Transport delays in the supply chain of companies with MTO systems

Bachelor thesis Organization & strategy

Supply chain management in international operating companies

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Preface

First of all I want to thank my supervisor Marc Overboom for his support during the writing of this thesis. Thereafter I would like to thank my discussion group that has provided me with proper advice as well. Furthermore I hope that the readers of this thesis will consider the writings as interesting and that future research will be performed on the topic.
Management summary

This thesis will give a clear explanation of the relationship between the supply chain and the Make-to-order (MTO) production process. This starts with a thorough explanation of the MTO system itself. Since the system is subjected to uncertainties these have to be described in order to understand the system. This uncertainty is also affecting the supply chain. Since the MTO process makes use of agile supply this uncertainty has large implications for the MTO process. In chapter 2.4 is it explained how delays in the supply chain affect the MTO system. It was found that the MTO process has a small ability to cope with these delays and that therefore it is most important to avoid them. Prevention of these delays can be found in the transportation of the demanded components. Chapter 3 gives a clear explanation of the different transport delays in the supply chain and how they can be managed. In chapter 4 the MTO process and the transport delays are combined and conclusions and recommendations are drawn in order to make the delays more manageable. The research has been based on literature reviews but it can be recommended to perform empirical research on this topic as well.
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1.1 Problem Indication

Nowadays companies have to deal with a business environment that puts more accents on the concept of customer-driven manufacturing. This creates an environment where there is more emphasis on differentiated product features, tight delivery performances and low costs (Hicks et al., 2000). In order to deal with these environments more firms decide to make use of “make-to-order” (MTO) manufacturing systems. MTO operating firms manufacture high variety products in relatively low volumes. “Often the volumes are low even at the component production stage as there is little scope for common components because products are manufactured to fit customer design and specifications” (Hendry, 1998: p1). “As of the customer-driven emphasis it is important for the manufacturing firm to consistently produce high quality products with competitive unit costs and high service levels (i.e. on time deliveries)” (Ebadian et al., 2007: p1). Revelle, 2001 confirms this by stating that the three major features of the MTO process are quality, cost and delivery.

In this research the focus will be on the delivery aspect since “Delivery lead time is the fundamental order-winning criterion in MTO contexts” (Konijnendijk, 1994; Hicks et al., 2000, 2001, as cited in Zorzini et al., 2008). Delivery dates in MTO systems are important since they are related to the delivery reliability (Corti et al., 2006). “Reliability in meeting agreed delivery dates is important to customers because it enables them to plan ahead and carry out their plans based on the delivery dates with confidence” (Kingsman et al., 1989: p2). Hence, a delay in the delivery of goods can be considered as a large problem for these companies. The transport of the components to the MTO firm can play a large role in this delay and needs to be minimized. Arns et al., (2002) state that supply chains can be characterized by the uncertainty present in the supply chain. Uncertainty is created by the supply of goods that is affected by transportation times, demand and market pricing (Vidal and Goetschalckx, 2000). But the MTO system itself creates uncertainty as well. This also raises the question whether these uncertainties are manageable and to what order. Consequently it is important get a better grasp of this uncertainty and its corresponding delays in the supply chain. This impact can be understood by looking at the relationship between the MTO firm and its suppliers. Additionally the ability of the MTO process to deal with delays and how these (transport) delays can be prevented will be studied.

To sum up, this thesis will focus on the impact and cause of delays in the supply chain of MTO firms, the ability of the MTO process to deal with these delays and the solutions to this problem.
1.2 Problem statement

What impacts do the transportation delays of supplied materials have on manufacturing process of companies with MTO systems and how can they manage this?

1.3 Research Questions

1. What are the consequences for the MTO production process when a delay in the supply of materials occurs?

2. How can the MTO production process adapt to these delays?

3. What are the internal/external causes of transportation delays?

1.4 Relevance

The MTO production process has become popular over the last few years. This has also resulted in numerous academic publications about MTO systems. From these papers it became clear that delay issues are of high importance in such systems. However the link with transportation delays has not been made specific though it is of great importance for this process. That is why this paper can contribute to the discussion about delays in MTO process.

Because the delays in the MTO process are of high importance for the manufacturing companies they will probably be interested in new academic publications in this field. By linking transportation and MTO production there will be more emphasis on subjects that should be linked more closely together. With a better understanding of the two factors it can lead to a better fit of transport and the MTO process within the company.
1.5 Research Design and data collection

Descriptive research will be used in order to answer the research questions. Literature reviews will be the source of information to answer the research questions. The literature that will be used will be of high quality. By using only high quality journals the research will have the necessary academic foundation which will improve the reliability of the research.

Information will be gathered by searching in the online academic databases from ABI/Inform, the web of science and Google Scholar. Once about 30 high quality papers have been gathered they needed to be scanned on relevance before time will be wasted on reading each and every paper. Thereafter the relevant phrases in the papers will be marked thus that they can be found easily. That information will be transformed and will be used as the scientific basis of this thesis.

Although there is a lot of information obtainable regarding MTO system, the research can be limited by the availability of literature specifically on the impact and causes of delays.

1.6 Overview of the rest of the Chapters

MTO production process
In chapter two there will be a short introduction about the MTO production process and all its features. Subsequently will be described what operations are important for the production process and the bottlenecks of the system will be pointed out. Then there will be a clarification of the relationship of the MTO production process with the supply chain and a clear enlightenment of what is important in this relationship. Finally the flexibility of the MTO system will be shown by adding (transport) delays in the supply chain.

Transport delays
Chapter three gives a clear explanation of what different transport delays exist in the supply chain. In addition to this it will become clear what causes these delays and how they can be managed.

Chapter four will combine chapter two and three and will make conclusions and recommendations regarding the manageable side of the problems.
Chapter 2: MTO production process

In this chapter it will be explained how the Make-to-order (MTO) process works and what its characteristics are. Thereafter further implications of uncertainty and delays in the supply chain will be discussed. In the end of this chapter it should be clear how the MTO process can account for delays.

2.1 What are the characteristics of a MTO production process?

This section will discuss how the MTO process operates. It will also be indicated what features are important for the discussing regarding the uncertainties and supply chain relations.

Business environments differ in the demand information that is available. Using a MTO production process is way of dealing with this uncertain demand information. Amaro et al., (1999, as cited in Stevenson et al., 2005: p4) present a concept that is based on “the level of work carried out after the order has been placed by the customer and the nature of customization”. When an order is placed at the MTO firm, the basic design of the product is available and the remainder of the work will be in the further manufacturing and assembly. Product design is also part of the MTO process, which means that the customer orders a basic design which they can adapt to their own preferences. This flexibility results in the availability of a wide variety of products, usually in small quantities (Elbandian et al., 2008). The MTO process cannot respond to the demand as fast the Make-To-Stock (MTS) companies but on the other hand it can offer more flexibility in the preferences of its customers. Stevensen et al., (2005) also state that MTO manufacturing firms are usually small and medium sized enterprises.

The term MTO refers to “products for which production and/or design does not take place until after the customer order confirmation stage” (Olhager, 2003). Hence, MTO companies have an early or upstream Order Penetration Point (OPP): “the point at which a product is linked to a specific customer order” (Olhager, 2003: p1). For example, the assembly process starts when demand actually occurs or manufacturing department will start with the further development of the product. MTO companies usually experience problems with accurately forecasting demand, order materials, producing in advance or effectively apply batch production methods (Stevensen et al., 2005). In addition, the material and production requirements of a single job may be very
different to those of other jobs in the factory. Hence a lack of parts similarity and variable job routings add to the difficulties of planning and control which will be explained further on.

<table>
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<tr>
<th>Product delivery strategy</th>
<th>Design</th>
<th>Fabrication &amp; procurement</th>
<th>Final assembly</th>
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Figure 1. Positioning the Order Penetration Point. (Olhager, 2003: p2)

The positioning of the OPP is a decision that is of high importance for the product delivery strategy because the position of the OPP has implications for manufacturing objectives such as customer service, manufacturing efficiency and inventory investment. Manufacturing that takes place upstream of the OPP is a characteristic of forecast-driven operations. Manufacturing that takes place downstream of the OPP can be considered as operations that are customer order driven. Factors that influence the position of the OPP are demand volume and volatility, and the relationship between delivery and production lead times

“The earlier OPP means that a greater degree of customization can be offered and this capability is an important strategic objective for many of these companies” (Spring and Dalrymple 2000; Hendry et al., (2003, as cited in Stevenson et al., 2005: p4). Figure 1 shows that the OPP of MTS companies lies at the far right hand side, which means that the customer is linked to a product when it has already been manufactured. For instance the products in a supermarket find their end customer until the consumer does his groceries. Engineer-to-order (ETO) is the opposite of MTS and has its OPP far upstream. This means that even the design process still needs to be done before the customer contacts the company. An example of a company that uses ETO is a construction company that builds customized houses. Olhager, (2003) states that the downside of having an upstream OPP is that this leads to high variability in the use of resources and non standard product routings. Therefore these companies use none or little inventories which result in long lead times. Hence this puts a large pressure on the product planning and control side of the firms that make use of an upstream OPP.
The delivery date (DD) from the customer point of view is “the time between when the order is placed by the customer and the order delivery to the customer” (Kingsman 2000: p8). In this respect, the delivery date consists of several stages which are depicted in Figure 2. These stages will be discussed during the rest of the chapter.

![Figure 2. The structure of the MTO system (Ebadian et al., 2009: p4).](image)

From figure 2 it can be understand that the MTO system starts at the order entry level where the order is placed at the MTO firm. In the negotiation process there will be discussion between the customer and the manufacturing about the design of the product, the price and the expected delivery time. When the order is accepted, a list needs to be made about the required materials. Furthermore it will be necessary to find out what tasks needs to be performed to manufacture the goods, in what order and how long they will take. Before a job enters the actual manufacturing process or the so called shop floor it will stay in the order pool until the order is released. The purpose of this pool is to make sure that everything on the shop floor will run efficiently and that resources will be used optimally.

Kingsman et al., (1989) have developed a production planning model that is based at the following three levels:

- Dispatching/scheduling.
- The customer order planning and due date assignment (order entry): this level determines how to respond to a customer’s enquiry and hence influences what orders the firm undertake.
- Job releasing.
Figure 2 indicates that the longest stage of DD is related to the shop floor throughput time. This can be efficiently controlled via appropriate allocation of resources over time to complete the orders. This problem is usually called production scheduling problem (Baker 1974). Dispatching rules are the main solution to this problem. A dispatching rule is used to select the next job to be processed from a set of jobs awaiting service (Blackstone et al. 1982). These rules offer a practical solution since they have the ability to make good and quick decisions. Karsiti et al., (1992: p3); Moodi, (1999: p4) present the following dispatching rules:

- First come first served: Select the job with the earliest arrival time at queue to be processed first
- Shortest processing time: Select the job with the shortest processing time requirement from among the jobs in the queue to be processed first
- Earliest operation due time: operational due times are assigned by the shop floor controller. They select the job with the earliest operational due time from among the jobs in the queue to be processed first
- Earliest final due date: select the job with the earliest job due date from among the jobs in the queue to be processed first.
- In-greatest-trouble rule, gives priority to jobs that are assessed as being in trouble, which indicates that those jobs are furthest behind schedule

“Scheduling is a relatively weak mechanism for control of queues and shop floor throughput time if to be used alone” (Hendry et al., 1998; Land and Gaalman, 1996, as cited in Ebadian, 2009: p4). To reach better results at production scheduling, the amount of workload in different workstations of the shop floor should be controlled. The control of workload in the shop floor creates a pool of orders waiting for release. The pool creates a buffer that protects the shop floor against external factors, like an overflow of jobs in the shop floor which will create disruption (Land and Gaalman 1996). This means that each new arriving order has to wait in the pool instead of immediate release onto the shop floor. Then, each unreleased order may enter the shop floor if it would not cause congestion and if the work load is in within bounds of preset levels. Hence work load control leads to reduced levels of work-in-process (WIP) and also contributes to a steady production schedule (Hendry et al., 1998). This control problem is also called the order release mechanism. Order release is used in workload control systems to determine ‘which order’ and ‘when’ should to be selected and released to the shop floor. This system has to make sure that the total manufacturing lead time becomes minimal and reliable.
“Using order release mechanism can have several beneficial effects on the shop including reduced WIP, less shop congestion and lower flow times” (Bergamaschi et al., 1997: p8). However Bertrand (1983a, 1983b); Baker (1984), as cited in Ebandian, (2009: p5) found that “these techniques can also lead to long delays in the order pool which might even increase the manufacturing lead time”. Hendry et al. (1998: p2) emphasized that “order release itself can be effective if the queues of orders in the pool are also controlled. Otherwise, orders may remain in the pool for too long, missing their promised delivery dates”. The control of the order pool and the workstations queues in the shop floor has an influence on the order entry level. Decision making at this stage are regarded to whether the MTO system is able to cope with the new arriving orders. This examination is necessary due to existing constraints such as capacity and suppliers’ performance (Ebadian et al., 2007).

Job routings or the so called Shop floor configuration is a factor of production planning and control applicability. These routings determine the sequence of workstations that a job needs to follow. There can be made a distinction between a Job shop and a Flow shop. The key difference between the job shop and the flow shop is the direction of material flow which can be random or very strict.

The Pure job shop is most commonly used in MTO systems (Muda and Hendry, 2003). The Pure job shop routing sequences are random; jobs can start and finish at any work centre allowing complete freedom and customization. However in reality there usually exists a dominant flow of direction (Oosterman et al. 2000). Flow shops consists of a routing sequence that always a dominant flow, in extreme situations all jobs have to pass the same work stations in the same routing sequence (Haskose et al., 2002).

From this section it can be understand that the MTO system is basically controlled by the order release mechanism. This is mainly controlled by work load but dispatching rules also have an influence. Finally the process can also be controlled with use of different routings at the shop floor.
2.2 How does the MTO production process respond to uncertainties?

This section will discuss what causes uncertainty in the MTO system, what implications this will have for the production process and how it should respond to these uncertainties.

The MTO sector is usually unpredictable, has low levels of repeat business and there is often a high level of variability in MTO with respect to the routings and processing times of different orders. Thus, “it is difficult to predict how and when the orders will be distributed among various workstations in the shop floor over time” (Kingsman et al., 1989: p2).

“The three fundamental elements that create uncertainty in MTO systems are: 1. the dynamicity due to volume and mix fluctuations; 2. the uncertainty related to product specifications; 3. the complexity of products flow” (Kingsman et al., 1993; Land and Gaalman, 1996, as cited in Corti et al., 2005: p2).

These uncertainties are hard to deal with in the negotiation phase when the MTO firm has to propose a reliable delivery date. Choosing an appropriate delivery date is difficult since lead time is hard to predict and proper information regarding the customer requirements and the production capacity availability is necessary (Wullink et al., 2004). In fact, customer preferences are unknown until the customer has placed its order, but even after the order confirmation they can change their preferred product design. This means that companies have to decide whether they give priority to minimizing the delivery lead time or minimizing the production costs (Hendry and Kingsman, 1993). Still it will be inevitable that during the negotiation phase uncertain information will be used in important decisions.

Ragatz and Mabert (1984) state that the ability obtain a DD does not depend only on the use of scheduling and dispatching procedures but also on the attainability of the deadline at the first place. Capacity planning should be accounted for when proposing a deadline. This capacity planning consists of the estimation of the through-put time is made by taking into account information from the planning procedure, such as the characteristics of both accepted orders and potential orders from which the conformation it not sure yet (Corti et al., 2005). This means that a delivery date is proposed while the future capacity of the system is highly uncertain. Though there are released orders from which the capacity can be calculated there are is also another group of orders that have not been released yet. For these orders there is uncertainty
Regarding the release dates and dispatching. In order to deal with this uncertainty the MTO firms calculate an upper and lower limit of capacity requirements for the unreleased orders. The uncertainty of workload control lies in the workload requested by order that have not been confirmed yet. They can be taken into account by multiplying the probability of order acceptance with the estimated workload. The only the MTO system can account for delayed job is by looking for ways to squeeze in the job without harming the process. Another solution would be to apply buffers in capacity that allows delayed jobs to enter the shop floor early. Finally it can also be decided to start with partially manufacturing the job until the point where the delayed components are required. However this method is likely to result in congestion at the shop floor.

In many MTO companies, it is the customer rather than the supplier that has responsibility for the design of the product (Amaro et al., 1999). Therefore, these companies do not deal with a regular type of new product development. If the company is asked to do the design, this will still be with a great deal of customer involvement.

Since the customer has a big influence on the design of the product it is hard for the MTO firm to aim at commonality and complexity of the parts. However Jina et al., (1996) state that this is possible by suggesting a common foundation of the design. This can result in a relative steady design. Furthermore this can lead to improved relations with suppliers, because they will receive orders for fewer parts but in larger volumes, which can drive down costs. In addition, it may be possible to become more involved in the design process of the customer thus improving the efficiency of the design (Hendry, 1998). Making the process more standard is a method that gives the MTO firm more control which leads to less fluctuations en less uncertainty. On the other hand it necessary to keep in mind that offering customers the possibility to adapt a product to their specific preferences is one of the order winners MTO firms. Thus standardization is a process that needs to be done carefully.

In order to deal with the complexity of the products flow Karsiti et al., (1992) suggest making use of a decentralized schedule method. This method gives the machine controllers at the shop floor more power and allows them to set or change the routings of an order. This method can deal with complexity, allows for flexible routing, but makes it hard for the firm to trace back the capacity levels.
From this section it can be concluded that uncertainty is caused by large fluctuations in demand, a lack of forecasting ability and because of high variability and complexity of components. This results in large pressures on suppliers and complexity at the shop floor. Uncertainty can be dealt with by setting feasible delivery dates, by partly standardizing the product design, by properly estimation of capacity, by keeping capacity buffers and by involving suppliers in the design stage.

2.3 What is the relationship between the supply chain and the MTO production process?

This section will explain how the MTO system and the supply chain are related. It will be indicated why delivery performance of the suppliers is important, how suppliers can be selected and how the relation between the supplier and the MTO firm can be improved.

On time delivery is one of the order winners for MTO operating companies. In the last few chapters it was explained how the MTO process tries to contribute to this order winner, however the supply of materials is something were the firms have less influence on. Rajagopal and Bernard (1993: p5) even state that “organizations achievements are only possible due to its sources of supply”. In this chapter the relation between the MTO operating firms and its suppliers will be explained. Suppliers are considered as companies that produce and ship the demanded components.

A company that produces under a MTO system will hold zero or little inventories (Choi et al., 2004). “With MTO systems each customer order is unique in terms of manufacturing and logistical requirements” (Viswanadham & Raghavan, 2000: p2). Holding zero inventories does eliminate the risk of wasted inventory but increases lead times. Therefore MTO operating firms are highly dependable on its suppliers and this requires close and improved supplier relations (Heide and John, 1990). The MTO operating firm has a longer lead time that its competitors that use MTS systems. In order to compete with the shorter lead time of MTS systems it is likely that the MTO firms put large pressures on their suppliers to make up for their longer lead time and to make sure that they can handle the uncertain and various demands. This leaves little room for error for the suppliers in the manufacturing and the transport of the components. Therefore good supplier relations are of essence. This starts with choosing the right suppliers. Weber et al., (1991) concluded that the best way is to select suppliers on basis of quality. This was followed by delivery performance and cost. Since MTO firm produce customized product the
quality is most important. Delivery performance is essential in order to make the manufacturing process run smoothly. In this research most emphasis will be on the delivery performance. Costs should also be taking into consideration but since the MTO firm offers customized products the customers are often willing to pay for the extra service. In order to help MTO firms with selecting the right suppliers Lorange et al., (1992) developed a model that is able to select the best supplier candidate on basis of market potential, competitors and simulation of worst-case scenarios. Further details about this model can be found in the paper: ‘Building successful strategic alliances. Long Range Planning’ by Lorange et al., (1992). According to Deming (1986, as cited in Pagell and Sheu, 2001: p6), “the supplier selection only on the basis of price tends to decrease the overall quality”. In addition to this Burt (1989) suggests to select suppliers by looking at the total costs. It was said before that close supplier relationships are important, Kekre et al., (1995); note that if a firm wants improve this relation and also wants to select its suppliers on basis of total costs, than it is necessary for the firms to reduce the number of suppliers. Less suppliers leads to reduction of total costs and higher levels of trust between the buyer and supplier (Treleven 1987;Newman 1988). Shifting to one single supplier could create even more trust and confidence but that will take away a level of competition which needs to be remained to keep the relations as effective as possible.

Cakravastia et al., (2002) explain how the further selection takes place: After an order has been received and accepted the MTO operating firm finally obtains the information regarding the customer requirements. Before the firm starts selecting its suppliers it has to set a certain amount of goals. These goals are based on the quality, quantity performance and costs. MTO firms are likely to ask their potential suppliers that can fulfill these requirements to make an offer. If all suppliers have place their bid, then the MTO firm has to select the supplier that will fit best to its customer requirements and offers the best price.
Figure 3. The classification matrix of suppliers (Kraljic, 1983, as retrieved from Luo et al., 2009: p7).

With use of the model in Figure 3, firms can differentiate different suppliers into different categories. Different strategies can be adopted for each category. For the MTO operating firms the most attention must be given to the Strategic and Preference suppliers which are located on the right hand side of the table. Both of these suppliers have a high supply risk and thus are likely to supply with a delay. MTO firms should pay most attention to the Strategic suppliers since these suppliers have a large financial influence and the amount of suppliers is limited in this environment. Therefore the buyers should build up close and long term relationships with these suppliers in order to create trust, loyalty and clear expectations. Preference suppliers are also important for MTO firms because there are also limited suppliers in the market but they do have a high supply risk. Even though the financial impact of these suppliers will not be high it is possible that delays with these suppliers can affect other processes within the firm which needs to be avoided. Buyers should try to build up continuity of supply, even if this would create additional cost. Leverage and Routine suppliers should also be considered but are given less attention because they have a low supply risk which means that they are less likely to deliver their products with a delay. Leverage firms do have a high financial influence but since there are a lot of suppliers in the market this risk can be reduced by hiring several suppliers. In the Routine category there are a lot of suppliers present in the market, they have a low supply risk, and low financial influence. These suppliers do not require specific treatment.
Uncertainty is not only a big issue for the MTO operating firms but also for its suppliers. The MTO firms are constantly trying to improve their internal process by changing their production schedules, design etc. As a result the suppliers have to deal with this uncertainty as well. Newman et al. (1993); Pagell et al. (2000) state that increased uncertainty in the supply chain will lead to increased costs. The fact is that if one member of the supply chain has to deal with increased costs than this will lead to a decrease of performance in the overall supply chain.

How supplier relations can be improved:

It was found by Hartley et al., (1997);(Hendry, 1998) that to reduce uncertainty and to improve the relations between the buyer and supplier it can be useful to involve the supplier in an early stage of the design process. By involving the supplier the situation will become more transparent which can result in lower costs and shorter delivery times. Supplier relations can also be improved by setting up long term relationships that creates trust and confidence. A good example of “firms with long standing supplier relationships are Asian firms. These long-term relationship might be the cause of the fact that these firms have high levels of performance” (Nishiguchi 1994, as cited in Pagell and Sheu 2001: p17).

Pagell and Sheu, (2001) found that the amount a firms outsources can affect the relationship between a MTO firm and its suppliers. One side of the story argues that a firm will be less able to handle its relationships if the firm increases the amount of outsourcing. Less attention in this case will result in lower performance. On the other hand it will likely that the MTO firm will get better and more experienced if the firm increases the amount of outsourcing. This situation will result in an improvement of the performance. Overall Pagell et al., (2000) found that there a significant relationship between the amount a firm outsources and the ability of the suppliers to deliver on time.

Luo et al., (2009) state that the relationship between the MTO firm and its current suppliers requires attention as well. A study by Moses et al., (2004) shows that making clear agreements with suppliers are of high importance. In these agreements should be stated that on time delivery is of essence and therefore exceeding these deadlines will be punished. Shapiro et al., (1992) note that it is common in the manufacturing business to use penalties that are proportional to the amount of days the delivery exceeded the delivery date. When a delay occurs at the suppliers of the MTO firm it can be demanded that the supplier has to meet the
due date at any cost. This can result in crash production or by taking goods from inventory to shorten the delivery time (Cakravastia et al., 2002).

The MTO firms require its suppliers to be reliable and keep up with its continuous improvements. Although long term relationships between buyers and suppliers generate increased performance it is also necessary to keep re-evaluating the relationships of its current suppliers on frequent basis. If current suppliers cannot keep up with the current improvements they do have to be replaced to keep customers satisfied. In order to improve the relation with suppliers. Samaranayake and Toncich, (2007) suggest to integrate real time date and information sharing between the MTO firm and its suppliers. This is a method that is used to overcome problems like the bullwhip effect and thus creates less uncertainty. Information sharing might not always be possible due to the presence of private and corporate information (Chan and Chan, 2009). It is also not always clear what information can or cannot be shared and to what extent. Lee and Whang (2000) note that inventory levels are one of the few information aspects that is appropriate to be shared. According to Chan and Chan, (2009) sharing information can be useful even this is done in small extent.

A Study by Cachon and Fisher (1997) shows that information sharing in combination with Vendor-managed-inventory (VMI) can create a larger competitive advantage then when only information sharing is used. (Choi et al., 2004) explain that In VMI programs the supplier is responsible for all decisions regarding the component inventory at the MTO firm. The supplier and the MTO firm have appointments regarding the stockout rate, the average backorder components and the guarantee of supplier delivery performance. These requirements are being monitored by third parties and underperformance will lead to penalties. In normal supplier/manufacturer relations the manufacturer has some power of the supplier in the sense that they can influence how suppliers organise their operations. However with VMI programs the MTO firm can only influence the performance of the supplier by setting required levels of performance. The MTO firm needs to share all information with respect to its demand, capacity and holding cost. Depending on the contract with the MTO firm the supplier holds its component inventory at their plant, a warehouse nearby the MTO firm or even at the MTO firm itself. The MTO firm is only responsible for the inventory of finished goods. Payments to the suppliers are done on basis of the components inventory level. The boundaries of the inventory level are set in the contract. This motivates the suppliers to control their production resulting in minimized costs for the MTO firms.
Suppliers are also responsible for the transport of the demanded goods. MTO firms require their suppliers to deliver on time and use penalties when they do not meet these dates. Suppliers can have different ways of organizing transport. Some suppliers ship the goods to the MTO firm themselves and others outsource the transport in order to shift the transport responsibility or to reduce costs. MTO firms can influence how these operations are organized. For instance, they can demand the use of certain transport companies, transportation types or routes. MTO firms can even decide to organize transport themselves in order to create more reliability or a better fit with the manufacturing stage.

To wrap up this section it can be said that effective supplier selection can be based on quality, performance and costs. Lorange et al., (1992) developed a model that helps us finding the appropriate suppliers. There should be clear appointments with the suppliers regarding the delivery performance and the organization of transport. Examples of how Supplier/manufacturer relations can be improved are decreasing the levels of uncertainty and by setting up long-term relationships.

2.4 How do delays in the supply chain affect the MTO production process?

In the negotiation phase the customer and the MTO firm will set a DD. The customer is counting on the firm to deliver the product on time. However if the MTO firm faces a delay in the supply of goods this will have a lot of consequences. In this section it will be discussed how a delay in the supply chain will affect the MTO production process. A delay will have different consequences depending on the situation. In this chapter it will be only discussed what impact a delay has if the corresponding order has not been released yet and thus has not entered the shop floor.

After the order acceptance the job needs to wait in the order pool before the job will be released onto the shop floor. In the order pool there exist dispatching rules that determine the sequence of orders to be released onto the shop floor. The different dispatching rules are explained at page 8 of this thesis. The ‘first come first served’ dispatching rule is most commonly used in MTO systems (De Croix and Risa, 1998). However when a delay occurs this could create a large disruption if the order release would only be based on dispatching rules (Kanet and Adelsberger 1987; Kusiak and Chen 1988). For instance, consider an order pool that consists out of 5 orders that are ranked according to the dispatching rules first come first served. Suppose that the third order in the queue faces a material delay, this delay will disrupt the
system since orders 4 and 5 are now facing an unnecessary delay. Order 4 and 5 are required
to wait because order 3 has a higher ranking in the queue while there is enough capacity
available to process these orders. If work load control and dispatching rules would be combined
this would create a different situation. This implies that order release is also restricted by
capacity, it is important to select only those orders that do not exceed the boundaries of
capacity (Land, 2004). In the situation of the example, it might be possible that order 4 or 5 is
released early since that it would be more effective in terms of efficiency. Order 3 will then be
produced as soon as the materials have been supplied and when enough capacity will be
available. In chapter 2.3 it was already found that buffer capacity can account for delays.
Another possibility is that order 3 is already partially manufactured until the phase where it
requires the delayed materials. However this may lead to exceeding workstation capacity which
will result in congestion on the shop floor, this phenomenon can be referred to as Blocking
(Haskose et al., 2002).

This rather simple example with only 5 orders already shows that is hard to determine where the
delayed order will be placed back in the queue since the work load control determines simply
the most efficient ranking. Zou and Li, (2006) developed a model that is able to reschedule the
orders in order to make room for ‘rush’ orders. These orders then will be integrated back into the
job shop scheduling model. Further details about this system can be read in the paper
‘Integrated and events-oriented job shop scheduling’. The In-greatest-trouble dispatching rule is
better capable of handling delayed jobs. Jobs that are furthest behind schedule will get priority
over other jobs. However in practice this rule can lead to large disruptions in the production
planning and to congestion at the shop floor. Furthermore, certain jobs can already be given a
higher priority in the negotiation phase. Customers that have a long standing relationship with a
MTO firm or customers that are willing to pay a premium price can be given priority to reduce
the lead times of these specific orders. MTO firms however need to keep in mind that when they
decide to use these priorities that the jobs of other customers will have to be pushed back to
make room for the priority jobs, which is likely to upset the customers. Additionally it is a fact
that future incoming orders are dependent on how customers perceive past deliveries (Moodie,
1999). Hence if it becomes clear during the negotiation phase that delivery dates will be tight
and might not be in reach then it might better to refuse an order. Moodi, (1999: p3) states that
“refusing an order does not necessarily mean losing a customer”. When an order is accepted
and during the manufacturing it looks like the deadline will be exceeded then it is better to tell
customers this upfront instead of disappointing them later on (Merit, 1990).
In figure 4 the price effect of the delay in the products of MTO operating firms is explained. On the horizontal axis there are two dimensions; responsiveness and delay. Responsiveness stands for the lead time the customer demands. Delay stands for the additional time the customer is willing to wait for the product. If the customer has to wait longer than the line indicates the order will not be accepted. On the vertical axis there are two dimensions; Base value and Premium. Base value stands for the amount the customer is willing to pay for latest acceptable delivery date. Premium stands for the extra amount the customer is willing to pay for an early delivery.

Abbreviations in figure four:
CPEDD (Customer price earliest delivery date), CPLDD (Customer price latest delivery date)
CEDD (Customer earliest delivery date), CLDD (Customer latest delivery date)
From the figure it becomes clear what the trade-off is between the on time delivery and the accompanied price. The cost related to the responsiveness represents the extra work by the
manufacturer in order to deliver the goods on time (Cakravastia et al., 2002). This theory is also visible in figure 4 where the customer needs to pay a premium since the product is delivered early. However if the process becomes delayed and the delivery date moves further to the right the price declines rapidly until it reaches the base value or the minimum price the customer is willing to pay. If the process is delayed even more the customer will become dissatisfied to such extent that it is not willing to accept the product anymore. The manufacturers have to determine for themselves whether or not they think it is worth to receive a premium for early delivery or accept a low price for a late delivery. This model can be used in price negotiations between the MTO firm and its customers and also in the relation between the MTO firm and its suppliers. With flexible prices pressures on the supply and manufacturing process will decrease leading to a more stable situation. Flexible prices can be a solution to handle delays though it will be doubtful whether MTO firms want to decrease their service level by leaving space for longer lead times.

From this section it can be concluded that delays in the supply chain can lead to longer lead times, disruption of the production planning, congestion at the shop floor and to lower prices. Since MTO systems do not hold any inventories and use lean supply it is difficult to control these delays. However the MTO system can try to control these delays by the use of in-greatest-trouble dispatching rules, which gives jobs with delays priority over others. Zou and Li, (2006) have developed a model that is able to reschedule the order pool efficiently if jobs are give priority. Another possibility is to hold a buffer in the capacity that makes it possible for delayed jobs to squeeze into the shop floor without harming the overall process. It can also be decided to start with partially manufacturing the job and wait for the delayed components when further manufacturing is not possible. Probably the best way to deal with delays is to make use of flexible prices that are based on delivery time.
Chapter 3: Transport delays

This chapter discusses what different transport delays there are in the supply chain, what causes these delays, what effects they will have and how they can be managed. In the end of the chapter it should be clear how transport delays can be managed by MTO firms. It must be said that delay by air transport is not taken into consideration since these factors alone should be able to give a clear explanation of delays as well. The length of the different delays described is not mentioned since there was not enough literature available on this topic.

3.1 What different transport delays do exist?

Zhang and Figliozzi, (2010) conducted interviews with several top managers in the manufacturing sector in China. They asked managers to rank what kind of transport was most likely to cause delays. It appeared that the biggest influence was caused by factors that were not transport related and were considered as ‘Other’ factors. For instance, manufacturing, customs, weather, or supplier related delays. Among transport related delays, transshipment was the ranked highest followed by delays at the loading and discharge port, direct land transport and the long haul journey at sea was ranked lowest.

Delay by direct land transport

We consider road transport and railway transport to be road or land transport. With land transport we mean the trip from point A to B and we do not take loading or unloading into consideration. Land transport usually takes place over long distances; this is also called Long-haul or intercity transportation (Crainic, 2000). Congestion has a large impact on road transport. Road networks of major city centers are heavily congested. Furthermore, the congestion problem has a substantial impact on the economy as a whole (Emmerink et al, 1995). In addition to traffic congestion we can also consider navigation problems, weather conditions and the breakdown of materials to be examples of factors that cause delays with land transport.

Congestion can be considered as an external influence. However congestion should be taken into consideration during the planning of routes. A logical solution would be to drive only overnight. This idea is bounded by the fact that not all companies operate 24 hours a day, which makes driving overnight ineffective. However the possibility it should be taken into consideration
when planning routes. If routes are planned during the rush hours then delays should be accounted on forehand.

Breakdown of materials falls into the category of internal and external causes. Bad maintenance leads to unnecessary breakdown of materials. On the other hand the breakdown of materials is also affected by external factors such as weather influences sloppy roads and road accidents which cannot be controlled. Furthermore, transport companies should also respect the maximum hours a driven is allowed to drive in order to avoid accidents due to fatigue. Thus partially avoiding these delays can be done by proper business policy from the suppliers or the transport companies.

Delay by activities related to loading port

A loading port is a place where shipments are loaded and secured aboard a vessel. This is can be considered as the starting point of the goods journey. This delay is simply the time it takes to load the goods onto the transport carrier. A loading port can be any place where goods are loaded onto a carrier; a common loading port is a terminal or freight hub. “In Terminals cargo and goods are consolidated, grouped or simply moved from one service to another” (Crainic, and Laporte, 1997: p11).

Delays at the loading port itself are likely to be generated by the operations of the carriers and traffic at the terminal. Operations of the carrier are the time it takes to load a vessel, the time it takes to store the loaded goods and the time it takes to get to the next loading job. These operations affected by the traffic at the loading port that can result in congestion. Another important loading delay is called a connection delay. This represents “the time spent waiting for on the designated service to be available” (Crainic, and Rousseau, 1986: p5). For example one vessel cannot be loaded because its goods still have to arrive with another truck or the vessel cannot be loaded since there is no fork lift truck available. Thus planning and preparation of the loading must be taken into account as well. Clear appointments regarding the loading dates must assure that shipment is expected and the goods are ready to be loaded.
With loading there also arise administrative problems. Drivers are only allowed to leave with appropriate paperwork. The time spent waiting for this paperwork while the vessel is already loaded is costly and delays the delivery unnecessarily.

These factors are partially internal and external to the transport process. Congestion at the loading port can be considered as internal for the suppliers and external for the transporters since they do not have an influence on the loading procedures. At the loading port there should be clear traffic rules which can be set by the supplier. There should also be certain boundaries to the amount of traffic on the loading port which can be regulated by accepting a maximum of orders in order to keep the traffic under an appropriate level. The connection delay is considered to be an external factor if the supplier and transporter need to wait for other parties to deliver the goods and internal if they are themselves responsible for the delay. This delay can be regulated by setting penalties on late deliveries. In addition it can also be smart use a buffer in order account for delays. Proper planning of the fork lift trucks is important in order to make the load process run smoothly. This can be considered as an internal factor for the suppliers and external for transporters. The administrative problems also have an internal cause. Transport should not be delayed by administrative procedures and thus company policy needs to be efficient at this point.

**Delay by transport of products by sea**

Sea transport usually travels over long distances; therefore the delays at sea are relatively small. Sea transport also deals with loading and unloading of goods but these delays are relatively small due to the long distance. Delays at sea by are usually caused by the weather and the breakdown of materials.

Like was mentioned before the breakdown of materials can be considered as internal as well as external and can be managed in the same way with land transport. Weather influence is considered to be external. Though some part of the weather can be forecasted and used in the planning of routes etc.
Delay by transshipment

Transshipment is also called intermodal freight transport which is defined as “the use of two or more modes to move a shipment from origin to destination” (De Witt and Clinger, 2000). Transshipment usually takes place at a terminal or freight hub like an airport, a railway station, seaport, distribution centre etc. “In terminals convoys are formed and dismantled, freights may be consolidated, loaded in und unloaded from vehicles, vehicles may be changed from one convoy to another, etc (Crainic, and Laporte, 1997: p11)”. Sometimes it is necessary for the distribution of the goods to change the transportation method because of geographic reasons. However it is often the case that this is done because of cost reductions. At the hub the goods are transferred to another type of transportation method. Examples of hubs are sea-road, sea-rail and road-rail or sea-road-rail. Delays by transshipment are caused when one transporter has to wait for other suppliers to deliver their goods before they can move further on to their destination. Delays with transshipment are not very different from delays at the loading port. However there is more emphasis on the connection delay. Therefore it is important that the goods are delivered on time, that they are stored properly and can be transferred onto another transport type rather fast. Transshipment has to deal with more parties than road transport; this has clear implications for the reliability. If road transport can achieve 98% reliability, the intermodal transport can only reach 90% since it has to multiply the reliability of several parties (Puil, 1994). Therefore state that “Intermodal transport adds complexity and delays to the supply chain”. Transport hubs are usually large facilities which are also more likely to generate delays because of their size and complexity (Newman and Yano, 1999). These delays are caused by the large distances that need to be covered by the carriers and the higher rate of bureaucracy and procedures. However the use of transshipment might be inevitable due to geographic or large costs reasons. Thus using transshipment is always causing a delay but is sometimes inevitable. Therefore direct transport is considered more reliable and leads to shorter delivery times.
Delay by activities related to discharge port

A discharge port is “a place where a vessel is off-loaded and the shipments are dispersed to their respective consignees. It may or may not be the port of destination. Also called port of unloading” or end destination (Business dictionary).

Delays related to the unloading of goods are considered as to be almost the same as with the loading of the goods and transshipment. The big difference can be found at the administrate side. If goods arrive at the final destination the paperwork needs to be appropriate. And it needs to be clear what goods the vessel carries. If this is not the case it is possible that the goods are send back to its point of departure. This factor can be considered as internal for the suppliers and transporters. Paperwork needs to be done properly to avoid unnecessary delays. Again clear appointments need to be made to make sure that delivery dates are clear and that shipments are expected.

Delay by other factors

Examples of these delays have already been mentioned; manufacturing, customs, weather, or supplier related delays (Zhang and Figliozzi, 2010). With manufacturing delays we mean problems with the production of the goods before they can be shipped. This is a non-transport delay and can only be influenced by setting clear delivery appointments. If the supplier announces that it cannot deliver the goods on time it must be demanded that ‘crash production’ is used to speed to shorten the delivery lead time. In addition it can also be demanded that the suppliers holds inventory in order to assure a reliable supply of goods (Cakravastia et al., 2002).

Weather has a negative influence on the transportation of goods. Simple examples are rain, wind and snow that delay the transportation significantly. Sometimes the weather can be accounted for by proper planning. Certain seasonal weather influences are known and can be taking into consideration when routes are planned. There are also certain events that are beyond the control of planning, such as earthquakes, floods etc (Prater et al., 2001).

Transports that have to pass ‘closed’ borders can result in unnecessary delays as well. Crossing political borders can always pose problems, especially in the case of countries with political instability (Prater et al., 2001). However even in political stable environments issues
can arise. Typical issues that can arise are corrupt customs, incomplete paperwork or sophisticated entrance requirements. These situations can be avoided by rescheduling routes or by providing drivers with proper paperwork. Additionally drivers should be given clear information about borders requirements and procedures in prevent surprises at the border. Other factors like corruption seem to be out of reach even though a lot of attention is given to it. One good example is the problems with the Somali pirates that keep hijacking boats although a lot of military attention is given to the situation.

From the above mentioned delays it appears that controlling the delays is only possible to a small extent. Preventing the delays from happening is only possible in limited degree. However there are some ways were the delay can be controlled if it occurs. This starts with clear communication from the supplier and transporters if a shipment is delayed. Loa and Hallb, (2008) suggest the use of real time tracking of the goods. Technologies have made it possible to develop a real-time travel forecasting methodology that results in online real-time logistical information about the goods. This system takes into account factors like, high way capacity, geographical factors, traffic etc. The online travel time prediction data is sent to the manufacturer or transhipment terminal, which they can incorporate in their process so that the possible delay has the least amount of impact. For a transhipment terminal this can lead to the more efficient coordination of fork lift trucks or to decisions that determine whether or not another will postpone its departure or that it will leave without the delayed goods. The MTO firms can incorporate the real-time predicted delivery time in the coordination of the order pool and shop floor.

Another mechanism to control the occurred delay is by use of priority shipments. If a delay has already occurred in the manufacturing this job can get the status of a rush order, which is explained earlier in this chapter. The same can happen with a job that faces a delay during the journey to its end destination. If this delay is likely to exceed the delivery date if the process is continued like a normal shipment it can be decided that priority is given to this job. This means that the job can get a priority over other jobs in the case of transhipment or offloading. Depending on the situation it can even be possible to transfer the goods at a terminal or distribution centre to a courier that has the capability to deliver the goods on time. These measures can only happen at additional costs.
Chapter 4: Conclusion and Recommendations

It can be concluded that delays in the supply of goods for MTO firms have a big impact on the further process of manufacturing. MTO firms can manage these delays by setting clear company policy that tries to prevent delays. Capacity and production planning should be taken into consideration during the negotiation with potential customers. If the potential job can result in overcapacity it can be useful to reject the job. In addition it was also found that it is better to reject a job in advance than delivering the product late. In the negotiation process possible delays can be prevented by setting feasible delivery dates. Thereafter the right suppliers should be found. Lorange et al. (1992) developed a model that is able to find the matching suppliers. It was also found that suppliers should be selected on basis of quality followed by delivery performance. Costs are of less importance since the customers are willing to pay for the extra performance. If the suppliers have been selected, clear appointments should be made regarding to the delivery of the goods. Delivery delays can be reduced by setting penalties that are proportional to the amount of days the delivery exceeded the delivery date. MTO firms can influence the way its suppliers organize its operations in order to improve the reliability. One way of doing this is by setting certain demands regarding to the transport of the goods.

During the research it was found that preparation of the transport is important to prevent transport delays. This preparation includes proper administrative work. Accurate paperwork gives a clear indication what goods are being carried by the vessel. The paperwork should allow the driver to smoothly pass the border or offload the goods. Drivers should also be thoroughly instructed when borders need to be crossed. Loading and offloading dates and times should be communicated in advance to make sure that it is accounted for by all parties. Transport vessels should be well-maintained to decrease the probability of material breakdowns. Routes should be planned at night in order to avoid congestion. Congestion should be accounted for in the lead time if avoiding rush hours is not possible. Politically unstable countries should be avoided in scheduling the routes because of risks like hijacking or corrupt customs. Weather conditions should also be taken into consideration when planning routes, especially with sea transport. If costs are relatively less important and short lead times are essential then transshipment should be avoided and direct transport should be used. Transhipment delays the process but can be required due to geographic reasons. If the supplier cannot meet the above mentioned prevention criteria or the MTO firm has no faith the suppliers ability to meet these requirements it can be suggested to outsource the transport. For the same reasons the MTO firm can even be
decide to organize the transport themselves. It was also found that supplier performance and reliability is improved when they are involved in an early stage of the design process, which takes away uncertainty for the suppliers. Other ways of information sharing also help to contribute to higher levels of reliability. The positive effects of information sharing can be increased by the implementation of VMI programs. By setting up long term supplier relationships performance is likely to increase as well.

A delay cannot always be prevented and therefore ways of managing these delays have been found. Since MTO firms do not hold any inventories it is process that is hard to control. The use of VMI programs is a possible solution. If a delay does occur there are several ways to minimize this delay. If the delay occurs already in the manufacturing of the components then the MTO can require its suppliers to make use of crash production to reduce the lead time. Thereafter it can be decided to let a courier take care of the further transportation. If the delay occurs during the transport it can also be decided to let a courier finish the route if there is a possibility to transfer the goods to a faster type of transport. Giving the shipment the status of priority order can also reduce the lead time. This priority status can result in faster offloading or further shipment at the transhipment terminals or discharge port. Delays during the transport should be communicated to the MTO firm so that they can already account for this in their planning of production. The use of real-time travel prediction can be supplementary to this communication. This gives transporters the ability to share online real-time data regarding the delivery arrivals. The real-time information allows the transhipment terminal and the MTO firm to account for the delay. When the delayed materials enter the order pool it can be managed by the use of in-greatest-trouble dispatching rules which gives priority to the jobs are furthest behind on schedule. In practice most MTO firms use ‘first comes first served’ dispatching rule, which is not suitable to handle delays. Under these rules it can be decided to partially start with manufacturing the job which creates congestion at the shop floor. It can also be decided that delayed jobs have to start at the bottom of the ranking. However if a job receives priority it can shift up in rank and released to the shop floor early. However this could affect the rest of the manufacturing planning process. This can be controlled by the work load control mechanism. It was found that although companies want to use their full capacity it can be advised to hold a small buffer in the work load in order to account for delays efficiently. The use of flexible prices is considered to be the best mechanism to control delays. The flexible prices are based on the actual delivery date. In contrary to the other control mechanisms, the advantage of flexible prices is that will lead to less pressure on the delivery and manufacturing process.
This research has been only based on qualitative research. In the future it can be recommended to conduct an empirical research that is better capable of measuring the effect of the different delays in the MTO process. Factors like lengths of (transport) delays should be included as well. The availability of literature regarding transport delays was very low. It can be recommended that this topic requires further research. This can be confirmed when looking at the effects of the recent transport delays due to the ash cloud in Iceland.
Chapter 5: References


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As cited from Delivery guarantees and the interdependence of marketing and operations


