuw (2000), the controllability of a system depends on a number of factors. A controlling system (e.g. the production planning) can only process that much data (confirmations, downtime, rush orders, etc.) from the controlled system (shop floor), before it overloads. If one processor (planner) is overloaded, a second processor can relieve the pressure. But having two processors requires internal coordination which in turn could cause miscommunication and requires extra work. This analogy also applies to the work done and feedback created on the shop floor. Reducing the amount of work on the shop floor or reducing the amount of feedback required to plan properly eases the efforts required from the planners. Control only that what needs to be controlled, and leave the rest up to the system. This theory is confirmed by the theory of Goodsflow Controlled Items introduced by Wielen et al. (1995) and the minimum critical specification guideline discussed in the previous paragraph.

POLCA and WLC both support this theory. POLCA ‘takes over’ control of the shop floor and requires only that the number of POLCA cards and the list of planned orders are controlled. POLCA regulates the flow of orders between machines and automatically restricts the flow of orders to bottlenecks. WLC limits the flow of information to a next planning level and thus protects the ‘processor’ from overloading. By not releasing all planned orders to the planners, but only the orders for the next four shifts, the planners cannot start planning orders prematurely, creating unnecessary WIP.

6.4.4 Influence: SAP

A final major influence on the development of the gap template is its interlink with SAP. As said, SAP will store most information used in the company. The system performs several basic functions like calculating lead-time, releasing orders to the shop floor and storing feedback from the shop floor.

WLC and POLCA have to interact with these systems and SAP should support WLC. If an order should receive a status change or follow an alternative routing, this information has to be stored in SAP.

6.5 Future state II: Workload Control

6.5.1 Workload control

As explained before, WLC limits the flow of orders to the shop floor and on the shop floor itself. This is done with the help of four filters, which allow only certain orders to pass from one level to the next. A total of three planning phases exist and each will be discussed briefly.

6.5.1.1 Customer enquiry phase

In this phase the customer has not placed his order yet. He is in discussion with the company about the order due date and if the company is willing to accept the order. The company in turn is figuring out if it can accept the order capacity-wise and if they will be able to make a profit. An order accepted in an already busy period may lead to capacity problems at bottleneck machines. The obvious trade-off being the loss of turnaround and possible profit if the order gets declined. The first filter is concerned with this trade-off. A detailed capacity loading overview can help this decision.

6.5.1.2 Job entry phase

If the order is accepted, the order enters a waiting pool of orders and will remain there until the second filter allows the order to pass on. In this pool, the production details like routing, quantities and required material are determined. An internal delivery date is also chosen, which is essential for the second filter to do its job. Based on the quantity, routing, the associated machine capacity and expected lead-time, the order will be picked from the order pool.

6.5.1.3 Job release phase

The order is now ready to be processed on the shop floor, but is restricted by a job release mechanism. This mechanism stops orders from overloading a specific machine or routing. If capacity is available on the required machines, the filter will allow the order to be released to the shop floor.

6.5.1.4 Shop floor control

Orders released to the shop floor are processed with the help of a predetermined processing rule like FIFO or 'earliest due date first'. If a machine breaks down or unforeseen problems occur, the planners have authority to stop or reroute orders. If necessary, requests for extra capacity are made to the higher planning levels.

6.5.2 Changes

The strength of WLC is in its ability to limit the release of orders from one planning level to the next. In the theory on WLC, several algorithms that focus on optimizing the flow of orders from level to level can be found. These algorithms help to sequence the list of orders to obtain a minimal WIP level, to maximize the loading of the bottlenecks and to improve the throughput rates. But applying these algorithms requires an almost perfect situation; all variables need to be known and no machine breakdown or quality issues should occur after the planning is drafted.

The current status of the shop floor makes any planning based on mathematical functions impossible. Minimum requirements like correct production rates, limited downtime and availability of all secondary resources like labor and skills, cannot be guaranteed. It is therefore chosen not to pursue a mathematical line of thought. From here on, it is assumed that the planners can perform the optimization functions needed on the shop floor as required by WLC. By using crude measures like setup optimization, some optimization is achievable. Over time improvements on the shop floor will lead to a more stabile production process. Once the shop floor can be 'trusted' more (mathematical) optimization is possible.

The current primary objective is creating the infrastructure required for WLC to work. This framework will be created with the help of SAP and several changes to the current planning procedures, as will be discussed. The changes required for WLC to be successful are given in paragraph 6.5.4 to 6.5.5. First, the framework itself will be introduced.

6.5.3 Framework

In Figure 6-5 an exploded view of the yellow enclosed 'workload control' area (Figure 6-5) is given. This overview is a future state and is based on SIG. It depicts the detailed working of Workload Control at SIG.

Appendix

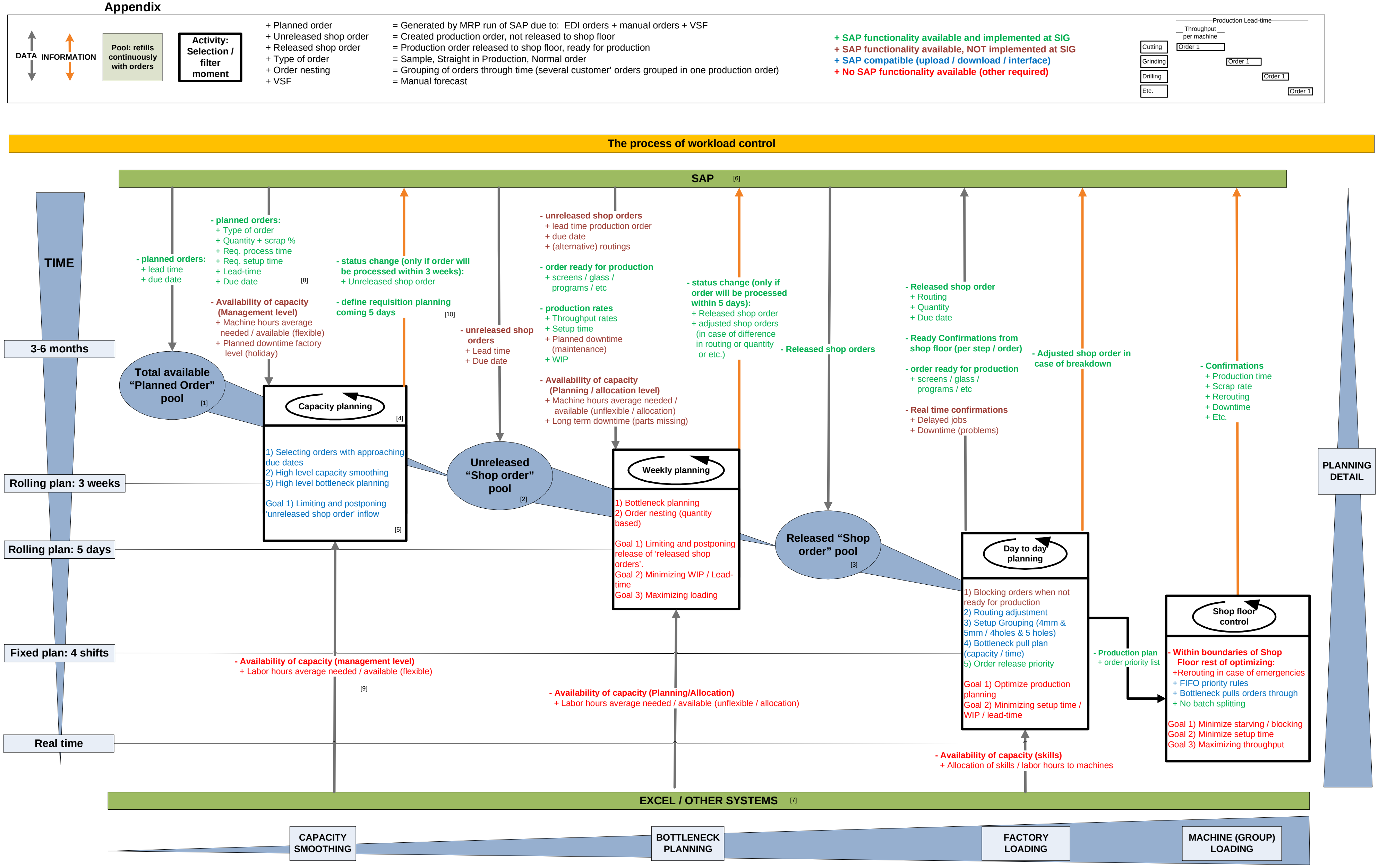


Figure 6-5 Workload Control

The thick black lined boxes represent the different production planning levels from Figure 6-4. Between these boxes, the different ‘pools’ [1+2+3] have been drawn. Every level performs an activity. E.g.: ‘capacity planning’ [4] selects orders from the total available pool of ‘planned orders’ [1] and blocks those orders that do not adhere to the goal [5] of this selection step. Capacity planning has the goal to limit the inflow of unreleased shop orders to the next level. Doing this will ensure the next planning level is not overloaded with orders they will not be able to process anyway (=Workload control).

On the capacity planning level, it is tried only to: 1) select orders with approaching due dates 2) smooth the orders over the available capacity in the coming three weeks 3) plan the bottlenecks on a high level. To be able to do this task, data is needed. Currently, data is provided from two sources: SAP [6] and other systems, like Excel [7]. As can be seen, the capacity planning receives ‘planned order information’ (from SAP) [8] and ‘information about the availability of capacity’ (Excel based) [9]. The output of the capacity planning phase firstly consists of a ‘status change’ [10] of the accepted orders and a ‘requisition planning for the coming 5 days’. This requisition plan will allow the supporting departments to create the necessary printing screens, order raw material and prepare jigs if necessary. Most of this work will have been done prior to this step. Only rush orders will receive this treatment.

The rest of the schema can be read in a similar fashion. The goal of this schema is to identify the required information for the different planning steps. The closer an order comes to its due date, the more detailed its planning becomes. As said, it is no use for the planners to know about orders that will have to be finished next month. This process helps the different management levels to control what they can and should control.

6.5.4 Gap analysis

As Figure 6-5 is based on the requirements of SIG, it has been completed in this fashion. Per planning step, several sources of information and links with other planning steps are deemed necessary. As this schema is a future state, not all information flows and functionalities are fully available or implemented. Four ‘gap stadia’ have been defined and indicated with a color. In the appendix of Figure 6-5, the stadia and corresponding colors can be found.

Some functionalities where already in place and are functioning properly. These are the green and blue colored items. Some functionalities are performed in SAP, some are done in other systems, like Excel. In a later stadium the blue functions ought to be improved and integrated into SAP if possible. This is done to minimize redundant databases and all associates risks. Focusing on the blue items now would be unwise: some real functional gaps exist that require immediate attention to make WLC work.

The brown colored items, defined as ‘SAP functionality available, NOT implemented at SIG,’ requires immediate attention. The required functionalities are available in SAP, but have not yet been implemented. Projects should be started focusing on these functionalities and how to make these available for the benefit of WLC and SIG.

For all functions and information flows colored red, solutions still need to be found. No direct ‘easy’ solution is offered by the literature on Workload Control or functionalities within SAP. The internal optimization functionalities of the different planning levels cannot be performed in SAP. As explained above, these functionalities will be ignored at first: once the basic structures and adjustments have been made, one can start focusing on optimizing these functions.

6.5.5 General changes

The main change proposed in the schema is the structuring of the information flow between the different planning levels. SAP can host most of these information flows, but this will also require a mentality change from all employees involved in planning.

First of all, the separation of responsibility between those who receive and plan orders will lead to an improvement. Order planners are not allowed to plan or release orders to the unreleased shop order pool. Release can only be authorized by the one who does the capacity planning. An order will reach the production planners if capacity is available within the next few shifts. This separation of authorities and tasks enables an essential improvement: the customer is not in control of the shop floor any more. Decisions can be made more rationally. Rush orders can of course not be banned completely, but a good working shop floor control system will support these ‘annoyances.’

6.5.6 Résumé

This brings us to the last aggregate zoom. Although changes can be made on each planning level, the shop floor is an obvious place to start improvements. Reducing the WIP, optimizing the supply to bottlenecks and minimizing the setup time can lead to drastic improvements on the other planning levels. POLCA is a way to reduce the WIP and reveal the problems underlying the seemingly high WIP levels and long lead-times.

6.6 Future state III: Shop Floor Control

The black box in the lower right corner in Figure 6-5 gives the functionalities performed on the shop floor. These functions, or goals, include: minimizing setup-time, maximizing throughput and minimizing production cell starvation/blocking. POLCA is a means to achieve these goals. POLCA helps to reduce the levels of work in progress on the shop floor. Based on several articles and a thorough review of the 5 step POLCA implementation analysis improved by Kraayenbrink (2007), a POLCA system can be proposed for SIG. Once POLCA is successfully implemented, it is believed that the shop floor is more controllable. WIP levels are manageable by varying the number of cards in circulation. POLCA also supports several of the socio-technical design guidelines (Table 6-3), specifically the location of boundaries and how to get rid of them. POLCA increases the need for communication between departments and ignores the traditional hierarchical communication and control lines. Sub-optimization is less likely to happen: The availability and sequence in which orders are processed is strictly controlled by the number of cards and a high level sequenced pull plan. Operators are directly responsible for their decisions: ignoring the visual signals or skipping the next planned order can create starvation or blockages in downstream processes. It is therefore imperative that the operators understand the logic behind POLCA and why it is necessary for them to actively cooperate in the implementation. If POLCA is not carried by the operators, it will fail.

A more detailed introduction to POLCA is essential and is given in 6.6.1. By following the implementation steps of Kraayenbrink (2007), the details and working of POLCA will become clear (6.6.2). This is followed by some additional changes that enable POLCA to work properly at SIG (paragraph 6.6.3).

6.6.1 POLCA introduction

POLCA limits the flow of orders between two production cells with the help of POLCA cards. A POLCA loop is created over two machine cells that process orders sequentially. Within a POLCA loop, orders flow from A to B, accompanied by an '[A/B]' POLCA card. POLCA cards are loop specific. Once machine B has processed the order, the POLCA card is returned to machine A. Only a certain number of POLCA cards are present in a loop. Before an order can be started at machine A, several preconditions need to be met: An operator has a sequenced production plan which he follows strictly. The operator selects the next order and identifies where it has to go after his process (e.g. it goes to machine B). He then finds the corresponding POLCA card [A/B]. If he does not have an [A/B] POLCA card, he skips this job and goes to the next on his production plan. Machine B apparently already has some orders sent by machine A and cannot currently process the orders. Machine A starts producing something for machine C, as he did have an [A/C] POLCA card. If the operator does not have any POLCA cards left, or if he runs out of production plan, he stops his machine and asks to be reassigned to a different machine. After a while, some POLCA cards are returned and he can start his machine again.

Machine B goes through a similar process. The order which came from machine A has the POLCA card [A/B] attached to its specification card. The order will continue to machine D. Machine B has to attach a [B/D] POLCA to the specification card. The specification card now holds an [A/B] and [B/D] POLCA card. Once machine B has processed the order completely, he returns the [A/B] POLCA card to machine A, signalling that he has processed the order and can receive some more work in the near future. The loop [A/B] will probably hold several POLCA cards. This ensures that machine B will always have some work in its inbound WIP and will never run out of work, given of course that orders frequently flow from machine A to B.

POLCA stops machines from building up WIP for machines that cannot process orders as fast as the supplying cell. The production plan is a pull plan based on due date. A high level MRP system decides which orders should be started to reach the due date in time. The MRP system also decides the sequence in which orders should be processed. This sequence should try to minimize setup times at bottleneck machines. An operator will always try to start a job that is most urgently required. Returning POLCA cards signal the availability of capacity at the next process.

6.6.2 POLCA scanning tool

Kraayenbrink (2007) refined the 'POLCA scanning tool' introduced by Suri and Krishnamurthy in 2003. This scanning tool can be used to establish if a company can implement POLCA. It also provides a checklist that helps to focus on those elements critical for a successful implementation. The tool consists of five phases, each with several questions or tasks to be performed in sequence.

6.6.2.1 Phase 1: Setting the POLCA goals

The first phase is concerned with setting goals and identifying the reasons why POLCA is to be implemented. The reasons why POLCA has been proposed for SIG and the problems it has to counter have been previously discussed in paragraph 6.1 and 6.2. The main goals are to reduce the WIP levels with 50%, to shorten lead time with 4 days and to reduce the departmental boundaries. See Table 6-4 for a complete overview of the goals.

The success of POLCA will be measured firstly by recording the average WIP levels on the shop floor. Secondly, a download from SAP will provide information with regard to the average lead-time. Measuring the other 'softer goals,' or attributes, will be more difficult. It is expected that questions with regard to the POLCA system will initially be addressed to the implementers and the planners. After a while people will start to understand the system and will inquire at their colleagues about the

SIG Objectives	SIG Attributes
Reduce total factory WIP with 50%	Pull instead of push production
Reduce average production lead-time with 4 days	Decrease departmental boundaries.
Maintain current delivery adherence (95%)	Increase decentralized planning decisions
	Stabilise capacity usage (reduce need for overtime)

whereabouts of POLCA cards and orders. If the system works correctly, machines will be knocked off once POLCA restricts the release of orders. Personnel will be transferred to other machines in need of operators and production will start to stabilize.

Table 6-4 Process vision objectives and attributes (copy of Table 6-2).

6.6.2.2 Phase 2: Identification of the POLCA cells

Material can be processed on either the fast line or in the remainder of the factory, typified as a flow shop. The fast line can be seen as one big work cell and is therefore excluded from the POLCA system. The assembly department is also disregarded as only a small part of products visit this area. Assembly can be seen as an internal customer with specific internal due dates. The focus of POLCA is therefore on the flow shop-part of the shop floor. In paragraph 3.4.3 a grouping has been made of the machines in the flow shop. Based on machine similarity and productivity 22 cells were identified (Table 6-5). These 22 cells are used as the POLCA cells.

This phase also deals with the following issues:

- Question: Where in a cell are the quality control moments?
    - Answer: As defects can happen at any time during the process, quality is monitored by the operators. If a concern arises, quality experts are called upon and the process will be halted or suspended until a solution can be found. A general quality check is performed after each department.
- Question: Where are the material buffers located?
    - Between all departments. Currently, all material is stored after a process until the job is required by the next process step.

POLCA cells	Grouped machines	POLCA cells	Grouped machines
CL1	Cutting line 1 + cutting m/c 3	SCH	Drilling m/c 15 (Schiatti)
B2	Bottero 2, C/M 2+4, Horizontal cutting bench, SCT, Tempax SC	CPC	Janbac 1, 3, 4, 5, 8, 9 (Control Panel Centre)
GL 4	Grinding line 4	HT	Janbac 10, 11, 14 (Hobtops)
GL 3	Grinding line 3	IPL	Printing line 1.1/1.2/1.3/1.4
R6&8	Rotary grinding m/c 6 + 8	PL 4	Printing line 4.1/4.2
R7&11	Rotary grinding m/c 7 + 11	PL 6	Printing line 6.1/6.2/6.3
INTMC	Rotary grinding m/c 9+10+12+ Waterjet	PL 3	Printing line 3 (Argon)+ SIAS+Hand printing bench
R1&2	Rotary grinding m/c 1 + 2	PL 9	Printing line 9
R5	Rotary grinding m/c 5	HF 1	Horizontal Furnace 1
WA	Wheel Arris m/c	VF	Vertical furnace
ILD	Inline Drilling m/c 12	BF	Bending Furnace

Table 6-5: Machine Grouping (Copy of Table 3-6)

Table 6-6 gives an overview of all possible inter POLCA cell routings in the factory (Based on Figure 3-5). Every cross represents a link. Sometimes an order will revisit a previous machine or will pass a machine twice. This happens in the printing department but also at grinding machines.

FROM \ TO	CL1	B2	GL4	GL3	R6&8	INTMC	R7&11	R1&2	R5	WA	ILD	SCH	CPC	HT	IPL	PL4	PL6	PL3	PL9	HF1	VF	BF
CL1		x	x	x	x	x	x	x	x	x											x	
B2			x	x	x	x	x	x	x	x											x	
GL4						x					x	x		x	x	x	x	x	x	x		
GL3	x	x		x		x				x	x	x	x	x	x	x	x	x		x		
R6&8						x		x			x	x	x	x	x	x	x			x		
INTMC						x				x	x	x	x	x	x	x	x	x	x	x		x
R7&11			x			x		x			x	x	x	x	x	x		x	x	x		
R1&2						x						x		x		x			x	x		
R5						x		x			x	x	x	x	x	x	x	x				
WA						x						x	x				x	x		x		
ILD															x	x	x			x		
SCH															x	x	x			x		
CPC										x					x	x	x	x		x		x
HT															x	x	x		x	x		x
IPL															x					x		x
PL4																x				x		x
PL6	x																x	x		x	x	x
PL3																x	x	x	x	x	x	x
PL9	x																		x	x		x
HF1																x	x	x	x			
VF																						
BF																						

Table 6-6 Routings to and from POLCA cells

6.6.2.3 Phase 3: Checking the basic requirements

The first requirement in this phase is establishing reliable average lead-times within the POLCA cells. Reliable internal lead-time and throughput rates are essential for the establishment of a high level MRP system. SIG already has an MRP system: SAP. Average lead-time is also essential for establishing a quantum per POLCA card. For example, if the average internal lead-time is 30 minutes per order, a normal (30min) job should get one POLCA card from the previous cell. If it is a big order (60min), 2 cards should be attached, as it will take longer to process this job and blocks more capacity at the next stage.

SAP holds all needed production and throughput rates. But in order to ensure a successful implementation at SIG it is chosen to 'standardize' throughput time: one POLCA card will stand for one production order. This is done to ensure that the employees on the shop floor will get to know the system. Suri and Krishnamurthy (2003) also believe it is wise to start with one POLCA card per order. Once the system is working and initial problems are solved, a more detailed investigation into throughput rates and 'quantum' per card will be started.

A second requirement is the availability of production lists on the shop floor, holding information such as 'next order', 'next work station of next order' and 'expected throughput rate'. These lists are currently available at SIG and hold all up to date information about the preferred order processing sequence and other relevant data. As SIG is currently a 'push' factory, these lists will have to be used differently in the future state:

Currently the production list is sequenced by the planners and varies per machine cell. This leads to plant wide sub-optimization as these lists are created with a push philosophy. Material is processed at the a workstation in 'optimal' sequence, but will then end up in stock waiting for the next process step, where a different optimal sequence has been chosen. In a pull production system the last processing step will pull the required orders forward based on the (internal) delivery date. The production plan of the upstream cells should adhere to the 'master' schedule as used at the last station. If POLCA cards are returned to an upstream production cell, the next sequenced order should be processed. This enables the last process step to pull the right products forward and stop those orders with lower priority. The sequence in which orders are pulled through the factory, should be a trade-off between minimizing setup time at bottleneck machines and orders with approaching due dates.

A third concern is the control and flexibility of available capacity. The average capacity utilization should be between 30 and 80% in order for POLCA to function. The current average utilization is difficult to establish at SIG (Table 3-7). Currently capacity is varied at non-bottleneck machines to ensure that the average capacity loading per shift is as high as possible. Labour availability can be varied on most machines, but some bottleneck machines do have labour capacity restrictions. Skill cross functionality training is currently tackling this problem.

6.6.2.4 Phase 4: Developing the POLCA framework

Based on an analysis of the production routings, the experience of the planners and logistics manager, the relevant from-to loops have been established (Table 6-7). Compared with Table 6-6, several loops have been excluded. These loops have been deleted as they happen very infrequently (e.g. once yearly) or concern rework on different machines.

Several loops traverse process steps and return to upstream stations. Some interdepartmental movement happens. The various colours in Table 6-7 represent the different departments.

	TO																					
FROM	CL1	B2	GL4	GL3	R6&8	INTMC	R7&11	R1&2	R5	WA	ILD	SCH	CPC	HT	IPL	PL4	PL6	PL3	PL9	HF1	VF	BF
CL1				x	x	x	x	x	x	x											x	
B2			x	x	x	x	x	x	x	x											x	
GL4						x					x	x		x	x	x	x	x	x	x		x
GL3	x					x				x	x	x	x		x	x	x	x		x		
R6&8						x		x			x	x		x	x	x	x			x		
INTMC										x	x	x	x	x	x	x	x	x	x	x		x
R7&11						x		x			x	x	x	x	x	x		x	x	x		
R1&2						x						x		x		x			x	x		
R5						x		x			x	x	x	x	x	x	x	x				
WA						x							x				x	x		x		
ILD															x	x	x			x		
SCH															x	x	x			x		
CPC						x				x					x	x	x	x		x		x
HT						x									x	x	x		x	x		x
IPL																				x		x
PL4																				x		x
PL6																		x		x	x	x
PL3																x	x		x	x	x	x
PL9																				x		x
HF1																x	x	x	x			
VF																						
BF																						

Table 6-7 Relevant from-to relations

The various POLCA loops need to be established in such a way that they contribute to the goals set in phase 1. In order to achieve a reduction of the total WIP, the amount of POLCA cards flowing between cells should be limited. This can only be achieved by establishing an initial number of cards and then gradually adjusting this number to optimize the WIP. The number of cards in a cell is based on the formula used by Epping (2005):

$$NA/B = (LTA+LTB) \times (NUMA,B / D)$$

Parameter	Definition
NA/B	Number of POLCA cards in a POLCA loop [cell A / cell B]
LTA	Estimated average lead-time for cell A
LTB	Estimated average lead-time for cell B
NUMA,B	Total number of jobs that go from cell A to cell B during the planning period
D	Length of the planning period

Table 6-8 Formula explanation

Table 6-9 gives the results of this formula. The number of cards in each loop is not 100% accurate. This number may vary over time due to changes in customer orders or product routing. The numbers give an indication of how to initially populate the loops. The correctness of the formula itself comes with clear warnings from the different authors. Adjustments are required regularly, especially in the initial stages.

FROM \ TO	CL1	B2	GL4	GL3	R6&8	INTMC	R7&11	R1&2	R5	WA	ILD	SCH	CPC	HT	IPL	PL4	PL6	PL3	PL9	HF1	VF	BF
CL1				2	7	3	4	3	4	1											1	
B2			2	2	2	6	4	1	2	1											1	
GL4						2					12	4		4	5	4	2	3	4	3		1
GL3	1					1				5	2	3	8		2	1	2	2		2		
R6&8						4		2			7	7		2	2	2	1			1		
INTMC										1	1	1	2	3	2	3	4	6	5	3		1
R7&11						7		3			3	4	1	2	1	2		2	3	1		
R1&2						2						1		3		3			2	1		
R5						3		1			2	2	8	1	1	1	2	1				
WA						1							5				1	1		1		
ILD															10	5	1			4		
SCH															9	10	3			2		
CPC						3				3					1	1	23	1		3		1
HT						2									1	3	1		1	1		1
IPL																				6		2
PL4																				10		1
PL6																		4		5	4	3
PL3																1	1		1	5	4	2
PL9																				5		1
HF1																1	1	1	1			
VF																						
BF																						

Table 6-9 **Number of POLCA cards**

6.6.2.5 Phase 5: Evaluating the effectiveness of POLCA

If the preceding phases have been successfully completed, it is assumed POLCA can be implemented. This phase focuses on the effectiveness of the POLCA system. Several factors can influence the successfulness of the POLCA system. The first concern is about converging material streams. As no materials are joined in the flow shop part of the production department, this concern is disregarded.

POLCA requires a high level MRP system that, simply said, decides when which orders should be released to the shop floor. The MRP system requires that the various production rates (setup-time, cell-lead-time, waiting-time) are correct, as this is necessary for calculating release dates and the number of POLCA cards. At SIG, correct rates cannot be guaranteed. Several of the rates are difficult to establish and depend on machine quality and operator experience. Establishing correct rates is an ongoing concern and leads to an adjustment of the POLCA system. In the initial calculation of the number of POLCA cards, some slack is taken into account. It is decided to overpopulate the loops and to retract cards when possible in a later stadium. Retracting will be done based on the monitoring of the number of cards in a loop. Daily the number of inactive cards on the shop floor will be recorded. The total number of orders and the corresponding WIP per POLCA cell will also be recorded. Cards will be removed to limit the flow of work to systematically overloaded work centres. Removing (inactive) cards will stabilize the output of a cell, making better high level planning possible.

It is expected that fine-tuning the POLCA system will be possible after several weeks. This process will start a reduction of the WIP levels.

6.6.3 Other Changes

Not discussed by Kraayenbrink in her POLCA checklist are two changes relevant and required for SIG to make the future PPC system work.

6.6.3.1 Change I: Order release

As said, POLCA needs a high level MRP system like SAP to function. Currently, the production planners release orders onto the shop floor when the order is received. For POLCA to work properly, this release function has to be restricted. Orders should not automatically be started if capacity is available at the first machine. SAP should only release those orders with approaching due dates. This is one of the reasons WLC is implemented. WLC improves the order release function of the high level MRP system.

6.6.3.2 Change II: Pull planning

POLCA is a pull planning concept. This entails that only the last process step is planned, the remainder of the factory is pulled into action when necessary. Bottlenecks should function continuously; machines that do not have a full workload should be switched off if possible. The task of the planner will change: From planning every order per production step, the 'future' planner will reshuffle the list of available orders in such a way that bottleneck products are prioritized. The list of planned orders is then optimized with regard to maximizing throughput and minimizing setup time. The task of the planner will be focussed more on planning the right amount of labour in those areas that need them.

6.7 Conclusion future state

With help of three aggregate views, a complete overview has been given of the proposed future PPC system. These three zooms helped to create an overview of how an order is handled, processed and controlled on the shop floor. The first zoom incorporates and links several elements of the production control concept as introduced by Bertrand et al. (1998). The structure shown in Figure 6-4 is an improvement of the current situation at SIG (Figure 3-1).

The second zoom has focused more on the area affected by workload control. The presented future state has been compared to the current state at SIG. Several functionality gaps have been found that need to be closed. WLC offers a structure that improves the working of the production planning. By setting several filters, new orders will be analysed before they are released to the shop floor. This process stabilizes the shop floor and will reduce the need for continuous varying production capacity.

Several weaknesses are also apparent: in the future state, several assumptions are made. First it is believed that no mathematical optimization is necessary to obtain the future state. Secondly, it is assumed that all functionalities that are currently available but not yet implemented, can be achieved without major problems.

The third and last zoom concentrates purely on shop floor control. With implementing POLCA, it is possible to achieve most of the objectives set in paragraph 6.2. The initial implementation will require active monitoring of the shop floor. After a while a good balance between WIP, throughput rates and the number of POLCA cards will be achieved, stabilising the shop floor even further.

The structure proposed in the future state will help to retake control of the different variables. A successful implementation will cause WIP levels to drop significantly. Average lead-time will be reduced and overall production planning will become much simpler. Labour can be allocated better, quality issues will be recognized sooner and rush orders can be accepted without too much problems. Eventually the improved lead-times can become a bargaining chip with new customers.

7 Gap analysis

The changes proposed in chapter 6 are designed specifically for SIG. As stated in chapter 5, several of the other flat glass companies participate in the standardisation project and are looking for changes in the way they plan and control their factory. The gaps and required changes between the current and future state of SIG have been given in paragraph 6.5 and 6.6. This chapter focuses briefly on a gap analysis that has been sent to the different flat glass companies. Goal of this effort was to establish the status quo and an overview of the future functional requirements of the different companies with regard to their PPC systems.

7.1 Creation

Figure 6-5 was at the basis of the gap analysis used for SIG. The overview helped to define the information streams necessary for each planning level to perform its various tasks. To get a similar overview of the other companies, an empty version was sent to the other flat glass companies (Figure 7-1). They were asked to fill in the blanks, in a similar fashion as was done at SIG. The returned results can be found in Table 7-1. The letters in the second column of Table 7-1 represent the locations in Figure 7-1 were information about the various information streams were requested.

7.2 Results

Table 7-1 should be read in the following way: VTF, Italvetro and Orim have returned the gap analysis. The first two columns give the type and location of the information on the initial gap analysis (Figure 7-1). Looking horizontally, you can trace the required information for each of the different companies. E.g. following line ‘F’ you see Italvetro currently does not have information on the capacity planning level concerning planned orders. They would appreciate the improvement of this functionality with an 8 on a scale of 1-10.

From the results of the analysis it becomes clear that the three companies that returned the gap analysis require improvements on several of their production planning functionalities. The results of this gap analysis will be used on the flat glass management level to focus the efforts on those companies that require them the most. The results of this gap analysis are not used to conclude which, if any, of the improvements proposed for SIG should be implemented at the other companies. A more detailed analysis similar to the one performed in the previous chapters should be done per company, before any conclusions can be drawn.

The returned analysis from Orim gives a slightly distorted view: The colours used in Table 7-1 give an insight in the use of various software programs to perform the planning functions. Orim currently uses its own software program that supports all its PPC functions. As the Orim plants are forced to use SAP starting in January 2009, their own software system becomes unusable. Orim therefore requires solutions in all areas. They have therefore indicated that they need improvement on all given functions.

During and prior to the sending of the gap analysis, it became clear that some of the companies did not agree with the assumption made in paragraph 6.5: ‘the planner is capable enough to optimize the production planning.’ Several planning-software-tools are currently available on the market. This research does not focus on selecting and identifying software, but tries to improve the current production planning structure. It is therefore chosen not to focus on software packages available on the market. Once the proposed planning structures are in place and the set goals (Table 6-2) have been obtained, a new project can be started to further optimize the production planning with the help of mathematical precision or support from planning software. As long as production has not been stabilized and the main problems removed, software will not improve the situation.

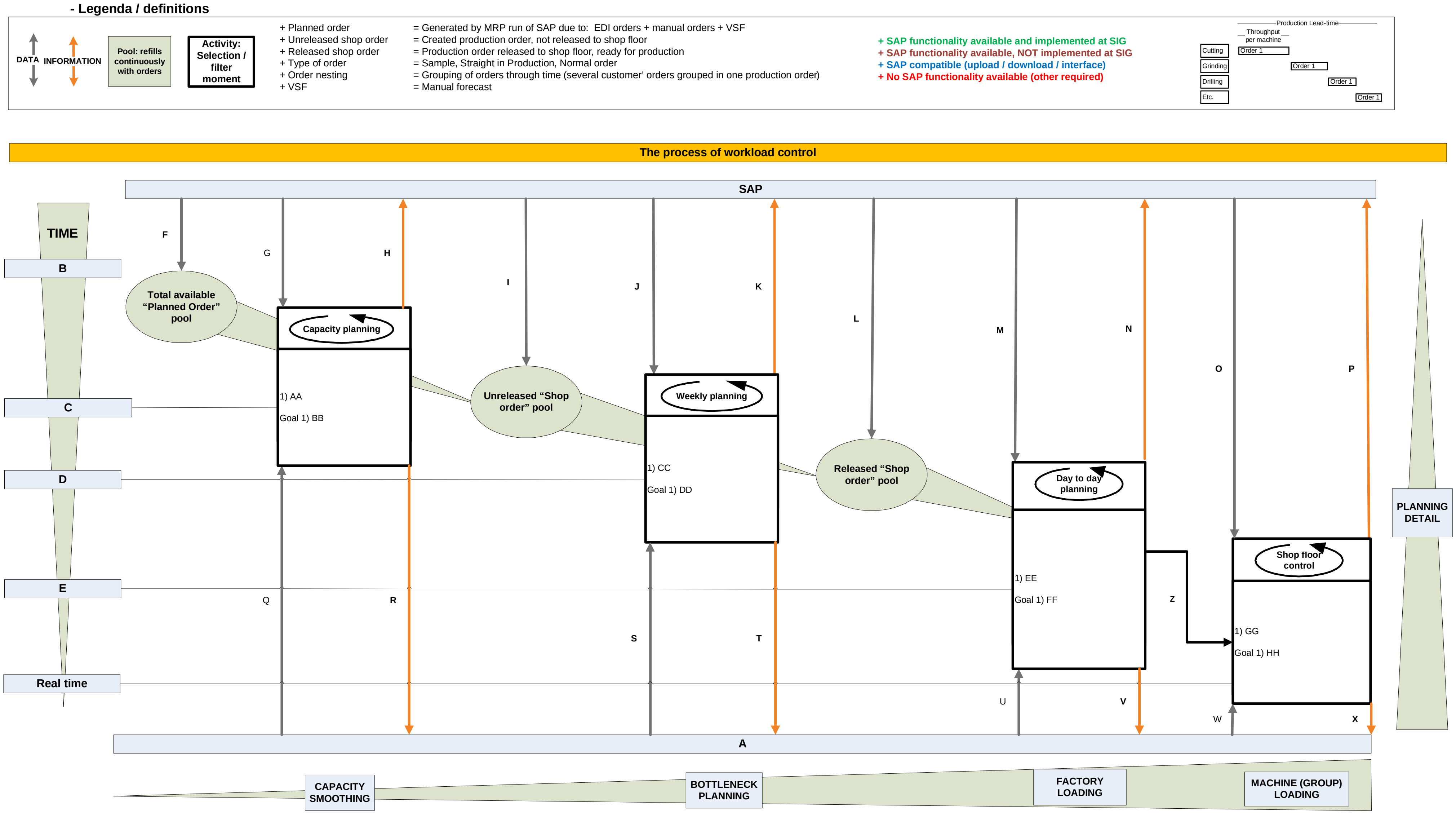


Figure 7-1 **Empty Gap Analysis template**

Type	letter	SCHOTT INDUSTRIAL GLASS			ITALVETRO			VTF			ORIM		
		SIG functionality	Func-tionality available at SIG	Value of improving functionality (Low1 - H10)	ITALVETRO requested functionality	Func. Avail-able?	Value of improving functionality (Low1 - H10)	VTF requested functionality	Func. Avail-able?	Value of improving functionality (Low1 - H10)	ORIM FUNCTIONALITY	Func. Avail-able?	Value of improving functionality (Low1 - H10)
definitions / dates	A	Excel	-	No imp. Nec. *	Excel	-	No imp. Nec.	**Long Term and Mid-term planning**			Database	Yes	10
	B	3-6 months	-	No imp. Nec.	3-6 months	-	No imp. Nec.	Best Group (monthly) - A+B	YES	7	24 months	Yes	10
	C	rolling 3weeks	-	No imp. Nec.	**rolling 4weeks**	-	No imp. Nec.	Best Group (Weekly) C+E	YES	7	rolling 8 weeks	Yes	10
	D	rolling 5days	-	No imp. Nec.	rolling 5days	no	10				rolling 9 days	Yes	10
	E	fixed 4shifts	-	No imp. Nec.	**fixed 3shifts**	Yes	8				fixed 9 shifts	Yes	10
		(added line)			(added line)			**Mid-term planning and Production Activity Control**			(added line)		
Data / information required from systems	F	Planned order info	Yes	No imp. Nec.	Planned order info	no	8	Planned order info (**F+G+H+I+J+K+L+M+N+P)**	YES	No imp. Nec.	Planned order info	Yes	10
	G	Planned order info	Yes	No imp. Nec.	Planned order info	no	8	Availability of capacity	YES	No imp. Nec.	Planned order info(add.cust.date)	Yes	10
		availability of capacity (management level)	Yes	8	availability of capacity (management level)	yes	8		YES	No imp. Nec.	availability of capacity (management level)	Yes	10
	H	Status change	Yes	No imp. Nec.	Status change	no	8		YES	No imp. Nec.	Status change	Yes	10
		define requisition planning coming 5days	Yes	No imp. Nec.	define requisition planning coming 5days	no	10		YES	No imp. Nec.	define requisition planning coming 9 days	Yes	10
	I	unreleased shop orders	Yes	8	unreleased shop orders	yes	8		YES	No imp. Nec.	unreleased shop orders	Yes	10
	J	unreleased shop orders	Yes	8	unreleased shop orders	yes	8		YES	No imp. Nec.	unreleased shop orders	Yes	10
		order ready for production	Yes	No imp. Nec.	order ready for production	no	8		YES	No imp. Nec.	order ready for production	Yes	10
		production rates	Yes	9	production rates	yes	9		YES	No imp. Nec.	production rates	Yes	10
		Availability of capacity	Yes	9	Availability of capacity.	no	10	VTF does not require improvements in these areas. SAP functions are currently sufficient.	YES	No imp. Nec.	Availability of capacity	Yes	10
	K	status change	Yes	No imp. Nec.	status change	no	8		YES	No imp. Nec.	status change	Yes	10
	L	released shop orders	Yes	No imp. Nec.	released shop orders	yes	No imp. Nec.		YES	No imp. Nec.	released shop orders	Yes	10
	M	released shop orders	Yes	No imp. Nec.	released shop orders	no	8		YES	No imp. Nec.	released shop orders	Yes	10
		ready confirmations	Yes	No imp. Nec.	ready confirmations	yes	10		YES	No imp. Nec.	ready confirmations	Yes	10
		order ready for production	Yes	No imp. Nec.	order ready for production	no	8		YES	No imp. Nec.	order ready for production	Yes	10
		real time confirmations	Yes	5	real time confirmations	no	10		YES	No imp. Nec.	real time confirmations	Yes	10
	N	adjusted shop order in case of breakdown	Yes	No imp. Nec.	adjusted shop order in case of breakdown	no	7		YES	No imp. Nec.	adjusted shop order in case of breakdown,	Yes	10
	O	-	-	No imp. Nec.	-	-	No imp. Nec.		YES	No imp. Nec.	Integration to the gannt chart	Yes	10
	P	confirmations	Yes	No imp. Nec.	confirmations	yes	8	Best group + Excel file	YES	7	confirmations	Yes	10
	Q	availability of capacity (management level)	Yes	9	availability of capacity (management level)	yes	9				availability of capacity (management level)	Yes	10
	R	-	-	No imp. Nec.		-	No imp. Nec.		No	10	-	Yes	10
	S	availability of capacity (planning / allocation)	No	9	availability of capacity (planning / allocation)	no	9				availability of capacity (planning / allocation)	Yes	10
	T	-	-	No imp. Nec.		-	No imp. Nec.	Excel file	YES	6	-	Yes	10
	U	availability of capacity (skills)	No	10	availability of capacity (skills)	no	10				availability of capacity (skills), optimizations	Yes	10
	V	-	-	No imp. Nec.		-	No imp. Nec.				optimizations	Yes	10
	W	-	-	No imp. Nec.		-	No imp. Nec.				-	Yes	10
Algorithm / functionality	AA	selecting orders with approaching due dates	Interface	3	selecting orders with approaching due dates	yes	3	Best group + Excel file	YES	7	selecting orders with approaching due dates	Yes	10
		high level capacity smoothing	Interface	3	high level capacity smoothing	yes	5	Best group + Excel file	YES	7	Other algorithms(setup, waiting time, etc..)	Yes	8
		(added line)			**Capacity Quota arrangement by customer**	yes	9	(added line)			(added line)		
		high level bottleneck planning	Interface	5	high level bottleneck planning	yes	7	Best group + Excel file	YES	7	high level bottleneck planning	Yes	10
Goal of planning step	BB	limiting and postponing 'unreleased shop order' inflow	Interface	8	limiting and postponing 'unreleased shop order' inflow	no	8				limiting and postponing 'unreleased shop order' inflow	Yes	10
Algorithm / functionality	CC	bottleneck planning	No	9	bottleneck planning	no	9	Only manual (shop floor scheduler)	No	10	bottleneck planning	Yes	10
		order nesting (quantity based)	No	9	order nesting (quantity based)	no	9	Only manual (shop floor scheduler)	No	10	order nesting (quantity based)	Yes	10
Goal of planning step	DD	Limiting and postponing release of 'released shop orders'	No	10	Limiting and postponing release of 'released shop orders'	no	9	Only manual (shop floor scheduler)	No	10	Limiting and postponing release of 'released shop orders'	Yes	10
		Minimizing WIP / Lead-time	No	8	Minimizing WIP / Lead-time	no	10	Only manual (shop floor scheduler)	No	10	Minimizing WIP / Lead-time	Yes	10
		Maximizing loading	No	8	Maximizing loading	no	8	Only manual (shop floor scheduler)	No	10	Maximizing loading	Yes	10
Algorithm / functionality	EE	Blocking orders when not ready for production	Yes	9	Blocking orders when not ready for production	yes	7	Blocking orders when not ready for production	YES	No imp. Nec.	Blocking orders when not ready for production	Yes	10
		Routing adjustment	Interface	9	Routing adjustment	no	9	Routing adjustment	YES	No imp. Nec.	Routing adjustment	Yes	10
		Setup grouping (4m&5m / 45holes)	Interface	8	Setup grouping (4m&5m / 4-5 holes)	yes	9	Setup grouping (4m&5m / 45holes)	YES	No imp. Nec.	Setup grouping (4m&5m / 45holes)	Yes	10
		bottleneck pull plan (capacity / time)	Interface	9	bottleneck pull plan (capacity / time)	no	10	bottleneck pull plan (capacity / time)	YES	No imp. Nec.	bottleneck pull plan (capacity / time)	Yes	10
		order release priority	Yes	7	order release priority	no	7	order release priority	YES	No imp. Nec.	order release priority	Yes	10
Goal of planning step	FF	Optimize production planning	No	9	Optimize production planning	no	10	Only manual (shop floor scheduler)	No	10	Optimize production planning	Yes	10
		Minimizing setup time	No	7	Minimizing setup time	no	8	Only manual (shop floor scheduler)	No	10	Minimizing setup time	Yes	10
Algorithm / functionality	GG	-	-	No imp. Nec.	-			-			Standards algorithms(eg.Jhonson, memetic,genetic etc)	Yes	10
Goal of planning step	HH	Within boundaries of shop floor rest of optimizing	No	10	Within boundaries of shop floor rest of optimizing	no	10	Only manual (shop floor scheduler)	YES	5	Within boundaries of shop floor rest of optimizing	Yes	10

LEGENDA
- SAP functionality available and implemented at company X
- SAP functionality available, NOT implemented at company X
- SAP compatible (upload / download / interface)
- No SAP functionality available (other required)
- TIME
- ACCESS/Excel
- If compared to SIG=> a 'different' or adjusted functionality is requested
- (added line)
- * : no imp. Nec. = no improvements necessary

Table 7-1 Results gap analysis

8 Current state of implementation

The proposed future state has been accepted by SIG. The first implementation steps have been set. The primary goal was to reduce the average WIP levels and reduce the average lead-time, in order to get more control of the shop floor. The current state of POLCA is discussed in paragraph 8.1. The second stage is focused on structuring the production planning in general, based on the principles of Workload Control. This will be discussed in paragraph 8.2.

8.1 POLCA

Several questions and problems arose during the initial implementation of POLCA. The literature on POLCA has not been uniform with regard to how to solve these issues. A short summary of the implementation, the problems and the required improvement steps are given.

8.1.1 Results of implementation

POLCA has been implemented in two phases. After having established the loops and the number of POLCA cards, a small trial was done. This trial involved specific products that could be traced throughout the production process. It involved the bending furnace, 9 POLCA loops and a limited number of products. The results of this trial were promising. Employees accepted the system and started using it. After a few weeks POLCA was introduced throughout the factory; fast line and assembly area excluded. The success of POLCA was monitored with the help of a daily information download from SAP. This download gave information about the levels of WIP in the factory and the total number of jobs waiting in front of the different POLCA grouped work centres. The initial number of POLCA cards in the system was purposely set too high. Employees could get to know the system before it actually started to restrict their machine. And although the system was over flooded with cards, operators nevertheless experienced restriction. This gave a clear indication that the WIP levels have been to too high and uncontrollable, supporting the acceptance of POLCA by management and shop floor.

As the summer holiday was about to start and unexpected behaviour from one of the top three customers drastically increased demand, no clear indication could be given about the effect of POLCA on the WIP levels. A rolling average indicated that the current WIP level has been reduced with 10% in the first two months. Although this reduction is positive, it is not sufficient. It is believed that the following months (November 2008 – February 2009) will be crucial for the success of POLCA.

During the initial months the number of POLCA cards has been reduced. This has been done by removing non active POLCA cards from the POLCA boards and by withdrawing cards in specific cells. Decisions about which cards should be removed are done on statistical data and the insight of the planners. Sometimes cards that were removed needed to be put back in circulation. This happened especially with loops that began in multi-machine cells. For example: Several machines in various POLCA cells feed into a washer manned by one person. If one machine in a loop is restricted by POLCA, the productivity of the cell as a whole will drop: the person at the washer will have less work to do, dropping the productivity figure. This conflicts with KPI's set by the Schott top management, justifying an extra POLCA card.

Starting January 2009, a round of changes will be made that will further improve the functioning of POLCA. A major change to be implemented is the quantification of the POLCA cards. The original POLCA system was set up with one card representing one order. As different machines have different throughput rates, a single job could take between 30 min to 2 days to be processed at the various machines, causing problems with the number of POLCA cards in a loop. The term 'quantify' is used by Suri and Krishnamurthy in their article on 'How to Plan and Implement POLCA' (2003). A quantum can be seen as a predetermined amount of time per POLCA card. The quantum per card is based on the average order process time in a cell.

An example: the cutting line will process a job in 60 minutes. After this, the job will go to the grinding line, at which it will be processed in 3 hours. The cutting line has to attach one or more POLCA cards reflecting this routing and the capacity utilization it will require of the next process. Or to put it differently: how much capacity will be required at the next process and how can we restrict this inflow? If we assume that the average process time at the grinding line is 2 hours, one [cutting line – grinding line] POLCA card will stand for two hours of work. The cutting line will have to attach 2 POLCA cards, as 3 hours is more than the quantum (of two hours) represented by the POLCA card.

Once this system is in place, cells can be restricted further. Knowing that 5 cards are in a loop, each representing 2 hours, the supplying cells knows that it has already sent enough work ahead to keep the next cell busy for at least one shift. Better labour allocation plans can be made: the supplying cell can be switched off for the next shift, relocating employees to machines that need labour.

A second improvement to be implemented is a refinement of the pull system and the order release function at the first process step. The shop floor starts a job when it is released by the planners. It is currently only restricted by POLCA, causing all kinds of problems. POLCA cards are used for jobs that end up waiting for several days before they are processed at the next machine. Rush orders cannot be processed as all POLCA cards are already in use. A pull plan ensures that only those orders are started which should be processed and are needed in due time. POLCA will then pull this order through the shop floor. Improving the release function will be discussed further in the next paragraph.

The initial steps towards a pull plan have been set, a practical pull system is not yet in place.

8.1.2 Conclusion

Although the trial and initial results seemed promising, several problems arose during the implementation of POLCA. Once the above described improvement steps have been implemented, it is expected that POLCA will work properly. It will require an additional estimated 3 months to reduce the WIP levels to the expected level. POLCA is still believed to be the right way forward.

8.2 Workload control

After the initial introduction of POLCA the attention shifted to the principles of Workload Control. As mentioned in the previous subparagraph, the POLCA principle was frustrated partly because of a lack of release restriction at the first processing step. This resulted in problems for rush orders and normal orders with longer lead-time. Piles of WIP could be found between the second and third process steps, most of it not due for days at a time. In the proposed future state this problem has been discussed and several theoretical steps were proposed. Currently, no implementation steps have been made, although several projects have been initiated. A short overview of the proposed phases and required projects to successfully implement Workload Control:

8.2.1 Phases 1: Release restriction

Restricting the release of orders into the system can partly be achieved by introducing a pull system on the shop floor. The last process step pulls work through the factory with the help of the POLCA cards. Orders that cannot be processed are not pulled into action until capacity becomes available. But POLCA is only partly successful in restricting the release of orders. Several additional changes need to be made to the high level MRP system to make POLCA truly effective:

Say for example that machine A supplies machine B and C. In week 10, there is a lot of request for products on route AB, but almost no request for route AC. In general, the request of orders on route AB and AC is 50/50. POLCA restricts route AB once the first few cards have been released. Machine A can now only start orders planned for machine C, but these orders are not due for another week. POLCA does not stop machine A from building up work for machine C until it runs out of cards. Machine C now has several days worth of work that will not be processed until capacity becomes available.

To restrict the production of orders on route AC, the production plan should give only a limited overview. The production planners should limit the production plan that goes out to the shop floor. Operators should only be allowed to see a maximum of 1 or 2 shifts ahead, reducing the possibility to start jobs not due for days.

8.2.2 Stage 2: Separation of control

The second stage is the separation of control between those who receive orders and release them onto the shop floor. In order to achieve this, an extra field is created in SAP: Orders that are received and accepted but not released will be given the status: 'unreleased shop orders.' If the order due date approaches, SAP will indicate that the order is due. This triggers the production planner or logistics manager to release the order and thus create a 'released shop order.' The production planners will then be able to start planning and production. This separation will remove the option for the production planners to prestart and create WIP that will not be needed for several days. The separation also limits the flow of orders to the next planning level: if the capacity planner foresees an overloaded period, he will be able to limit or increase the number of orders flowing to the planners. He can do this by changing the internal due dates, smoothing capacity loading.

8.2.3 Stage 3: Including customer enquiry

Once the above stages have been implemented, the WIP levels and the average lead-time have been reduced with the help of POLCA, the shop floor will be better controllable. Lead-time can be reduced by limiting the flow of orders to the shop floor. More accurate and shorter lead-times can be predicted, making it possible to give more precise delivery date promises. Although it is still preferred to have accurate demand forecast from customers, it will become possible to accept (some) rush orders. This reflects the mission statement created by management. Another problem that will be solved due to shorter lead-times is the processing of not confirmed orders. Currently some forecasted orders are started prior to customer confirmation, to ensure due date adherence. Orders are then suddenly stopped on the shop floor as the customer changes order details. If lead-time is reduced, confirmed orders can be processed within a few days, still achieving the agreed due date.

8.2.4 Conclusion

Several steps need to be made before WLC will function properly. The biggest hurdle to take is changing the mindset of the production planners. Not starting production whilst the machines are able to run will take some convincing, as this is the way they have 'successfully' planned the factory before. Customers will be less in control of what is produced when in the factory: An order is not automatically released onto the shop floor anymore. But once lead-time has dropped, orders can be started later. This will reduce the creation of non-required material and will further stabilise the shop floor, enabling the acceptance of rush orders.

9 Conclusion and recommendations

This research has tried to identify and solve the problems with regard to the production planning at SIG. Paragraph 9.1 discusses if the set goals have been achieved. This is followed by recommendations in paragraph 9.2.

9.1 Conclusion

The initial goal of this research was to:

'Analyse, evaluate, and redesign if necessary, SIG' production planning and shop floor control systems.'

As it wasn't very clear what the actual problems were at SIG, a relatively long analysis phase followed. The focus was on production planning, but it was difficult to just blame 'logistics'. After several weeks it became clear that SIG is in a very difficult position: On the one hand they are losing sales to cheap labour countries, on the other hand the remaining customers are allowed to do more or less what they want. This, combined with a lot of machine downtime and skill allocation problems, continuously causes pile-ups of WIP and very long lead-times. When comparing SIG to Schott sister companies, it became clear SIG could do with an overhaul of their production planning and shop floor control system.

To improve the planning structure a literature study was performed. Several concepts were found, but eventually it was chosen to implement the shop floor control system POLCA and to introduce several elements of the methodologies of Workload Control. The production planning concept Workload Control includes several shop floor control guidelines. These can only be introduced if all factors influencing the shop floor are known and if production rates are stable. POLCA is more forgiving and can be introduced without having to know all details and correct rates. WLC requires that various information streams and associated filters are in place for it to work correctly. Some gaps between the current state and proposed future state have been identified. It is important that these gaps are closed as soon as possible to make WLC work. Especially the shop order release function and a factory pull plan need to be implemented fast, as has been indicated repeatedly. A shop floor pull plan needs to be sequenced focussed on minimising setup time at the bottlenecks. Optimising per department leads to plant wide sub-optimisation, reducing productivity.

The initial implementation focus was on POLCA. Reducing lead-time and WIP levels will decrease the effort planners have to make to control the shop floor. If the amount of orders on the shop floor is halved, the planners also only need to focus on half. Focussing purely on the shop floor will not reduce WIP sufficiently. The complete planning structure from customer order to a shop floor released order has therefore been redesigned.

Although not all elements of the proposed future state are in operation yet, it is believed that the given steps are sufficient to improve production planning at SIG. The original goal to provide a redesign to improve the production planning has been achieved. The set boundaries have not been crossed either: Disturbance of the shop floor has been kept to a minimum. POLCA has been accepted with some enthusiasm and has already improved shop floor controllability. Implementing WLC and fine tuning POLCA is taking longer than expected though. Various causes can be given, most to do with the turbulent environment SIG has found itself in recently.

The structure proposed in the future state is a way to stabilise the shop floor and planning processes. Once everything is in place, this new planning structure will prove to be a very powerful tool. It will become possible to give customers shorter lead-times than the current set three weeks. Rush orders can also be dealt with without causing too much interference. This could be a selling point that will attract customers.

The biggest hurdle for SIG will be to accept the new ways of planning. It is very easy to revert back to the old ways when not everything goes according to plan. Great care must be taken whilst implementing the remaining WLC elements and the improvements to the POLCA system. Some steps will cause major changes to the way planning is performed. Letting go of the old ways will take some convincing. SIG is currently going through a very difficult period. Changing too many things at once might not be a good thing. Haste is required though, as not changing the current routines will cause far worse problems.

9.2 Recommendations

Some assumptions have been made in this thesis. It has proven to be difficult to find reliable data during the analysis phase of this research. Due to the flow-shop nature of SIG's shop floor, not many simplifications or general conclusions could be made. Trying to bring structure to an environment were no variable is controlled has proven to be troublesome. Although both POLCA and WLC are theoretically geared up to control these variations, real world is always a bit more unpredictable than the most flexible of theories. It is very important that any implementation steps are prepared thoroughly and evaluated in due time. POLCA is a relatively new theory and needs to be monitored carefully in the coming months. The proposed quantification of the POLCA cards needs to be thought through thoroughly. Only the initial structuring elements of WLC are used. WLC can be made as detailed as possible. Further detailing WLC in a later stage is recommended.

Finding and verifying all production rates is also essential. POLCA and WLC both require that all rates are known and correct. Rates are essential for the high level capacity planning. Projects should be started that focus on establishing and updating rates on a regular basis.

One of the causes of the shop floor instability is customer behaviour. Minimum lead-times and fixed planning periods should be introduced, restricting customers in their order placing behaviour. This is a project that is partly outside the scope of the logistics department and should be started in cooperation with sales. Once customers become more predictable, planning will be easier.

Care should be taken when giving out extra POLCA cards due to productivity reasons. If a machine in a multi machine cell is restricted by POLCA, the entire cell should be switched off. If the operators are relocated, no productivity will be lost. Building up extra work by adding more cards will not help to achieve lower WIP levels. Management should be aware that supporting POLCA only when it does not interfere with the old ways of production will not be sufficient.

The analysis of the PPC systems of the different flat glass companies should not lead to solid conclusions. The reported issues might indicate in which directions improvements should be headed, but a more thorough analysis of each company is necessary before conclusions can be drawn. Simply proposing POLCA or WLC will not be sufficient.

You can find my phone number in the Schott directory.

Ewout J. Verweij

December 2008

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