The role of time variability in supply chains - a multiple case study

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Abstract

In this paper we present an approach for identifying problems in the managerial principles of supply chains. The approach is especially designed for analysing export deliveries in process industry. The key idea of the approach is to divide the logistic chain into major steps, measure the time variability at each step and to focus on the slow moving deliveries. The approach was tested at three paper mills and three paper board mills. The results showed that the approach is very powerful in identifying concrete logistics problems, which could be generalised in major problem areas. The analyses also showed the huge saving potentials that could be achieved by cutting the "tails" of the time distribution in material flow.

Keywords
Time based management, Logistics, Supply Chains, Process industry, Performance measurement

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35321-0_72

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1. INTRODUCTION

Most manufacturing enterprises are organised as networks of manufacturing and distribution sites that may be scattered around the world. These networks that we call supply chains affect crucially both customer service and the total cost at the customer. During last decade there has been a clear shift from developing operational performance of single factories towards improving the performance of entire supply chains. This change of focus is widely discussed in literature (e.g. Christopher (1992), Schonberger 1996, Bowersox&Closs 1996). It has been commonly argued that by effective supply chain management it is possible to achieve reduced inventories and overall costs simultaneously with better customer service. However, companies that have tried to apply the new approach have commonly recognised that managing of supply chains is more demanding than managing single factories. Neuman and Samuels (1996) studied supply chain integration in their study among logistics executives. They revealed a widespread support for the idea, but little evidence of actual implementation of the process.

The difficulty of managing supply chains has several obvious reasons. Firstly, responsibilities are commonly split in the supply chain, which tend to lead to sub-optimisation. Secondly, information systems are still rarely integrated through the supply chains which makes it difficult to co-ordinate both information and material flows. Also the big number of various sites that are often geographically wide spread makes management of supply chains difficult. Performance measurement is generally considered a key issue in effective management of operations. In supply chains management it is a necessity.

According to Bowersox (1996) the objectives of performance measurement and controlling activities in logistics is to track performance against operating plans and to identify opportunities for enhanced efficiency and effectiveness. He divides performance measurement into four levels: direction, variation, decision, and policy. Direction measurement is concerned with execution of the operational plan, variation measurement is concerned with accumulated deviations from plan, decision measurement is concerned with modifications to the operational plan, and policy measurement involves a change in objectives. Bowersox argues that the ideal performance measurement system incorporates three characteristics that provide accurate and timely direction for management: cost/service reconciliation, dynamic knowledge-based reporting, and exception-based reporting.

Frameworks for measuring the performance of supply chains are presented in several articles and research reports. Van Amstel and D'Hert (1996) presented a framework of performance indicators that was divided into four hierarchical levels, which matched quite close to the levels presented by Bowersox. They also listed numerous metrics that they suggest to be used at each level. PRTM Consulting (1994 in Bowersox (1996)) have presented a framework for integrated supply chain performance measurement, which divided the metrics into following types: customer satisfaction/quality, time, costs, and assets. ENAPS consortium (European Network of Advanced Performance Studies) has presented a model for measuring logistics processes especially in electronics, aerospace and automotive industries. It is has also a hierarchical structure, but the hierarchy is based on logistics processes. The model identifies six high level processes, four business processes and two secondary processes. Each of these processes include several sub-processes and activities (Mobråten 1997).

Caplice and Sheffi (1994) argue that there is not a need for developing new metrics, but to evaluate the usefulness of the existing metrics and measurement systems. They present eight criteria for evaluating logistics performance metrics: validity, robustness, usefulness, integration, economy, compatibility, level of detail, and behavioural soundness. The selection of the metrics should be carefully analysed using these criteria to ensure that they support the selected strategy.

In this paper we focus on performance metrics at variation and decision levels of Bowersox's hierarchy. We present an approach for effective identification of problems in the supply chains. The approach emphasises time variability as the key metric. The approach is tested in six case companies, one of which is used to illustrate the results achieved. The selected metric is evaluated using the criteria of Caplice and Sheffi (1994).

2. THE RESEARCH QUESTIONS AND APPROACH

The research questions of this study are stated as follows:

- What measures should we use to identify the throughput time reduction potential in supply chains?
- What is the most effective approach to shorten the total throughput time of supply chains?
- What is the impact of throughput time reduction on the profitability of the company?
- What means have the biggest impact on the time performance of supply chains?

These research questions are studied by an in-depth analysis of the throughput time structures of supply chains at three paper mills and three paperboard mills. Situation was analysed on very detailed level by using the production databases of

the mills. The samples varied between approximately 6000 deliveries during 8 months period and over 20 000 deliveries during 18 months period.
Data comprised detailed time stamps for each delivery, i.e. when the order entered mill's order handling process, when the requested paper was produced, cut, packaged, dispatched, shipped, received by the sales office and delivered to the customer.

The objective was to find out the throughput time structure and its variability at each step of the different supply chains. This information was used to identify problems in the supply chain and to plan improvements. In general, the logistic chain of an exporting mill using sea transport can be divided into following phases:

- Order handling and production planning
- Production and work in process inventory
- Stocking at the mill
- Land transport from the mill to domestic harbour
- Sea transport to export harbour
- Land transport from harbour to sales stock
- Stocking at the sales office
- Land transport from sales stock to customer.

In this study the supply chain was divided into five steps of the physical material flow. This was done according to the availability of the data in the cases. The first step is from machine reel i.e. paper or paper board machine to dispatch, which measures the time spent at the mill. The second step is dispatch-shipping, which tells the time deliveries are waiting the departure of the ship. The third step, shipping-estimated time of arrival (ETA) is the time spent at the sea transport. The mill order is usually divided into smaller customer deliveries at the sales stock. Therefore the last leg in the logistic chain is divided into two steps. The fourth step is the time between the arrival to the sales stock and the first customer delivery. The fifth step is the time between the first and the last customer delivery. In addition to these five steps of the physical material flow, we measured also the time between receiving the order and production. This tells how long time is reserved to production planning. From the customer's point of view this is a part of the delivery time. Also the time spent at the mill could be further analysed into smaller steps between cutting, sheeting, packaging etc., but the results from these analyses are not within the scope of this thesis.

The throughput times of each of these steps were analysed statistically. The throughput time of each of the step was divided into time buckets in order to find out the variability. Next the effect of throughput time reduction by cutting the "tails" was calculated. The reasons for the long throughput times were analysed in working groups that consisted of researchers, sales personnel, production and shipment planners and mill managers. Finally, conclusions were drawn considering contribution to the existing knowledge in the field.

3. RESULTS OF THE CASE-ANALYSES

The analysis results in the six cases followed a very similar pattern. Figures 1-6 provide an example of the analysis results. The first common phenomenon was that the measured average total throughput time was longer than what was estimated by the marketing, logistics and production managers of the mills. The average throughput times from the production to customers varied between 60-120 days. If the order handling and production planning time is added, the throughput time is 20-40 days longer than that. The estimates before the study were commonly less than half of this, which matched quite well to the majority of the deliveries which had went as planned. However, the main reason for the long throughput times was in all cases the 5-30% of deliveries that had considerably longer than average throughput time. The class "over 48 days" in figures 1-6 represents these deliveries, and the average for this class was in many cases more than 100 days.

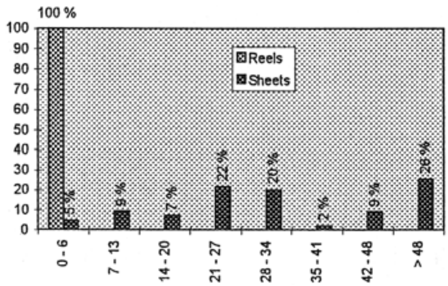

Figure 1. Production sample: Cutting - Dispatch.Thoroughput time distribution in weekly slots

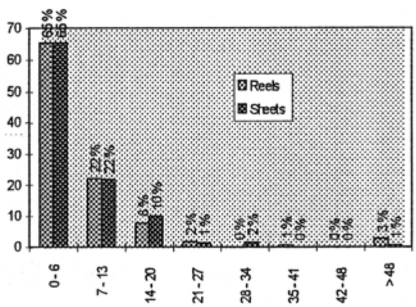

Figure 2. Production sample: Dispatch - Shipping.

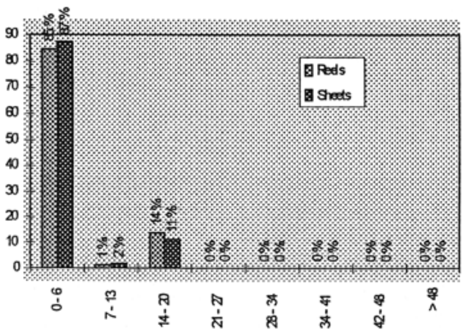

Figure3.Customer order sample: Shipping – ETA (Estimated Time of Arrival)

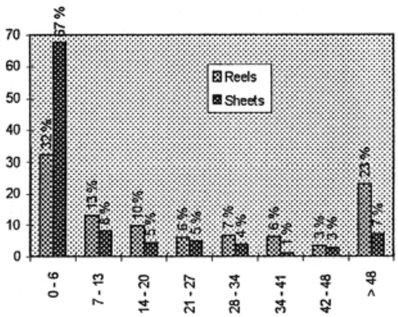

Figure 4. Customer order sample: ETA – first batch to customer

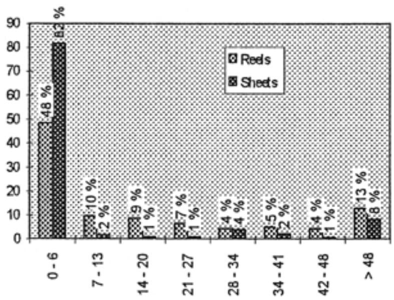

Figure 5. Customer order sample. First and last Delivery from the sales office to the customer.

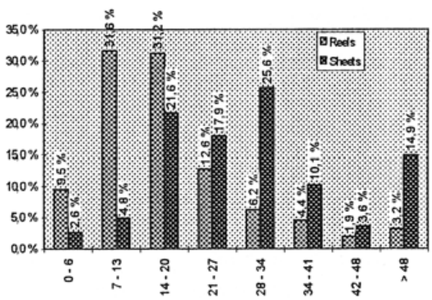

Figure 6. Average times to finish order before the due date.

The "over 49 days" or "7 week" class at each step was taken into closer consideration. First, the impact of this class to the logistics costs was estimated by calculating the cost saving potential if all deliveries flow in less than 50 days through each step. This would theoretically still allow maximum 250 days of total throughput time. In practice this calculation was made so that all deliveries that had over 50 days throughput time at some step was given 49 days throughput time. The savings achieved at each step by this change were calculated by using 30% interest rate. This included both inventory carrying costs and warehousing cost. It is a rough estimate that is based on the values generally presented in the literature for these kind of heavy and cheap products that require good warehousing facilities. The cost saving potentials varied between 10 million FIM and 24 million FIM per annum. Table 1 provides an example.

Table 1 Cost savings potential in an average mill, when class >50 performs under <50 days.

Mill1: cost savings potential if >50 classes do not exist						
Annual turnover:	**900'000'000 FIM**					
Sheet:	**500 000 000 FIM**		**Interest%**	**30%**		
Reel:	**400 000 000 FIM**					
Sheets	**cutting-packacing**	**packaging-dispatch**	**dispatch-shipping**	**shipping-sales office**	**sales office-customer**	**SUM**
class average	161	125	95	98	785	-
% of volume	5.25%	0.60%	1.11%	2.12%	3.65%	-
savings	1'839'345	142'643	159'723	324'951	8'403'428	10'870'089
Reels						
class average	139	82	77	99	602	-
% of volume	9.57%	1.77%	0.91%	8.05%	6.77%	-
savings	1'612'235	109'336	47'695	753'425	7'007'899	9'530'589
Total savings	3'451'580	251'979	207'418	1'078'376	15'411'326	20'400'678
Assumption: the cut production will have the throughput time of 49 days						

It was obvious that in no case it was planned to keep any delivery more than 50 days at any of the five steps. In these deliveries the mission of logistics management, to deliver the right products to the right place at the right time, was clearly failed. Therefore the closer analyses of these deliveries was expected to identify the problems of logistics management. This hypothesis was tested in working groups that were founded at each mill to discuss the analysis results. The working groups consisted of researchers, sales personnel, production and shipment planners and mill managers. It turned out that the analysis approach helped to identify problems at very concrete level. Typically it appeared that the main problems could be restricted to some main market areas or product groups and further to a limited number of customers or products. Focusing on developing practices with these customers, sales offices and the mill it was able to gain major benefits.

When the specific problems that could be identified in the working groups were studied, we were able to identify the main sources for the problems at general level:

- The strong preference towards optimising production waste during the cutting (slitting) and sheeting operation result in poor inventory turnover at the stock (see also Hameri 1995). The approach to optimise the production waste causes problems in overall performance level of the process.
- Due to long and varying delivery times customers are not able to forecast their need. Therefore the orders are in practice not fixed, resulting frequent changes in order sizes.
- The long lead-time and lack of transparency of the supply chain cause uncertainty that leads to big safety times and security stocks. Eventually the outcome is distortion in the whole information flow in the supply chain, which generates surges in demand information at the mill (see also Towill 1996).
- Long production cycles of the paper machine is in the heart of many problems in the supply chain. Orders must be received long time in advantage, the timing of production often does not match customers needs and the production lot sizes exceed remarkably customer delivery lot sizes. In many cases some orders were produced several weeks in advance because of the production cycles. They could also be shipped to the sales stock where they waited for a long time the first delivery to the customer. In worst cases the customer need was changed, products could not be delivered to customer and finally they were forgotten to the sales stock.
- The sales offices tend to order from the mill in much bigger lot sizes than customer deliveries. The sales office tries to save ordering costs that lead to high inventory costs and obsolescence risk. The ratio customer deliveries/mill order appeared to be one of the best indicators of the average total throughput time, as illustrated in figure 7.

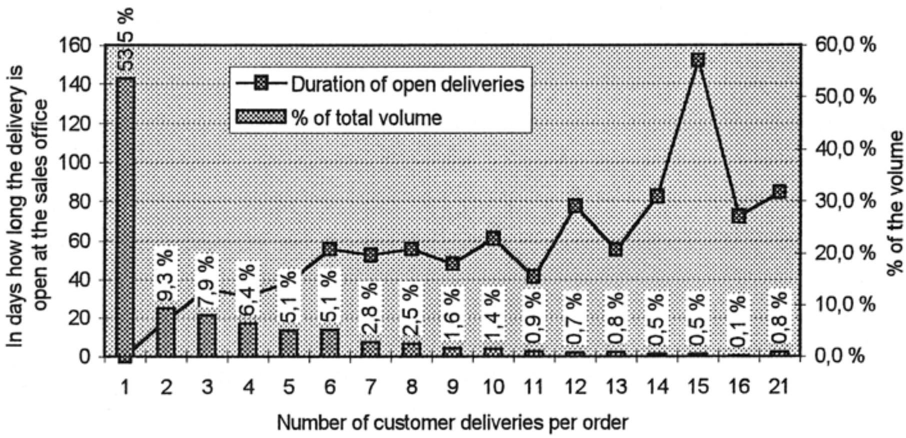

Figure 7. Comparing the number of customer deliveries with the average length of an open order at the sales office; e.g. orders with 12 customer deliveries are on average 80 days open at the sales office. Included is also the sum of tons delivered by each number of deliveries per order.

- Big number of low volume products was also one of the main indicators of logistics problems. This is a problem that is also discussed a lot in the literature (see e.g. Coopers and Griffiths, 1994). If the actual activity based costs of these products were calculated, they rarely are profitable. Therefore their strategic role in the product portfolio should be carefully analysed.

4. CONCLUSIONS

In this paper, an approach for identifying problems in the managerial principles of supply chains has been described. The core of this approach is the analysis of time variability at each step of the supply chain. It is a very focused metric, which does not attempt to catch all aspects of performance but focuses on time performance and logistics costs, and on variation and decision levels identifying opportunities for enhanced efficiency. In the following we evaluate time distribution as logistics metric using the criteria presented by Caplice and Sheffi (1994) in the light of the experience gained from the six cases.

Criterion	Description	Evaluation of time variability
Validity	The metric accurately captures the events and activities being measured and controls for any exogenous factors.	Validity is high because the metric reflects problems in the managerial principles that are in the control of firm's management.
Robustness	The metric is interpreted similarly by the users, is comparable across time, location & organisations, and is repeatable.	Time is an unambiguous metric and easily comparable over time.
Usefulness	The metric is readily understandable by the decision-maker and provides a guide for action to be taken.	The experience from the cases provided significant evidence that time variability is an effective metric for identifying actions to be taken.
Integration	The metric includes all relevant aspects of the process and promotes co-ordination across functions and divisions	When time variability is simultaneously analysed at each step of the supply chain, it effectively reveals sub-optimisation in the chain and promotes co-ordination.
Economy	The benefits of using the metric outweigh the cost of data collection, analysis, and reporting	The data required for calculating time variability is usually routinely reported. The analysis takes approximately 1 person month work due to the huge amount of data, but the potential saving are significant, as illustrated in table 1.
Compatibili ty	The metric is compatible with the existing information, material, and cash flows and systems in the organisation	When time variability is measured in terms of throughput time in days it is compatible with most logistics information systems.
Level of detail	The metric provides a sufficient degree of granularity or aggregation for the user	In many cases the time variability need to be analysed in more details: which product groups and which customers are having exceptionally long throughput time.
Behavioural soundness	The metric minimises incentives for counter-productive acts or game-playing and is presented in a useful form	When time variability is simultaneously measured at each step of the supply chain and it is used for identifying exceptionally slow movers (over 50 days), the risk for counter productive acts is minimal. When the time variability is further decreased the effects to production and transportation costs must also be measured.

Against this facet we may answer the research questions set in the beginning:

- What measures should we use to identify the throughput time reduction potential in supply chains? Apparently the only underlying measure that best depicts and to which most of the other measures base is time. Inventory costs and volumes are both time dependent, and the same is with customer service level and punctuality of the operations. By splitting the material flow in detailed slots and measuring the time consumed at each slot, one is able to draw the overall picture on the consequences of managerial actions and procedures.
- What is the most effective approach to shorten the total throughput time of supply chains? The mill in the beginning of the flow sets the initial pulse for the whole supply chain. This cycle sets the ultimate constraints for customer service and safety stock levels. The simple logic is: the faster the mill the better service level and the smaller the need to establish safety buffers in the chain. Therefore the most effective approach to trim the material flows in a supply chain is to shorten the production cycle at the mill. Once in operation fixed and short cycles enable better partnering with other forwarding units in the chain.
- What is the impact of throughput time reduction on the profitability of the company? According to the sample the direct cost savings potential from reducing the throughput time distribution in the chains is of the level of 2-5% of the annual turnover. It should be pointed that this savings potential can be achieved without any additional investment, by applying new managerial principals for production and supply chain partnering. This savings potential affects directly the profitability of the unit.
- What means have the biggest impact on the time performance of supply chains? As already discussed the cycle time at the first leg of the supply chain is the one that sets the phase for the whole supply operations. Fixed production cycles enable fixed delivery cycles, which in turn generate means to controlled material flow. Fixed cycles also cut the tails of the throughput time distributions at each step of chain, which ultimately improves the performance through improved controllability.

5. DISCUSSION

As a conclusion we argue that time variability fulfils well the criteria of a good logistics metric. However, we underline that the following issues are crucial for the effective use of the metric in supply chain development:

1. Time variability should be measured simultaneously at each step of the entire supply chain.

2. The results of the analysis should be analysed in a cross-functional team where sales, transportation, warehousing and production are all represented.
3. There is often a need for analysing the slow movers in more details to identify the actual problems.
4. When the conclusions from the analysis results are made in the teams, focus is first on identifying causes for bad performance at specific level: identifying products or product groups, customers or market areas causing the problems.
5. When the specific problems have been identified the focus shifts to identifying the needed changes to the managerial principles in the entire supply chain: sales, transportation, and production. It is also important to review the effect of product palette to logistics performance.

Encouraged by the results achieved in this study the case companies are in process of implementing a system for continuous monitoring of throughput time and time variability in the supply chain. We strongly believe that it will significantly improve the effectiveness of their supply chain management. We also argue that the approach has a wider applicability especially for process industry that has multi-step supply chains with dispersing material flows.

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7. BIOGRAPHY

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