TAMPERE UNIVERSITY OF TECHNOLOGY

TERO JUTILA

STRATEGIC MATERIAL LOGISTICS MANAGEMENT AS A PART OF SUPPLY CHAIN MANAGEMENT IN HEAVY HIGH-TECH INDUSTRY

Master of Science Thesis

Examiner: professor Jorma Mäntynen
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TIIVISTELMÄ

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Logististen toimintojen merkitys on kasvanut nykykonepajateollisuudessa toimitusketjujen monimutkaistuessa hajautetun kokoonpanon ja hankinnan myötä. Oirehtivan toimitusketjun ongelmat ilmenevät usein logistisissa toiminnoissa, mutta juurisyyt ja parhaat kehitysmahdollisuudet saattavat löytyä muista toiminnoista tai prosesseista. Palvellakseen yrityksen tarpeita parhaalla tavalla on tärkeää kehittää logistisia toimintoja, välineitä ja prosesseja osana toimitusketjun hallintaa.

Tämän diplomityön kohdeyritys Sandvik Mining and Construction’s Surface Drill’s Supply on kohdannut haasteita materiaalilogistiikassa ja varastonhallinnassa toimitusketjussaan. Nykytila-analyysi nostaa esille tarpeita logistisen tiedon hallinnassa, varastoinfrastruktuurissa, materiaalivirtojen hallinnassa, varastotasoissa, pitkissä läpimenoajoissa, tuoterakenteen modulaarisuudessa, muutoksen hallinnassa ja toimintojen välisessä vuorovaikutuksessa.

Kasvava kilpailu ja asiakasvaatimukset yhdessä kasvaneen epävarmuuden kanssa pakottavat yritykset kehittämään tuotettaan ja toimitusketjuaan vastaamaan tarpeisiin nopeammin pienemmillä riskeillä ja kustannuksilla. Läpinäkyvä tiedonjako ja yhteistyö toimintojen ja toimittajaverkoston välillä ERP ja PLM työkalujen avulla mahdollistavat kokonaisvaltaisen toimitusketjun hallinnan. Ketterä/lean toimitusketjun hallinta yhdistää kustannustehokkuuden ja joustavuuden hyödyntäen modulaarisen tuoterakenteen mahdollisuuksia läpimenoaikojen lyhentämiseksi.

Joustavuus, läpinäkyvyys ja läpimenoaikojen nopeuttaminen otettiin lähtökohdiksi logistisille ratkaisuille. Tehokas materiaalivirtojen hallinta ja varastonhallinta mahdollistuvat parantamalla nimiketiedon luotettavuutta ja läpinäkyvyyttä ERP:ssä. Varastojen tiedonhallintaa tarkennettiin riittävästi uusilla ratkaisuilla ja mobiili logistiikkaportaali mahdollistaa suoraviivaiset ja joustavat prosessit.

Toimitusketjun kaikkien toimijoiden tulisi ymmärtää yhteiset tavoitteet ja omien toimien vaikutukset. Yhteinen operatiivinen tieto, jota logistiikka omasta puolestaan tarjoaa, on merkittävässä roolissa tämän ymmärryksen saavuttamisessa.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
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Logistic operations have increased significance in today's engineering industry due to decentralizing of purchasing and assembly, and hence more complex supply chains. Problems of ailing supply chain often appear in logistic operations but root causes and best development abilities may exist in other functions or cross-functional processes. To serve company's demands best way it is essential to develop logistic operations, equipment and processes as a part of overall supply chain management.

This thesis' target company Sandvik Mining and Construction's Surface Drill's Supply (SMC) has faced challenges in material logistics and inventory management in its supply chain. Current state analysis points out demands in logistic information management, storage infrastructure, material flow control, inventory levels, long lead-times, modularity of product structure, change management and cross-functional interaction.

Increasing competition and customer requirements together with increased uncertainty in business forces companies to develop their product and supply chain to answer quicker the demands with less costs and risks. Modern supply chain management literature emphasizes the meaning of modular product structures and co-operation in supplier network to reduce logistic lead-time. Transparent information sharing cross-functionally and lean/agile supply chain approaches enable cost effective and flexible overall supply chain management.

Product Lifecycle Management (PLM) system and approaches offer useful ways to manage product design and product related information centrally, and interact between parties. Overall supply chain management can benefit from PLM, but system implementation and approaches must be redesigned and integrated purposely.

Transparency, flexibility and acceleration of lead-times were taken as principles on logistic solutions. Effective material flow coordinating and inventory management are enabled by improving reliability and transparency of material information in ERP. Stock information management was taken enough accurate level with rearranged infrastructure solutions and mobile logistic portal enables more linear and flexible processes.

All the parties in supply chain should understand common goals and effects of own actions to secure effective supply chain management. Common operational information that logistics on their own behalf provide has significant role enabling this understanding.

PREFACE

Achievements are always more satisfying when the route has been challenging. Research and writing the thesis has been first and foremost a learning experience for me; professionally and personally. Topic and research environment were simultaneously interesting, wide and challenging. Numbers of less relevant issues were investigated to find the most relevant issues ending up to this thesis. The project gave an opportunity to combine lot of different doctrines learned within years in university. I hope this thesis would disseminate the same cross-functional understanding that I learned within this research.

Much of the work was done alone in library or in computer class, but the most creative ideas and perspectives were formed from discussions with people. I want to express my warm thanks to all the co-workers that gave their contribution to this work. Those discussions in the middle of rush would have seem like loss of time but they have been vital to this research. I would especially like to thank logistics manager Joonas Saarikko and all the co-workers in logistics department. The support and team spirit I experienced was memorable. My special thanks I want to express for examiner professor Jorma Mäntynen. The support, advices and professional steering I received was something exceptional.

Thanks for support and understanding to my family, especially for my beloved Anna.

Tampere, 9.2.2012

Tero Jutila

CONTENTS

TERMS AND DEFINITIONS

BOM	Bill of Materials
EDI	Electronic Data Interchange allows computer-to-computer interaction according to pre-defined profiles and processes. (Leenders et al, 2006. p.96)
ERP	Enterprise Resource Planning –system
FIFO	First In – First Out, stock velocity model
Logistics	Operative functions of managing materials and information connected to them.
MP1, MP2, MP3	Names of building complexes on SMC's Tampere site
Operations	Term operations is used to cover widely the whole process, that is went through in company, when incoming factors and resources are modified to produce ensembles of products and services to be delivered for the customer. (Heikkilä & Ketokivi, 2005)
OSMI	Obsolete and slow moving items
PDM	Product Data Management
PLM	Product Lifecycle Management
Sandvik	In this thesis, if else is not defined; Sandvik means Sandvik Group.
Satellite (SAT)	In this thesis satellite means external assembly or subassembly subcontractor companies.
SF	Sandvik Mining and Construction Surface organization
SMC	In this thesis, if else is not defined; SMC means Sandvik Mining and Construction Oy's Surface Drills organization at Tampere site.
Supply chain	Process that integrates, coordinates and controls the movement of goods, materials and information from a supplier through a series of customers to the final consumer.
UG	Sandvik Mining and Construction Underground organization.

1 INTRODUCTION

Supply chains in today's engineering industry have become more complex due to decentralizing of purchasing and assembly. Complexity adds logistical challenges as material and information needs to be transferred between risen amount of suppliers, subassembly subcontractors and final assembly centres. Often the problems occur at the logistical operations when logistical operations cannot deliver the material for the production in time, the material gets lost, the material gets injured or it's not currant. Logistical costs can also rise over acceptable. (E.g. Stevenson, 2009; Christopher, 2005) Similar problems have occurred at Sandvik Mining and Construction Oy's Surface drill rigs' supply in Tampere (later SMC). SMC produces high-technological drill rigs which qualities are innovative and ones of the best in the market. Still, its complex supply chain causes challenges and problems in supply and delivery which weakens company's competitiveness and profit. With quick overview to SMC's logistical processes and material flows, information systems, warehouses and equipment, it is clear that there is need for development in all these matters. Still, to understand which problems finally are logistical, which are important and how they should be solved, it is necessary to look behind the problems and estimate supply chain as a whole.

Supply chain management is often understood as a wider meaning of logistics. Advantages are often sought from logistical solutions. Logistics is still only one factor in chain, though its role is often very important. Supply chains in global industrial companies have generally widened in the past few decades and the group of stakeholders can signify hundreds of actors. Supply chain management as a term has been settled in use in business, but often the approaches and practical facilities are based on time when most of the functions were centred on the same site and supply chains were very linear. Supply chains exist without any separate actions and its operations are managed somehow, often with informal practices. Supply chain management although should be understood as a strategic view to designing and managing all the operations in the chain.

The premise for research in this thesis was to improve logistical operations at Sandvik Mining and Construction Oy's surface drill rigs' supply in Tampere and to improve logistical quality and supply. Even if the actual development focuses on logistical operations and equipment, the research extends to earlier stages on supply chain, to understand production's real logistical demands and to discover roots for logistical problems. It is also necessary to look forward as logistics serves production demands. Developing logistical operations separately in supply chain without considering the operations strategy, will not serve the supply the best way and supply chain is no longer managed as a whole.

The goal for this thesis is to find causes for logistical and other supply problems and figure out solutions to actual logistical problems, braking down the logistical barriers in supply chain and to find development targets. The goal is also to propose further research for other found problems or development targets in supply chain as they can bring competitive advantage, improve manageability of supply and improve work environment. Global perspective must be considered as SMC's Tampere SF Drill's supply is only one part of the global Sandvik Group. Aim is to secure the continuity of functions in Tampere site by ensuring that it can be effective and profitable operator, whatever the business environment or mother-groups business strategy will be in the future.

This thesis proceeds step by step progressing the understanding towards the end. First chapter presents context and methods of the research. Chapter two presents the target organization studied, business environment and project operated, and the most obvious problems and demands. Theory in chapter three and four widens and deepens the understanding of the environment operated. The concepts around Supply Chain Management are defined, investigated, compared and combined especially from the operations (purchasing, logistics and manufacturing) point of view. Theories and best practises from supply chain management and purely logistical subjects are investigated with literature and benchmarking. Chapter four takes a look to product lifecycle management, its possibilities and benefits as a collaborative tool in overall supply chain management. Chapter five implements theory to practise in SMC's logistical solutions, and supply chain management processes. Solutions and approaches are progressed from strategy to implementation. All the found matters in study are not solvable with logistical solutions and these matters need high-level co-operation between company's functions and processes for development and further investigation. These future development and investigation targets are presented in chapter six. Finally in summary chapter the investigated matters, their relation to most essential theories and concepts are gathered.

1.1 Subject and defining

The base for this research comes from the vision of Sandvik Mining and Construction's Tampere sites 'SF Drills Supply Material Logistics Development Project' where the researcher acts as an investigative project manager. The mission in project was to improve logistical quality and supply, traceability, weather proof and safety and reduce logistical costs. Investment payoff time was set to 17 months from the time all investments are completed. The vision included numeric measures for all the sub areas but from the view of researcher and developer, numeric measures can be hamper and misleading. At the moment, the logistical information management and transparency are not at the level that measuring about actual events would be reliable or expedient. Strictly focused measuring and research target can also lead to partial optimizing that does not necessarily serve the supply chain as a whole in a best way. 'When focusing on rising up the speed per kilometre, the shortcut may pass unnoticed.'

The research focuses on the material logistics role in supply chain in global heavy high-tech industrial companies and especially in the target company. Causes, effects and demands are investigated cross functionally in supply chain. The applied section of the thesis focuses on the base project and inbound logistics at Sandvik's Surface drill's supply. The underground drills production and logistics at the same factory are mainly separated, so it is left outside this research. Final product delivery logistics, shipping, spare part logistics and reverse logistics are also mainly left outside of the research as they do not have primary effects to focused inbound logistics in this target company.

1.2 Frame of reference

When talking about trends of logistics, Just-in-time (JIT) model, where exact material is delivered to demand place at exact time demanded, has been one of the major logistical trends in assembly industry. From business and economical point of view, the reduction of value-stocks has been another major trend and these two ideas serve each other. There is also critic against these trends as they both can be complicated to manage, bring hidden costs and cause breaks in production when timing is too tight. (E.g. Christopher, 2005)

Third major trend effecting to every area of business is globalization. It is not any more way to get competitive advantage but more a necessity to survive in competition. Globally or locally, the outsourcing has increased to a significant role in all the areas of companies' functions. Starting from outsourcing clearly supporting services like cleaning or security, outsourcing today extends to companies principal business like assembly or designing. Strategic decisions of outsourcing the production or getting flexibility with capacity subcontracting play significant role today in every industry. Production has therefore been more clearly separated to manufacturing from raw materials, subassemblies and final assembly. Globalization and outsourcing have affected to demand and role of logistics as the supply chains can be highly decentralized and supply for customer can bring competitive advantages. (E.g. Stevenson, 2009; Stratton & Warburton, 2003)

To support or enable the trends above, product development and designing have had to be developed within. Product Data Management (PDM) or more advanced Product Lifecycle management (PLM) as a way of managing the product related information with purpose suitable information system has during past fifteen to twenty years become facilitating the designing and data transfer to production. (Sääksvuori, 2009) Often managed with PDM-systems, modularity is a way to design product structure that consists of subassemblies put together. Modularity enables possibilities in supply chain like outsourcing the production of subassemblies to different location and delaying the customization of product. (E.g. Heikkilä & Ketokivi, 2005)

The role of information and information management has risen during last three decades. Logistic functions and production management base more and more to information technology. Enterprise Resource Planning (ERP) systems are basic tools to manage operations in today's manufacturing industry. When computers and information transactions increased exponentially during 90's, the information security became concern. Tight security acts started to harm information sharing in decentralized network of stakeholders and trend today is rather controlled transparency. Information management system and equipment are today as important for modern logistics as forklifts. Traceability and information monitoring enables more effective management of physical material flows (E.g. Christopher, 2005).

1.3 Research approach and research methods

Traditional engineering sciences base on natural sciences and natural sciences base on positivism as a concept of science. Positivism relies on proven facts and evidences and it does not allow any interpretation or meditation in results. (Olkkonen, 1994. p.26-28) Matters that effect to performance, reliability or quality of logistical processes in complex supply chain are difficult or even impossible to verify or measure unambiguously. As said earlier, the numeric measurement in these matters should be carefully used even if quantitative research approach is generally used in engineering sciences and especially in engineering industry. Subject and frame of reference are wide and different functions in supply chain have influences to each other. By measuring one variable, important issues may remain unobserved. One must understand first before he can measure. (Olkkonen, 1994. p.36)

Hermeneutics as a concept of science underlines the meaning of interpretation and meditation as "hard" research methods cannot be applied. Hermeneutic approach tries to get new knowledge from empirical research material, as tries positivism, but the material consists of short number of cases which representativeness is difficult to manage. The material is viewed qualitatively and it is possible to process it more deeply and make unexpected founds. (Olkkonen, 1994. p.36-37)

This research is combination of descriptive and normative research. Status quo description, analysis, and applied parts are descriptively studied and reported. Concepts and theories are studied more normatively. Ghauri and Grønhaug (2005) underline the influence of researchers background in to research orientation thus researcher should stay as objective as possible for the study researched. The influence of the researcher in this study is probably best seen in the subjects and study targets given deeper consideration.

Several different research methods are used in this research process as the thesis has different dimensions and parts. Some methods are handier for some meanings and unusable for others. Theories and concept analysis are mostly done by literature research using books and articles dealing with logistics, business, supply chain management, operation management and scientific research. Empirical part of the thesis uses participative empirical study methods and case study methods. As a researcher I am also working as a project manager at the logistic development project in SMC, so I get the empirical information about current conditions, problems, demands and results of the solutions. The information and data is collected by empirical work, from employees in discussions, from company's ERP-system and from company's intranet. More formal interviews are conducted with employees with whom the researcher is not in everyday co-operation. A benchmark excursion to relevant company is also conducted during research. Research and development focuses on challenges, experience and information collected from one company but important questions and demands are often similar in any company in assembly industry. Even if chosen best practices or physical solutions may differ.

1.4 Research questions and objectives of the research

To ease both, research of the subject and readability of this thesis, research questions have been divided to wider main questions and more specific sub-questions. The objective of this thesis is to answer or find views and best practises to all these questions.

1. What are the main connecting doctrines and guidelines of concepts Product Lifecycle Management (PLM) Lean Extended Enterprise (LEE) Supply Chain Management (SCM) and its types of Lean Supply Chain and Agile Supply Chain?
2. What logistical challenges there are in complex supply chains especially in heavy high tech industry and SMC, and how they occur?
3. How these found logistical and supply chain management related challenges should be concerned based on doctrines investigated earlier?
4. Which challenges are strictly logistical?
    - Which approaches or instruments should be used to deal with these challenges?
    - How these should be dealt with in Sandvik?
5. Which challenges or problems would be more effective to solve in other functions than logistics?
    - How these challenges should be approached?

First question is studied with more conceptual analysis methods. Rest of the questions are studied with case study and literature analysis methods. SMC's organization is used as a material source and as a study and development target.

2 TARGET ORGANISATION & STATUS QUO

To understand the business environment and the organization where the study and project is taken over we are exploring Sandvik Mining and Construction's organization, products, supply chain and logistical operations.

2.1 Sandvik Mining and Construction Tampere sites Surface Organization

Sandvik Mining and Construction is a part of international Sandvik Group and it has its headquarters in Sandviken Sweden. Sandvik Group is a high-technology engineering group operating in more than 130 countries with 47000 employees (2010). Total sales in 2010 were approximately SEK 83 billion (≈ € 9 billion). Core business areas of the group are divided in three areas presented in figure 1: Sandvik Tooling (annual sales SEK 24 billion), Sandvik Materials Technology (annual sales SEK 18 billion) and biggest Sandvik Mining and Construction (annual sales SEK 35 billion). (SMC a, 2011)

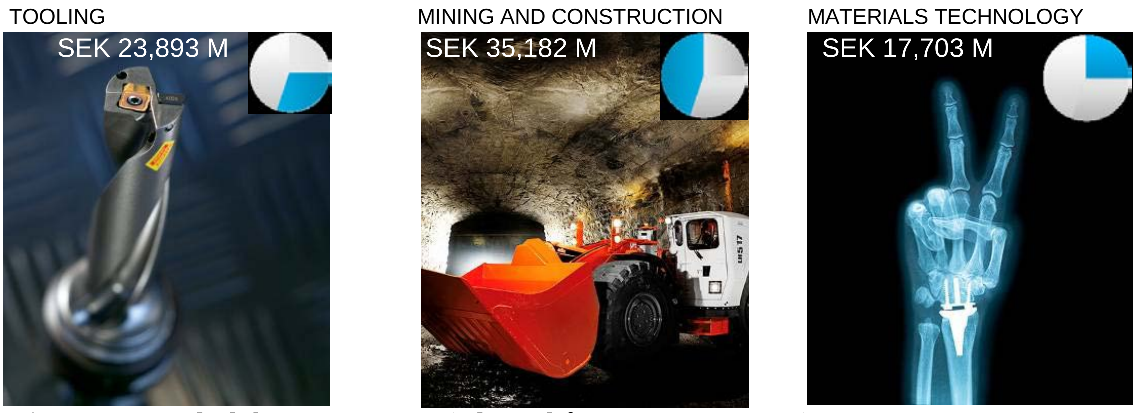


Figure 1: Sandvik business areas (adapted from SMC a, 2011).

SMC offers a world's widest selection of products to rock drilling, quarrying, crushing, breaking and material handling. In Finland SMC Oy have factories or offices in Tampere, Turku, Hollola, Lahti and Vantaa. At Tampere site there are surface and underground mining drill rigs designed, produced and marketed. This thesis and study focuses on surface drill rigs' production at Tampere site. Tampere factory has a long history as its former company Tampella was founded in 1856. Company and its products have become familiar with name Tamrock but were renamed as the new owner Sandvik integrated its functions and harmonized the brands in 2006. (SMC a, 2011)

The production volume of global surface drill rig's organization is approximately 700 rigs annually. At Tampere site, with subcontracting final assemblers, there are approximately 350 rigs produced annually (150 rigs in SMC final assembly, 200 rigs together in three subcontractor final assemblies). The volume is planned to be tripled in one year. Added to this, Tampere site also supplies and ships the core parts and subassemblies for assembly centre in China. Main market areas are Europe, North America, Africa and Australia. Africa is a big market area for robust older technology products same time as North Europe and North America are big markets for the most innovative technology on market. SMC has assembly centres also in China and India that cover Asian market areas. Tampere site supplies the core technological parts and subassemblies for assembly centre in China.

During this research, there are some organizational reorganizing taken over in the group and company. Headquarters of the company are transformed to Stockholm and some changes are implemented also in site level organizations. The changes do not have significant direct effects to study researched, but this changing and uncertain environment must be taken into account.

2.2 Products

In Tampere site SMC Oy engineers and produces drill rigs for surface and underground purposes. Underground and surface segments are divided in almost all the operational functions as products and production are very different. Underground devices are many times larger than surface rigs and volumes in surface rigs are much higher. Surface drill rigs are designed for high-capacity rock drilling in quarries, opencast mines and construction projects.

2.2.1 Product lines

Product lines in surface drill rigs can be divided into two major classes by their principles, "top hammer" rigs and "down-the-hole" (DTH) rigs. Main interest in this thesis is put on those rigs with cabin as they are major products in Tampere site. The outer appearance in all rigs with cabin is comparatively similar as we can see from figures 2 and 4. All these rigs have caterpillar drive, cabin in front of the frame, engine and device room behind the cabin, and a feeder device with a drill attached to boom in front of the rig.

Top hammer (TH) rigs product lines:

- **DPi** (the most high-tech TH rig with cabin), 4 different models (figure 2)
- **DP** (older technology, robust version of Dpi), 4 different models
- **DX** (lighter TH rig with cabin), 5 different models
- DXR
- DC

Figure 2: Slightly dirty after test drilling, DPi-series top hammer drill rig in front of MP3 building.

DC and DXR rigs are remote-controlled and have no cabin. Smallest DC rigs are also light weight (2800 kg) compared to ones with cabin (15t-23t).

Figure 3: Light weight DC-series drill rig.

Down-the-hole (DTH) rigs product lines:

- DI550 (new DTH product) (figure 4)
- DIXXX (old ramp-down products, designed and originally produced in Austria)

Figure 4: New DI550 DTH-rig.

Next we take a closer look to a product structure to understand how these rigs are designed and produced.

2.2.2 Product structure from supply point of view

The supply and final assembly centre operations of SMC base on the modularity of the product structure. The difference between terms module and subassembly in this context is that;

- **Modules** are units used in final assembly and they form the final product. Modules can be subassemblies like power unit or big individual items like frame for example.
- **Subassemblies** can be modules but all the subassemblies are not as they are used as a part of another bigger subassembly.

The main modules of the rigs are described in table 1 in order of final assembly.

Table 1: Main modules: 'Standard' -column identifies if the module is standard inside the product line or if it has options inside.

Module	Standard	Purchased or sub assembled
Frame (upper and lower frame in DX)	Yes	Purchased, Sandvik designed
Caterpillar pair	No	Purchased, Sandvik designed
Tank assembly	No	Sub assembled
Fender assembly (including hydraulics)	No	Sub assembled
Boom assembly	Yes	Purchased, Sandvik designed
Feeder assembly	No	Sub assembled
Engine assembly or power unit	No	Sub assembled, engine purchased as a commercial product
Cabin	No	Purchased, Sandvik designed

There have been two premises for modularity in SMC: 1. Modules enable that final assembly operation can mainly connect subassemblies and add the hoses and electricity to the whole, and 2. the assembly or purchase of the modules can be outsourced to subcontractors.

What has not been one of the premises is the aspect of 'late customizing', explained more specifically in chapter 4. All the modules have been directed to specific final assembly (final product) with work number. That's because: 1. all the non-standardized modules can include options or variations specified for the individual final product, 2.

the purchase or ordering can be timed to confirmed final product order, 3. the logistical control of modules bases on work direction.

There are differences in different models inside the product line and every individual can include different options. Added to this, engineering changes are transferred in to production continuously. The structure of the final product lives continuously without version stages. Bigger changes are transferred into production as a new tier version though. These simultaneous but hardly transparent versions, options and changes cause complicity to material flows and raises stock level. By simplifying the final assembly, the complexity has been decentralized to earlier stages in supply chain, where the management of complexity is even more challenging with current approaches.

Production and logistical direction of modules and most of the subassemblies is realized with individual work numbers. It happens that there would be modules to assembly five undefined DX or DPi rigs but there are not all modules for any specified individual rig. Modules may have some individual options or not but logistical personnel or production personnel at final assembly cannot use them to other final assemblies. That causes production delays or rearrangement in production, and logistical problems and jams in storages as accumulating modules need space.

There are also exceptions that actually question the use of individual work numbers in certain cases. Boom assembly modules for example are directed with individual work numbers but they are all (assumed to be) similar inside the product line and there are no options. When boom parts directed for starting assembly have not arrived, the existing ones are often used to other works than they are directed to. This cross-using is allowed and performed informally, basing on assumption that these certain modules are similar. There are two risks in this approach:

1. FIFO (first-in-first-out) approach does no longer realize reliably and some items may stand months and cause quality problems (rust, damages etc.)
2. From product development or production coordinator point of view, the items are expected to be used for a certain individual final product according to work number. Changes can therefore be implemented continuously considering the interface to other related items in the same individual final product. The risks are that interface to related items may be unsuitable and from After Sales point of view, the information about the items in individual product is incorrect.

2.2.3 Rundown production

There is a problematic situation with old DTH product line which development has been discontinued and all the resources have been minimized but they are still in production at least till the March 2012. The production of the DTH-rigs was transformed to Tampere from Austria just couple of years earlier. The remaining production storage was also transformed from Austria to Tampere. Soon it was decided to end the production of these old-fashioned DTH rigs and to develop a new DTH product that would replace the old ones. SMC has been forced to keep alive the old DTH production and hurry with the new product, as the competitor had a lead in this technology and they had a power to force down the prices of SMC’s main product area, the top hammer products.

When decision of rundown of the old DTH products was committed, all the efforts to support their production were minimized. BOM structures (Bill of Materials) for these old DTH products in PDM system are not kept up to date and therefore material reservations in company’s ERP system are not up to date either. There are number of mistakes and flaws in material reservations and logistics got aware of this when OSMI (Obsolete and slow moving item) was intended to be dramatically reduced and OSMI listing in ERP did not match with reality. This causes need to store numbers of items which are obscure and mostly redundant, but can be needed in production and are expensive. Items are also very difficult to repurchase if they are later demanded so that is why they need to be maintained. These items are often badly packaged and inadequately marked. Because these items are long term stored with poor packaging, it is often necessary to store them in covered storages to avoid corrosion and other damages. Because of their slow velocity in storages, these items are often blocking or disturbing the use of storages, and therefore the material supply for volume production as there is not too much covered storage space.

2.3 Supply chain in SMC

Supply chain for surface drill rigs is now studied from wider point of view to understand the nature of supply chain, order-supply chain and material flows. In its former company’s history SMC has been more typed as a manufacturing company. Today, the drill workshop is the only part of SMC that manufactures items or products from raw materials. Today SMC represent assembly industry quite purely. It is good to understand the difference between pure assembly industry and manufacturing industry. Still, many writers are talking about manufacturing and manufacturing industry in a wider sense meaning production of items and products. Assembly is all about connecting the manufactured and purchased items, modules, components and equipment together to produce functional product or part of it (Ruohomäki et al., 2011).

2.3.1 The order-supply chain

Based on high level decision, SMC manufactures rigs only for demand which means that production can start as order is ensured. Still, the supply chain or product itself is not designed to produce the products quickly right on demand. There are options and variations deep in the product structure and therefore delivery times for certain subassemblies are over a month, which is a relatively long time. Therefore there is a need for twelve month production forecasting and planning. The actual order-supply chain at SMC can be divided in to three major parts; Planning, Order and Supply. In Sandvik Group, there is region level sales department that gives sales forecast every month for twelve months in advance. So for example in August 2011 the forecast tells what the sales will be in August 2012. Local actors globally give their sales forecast with arguments and marketing department in Tampere evaluates these forecasts and gives their own forecast for production planning meeting. The production is planned based on this forecast and all the production is scheduled in ERP-system eleven months before the planned production date.

The accuracy of forecasting and planning is on model level. This means that the options are not forecasted but models are forecasted and recorder to production plan. This production plan is also delivered for suppliers and assembly subcontractors as planned orders. Suppliers and subcontractors have their own concern and distrust to these forecasts and plans. Because of this distrust SMC needs to bring forward orders and raise stock levels to ensure the continuity of the production.

Works (final assemblies) are established into ERP system as a prediction work with almost absolute product structure. Predicted works bring on material reservation that guides purchase operations and logistical planning. These prediction works are opened and turned to ‘real’ works by production controller when the customer order is fulfilled. Production controller checks the product structure, bill of material structure (BOM) and material reservations for every opened work. The actual operative purchasing is performed either by material controllers in production or automatically with EDI (Electronic Data Interchange) basing on profile in ERP. Material controllers make the purchase operation based on planned or opened works material reservations, depending on the expected delivery time of the item and stock level profile.

Sourcing is not only separated as a function but as a department too, located to another building. The role of sourcing department is to choose the subcontractors for items, module assemblies and transportation services. They negotiate the prices and delivery terms and conditions. Sourcing department is not involved in every-day operative functions of material purchasing and interaction with production or product development is not always fertile on operational level.

2.3.2 Global and local suppliers

The range of suppliers is almost as wide as possible. Many of the suppliers are relatively small workshops from Tampere region but there are also multinational enterprises which are many times larger than Sandvik Group. The supplier relationship with these giant companies is different than with those small local ones. Bosch Rexroth and Caterpillar are examples of vital and huge suppliers for which Sandvik, and especially Tampere site, is just one of the small customers among others. Small local suppliers are often almost dependent on SMC and its orders. Contacting with small local supplier can be very spontaneous and informal, in good and bad. Things are easier to negotiate with small suppliers, but their ability to implement new technology is more limited.

2.3.3 Network of final assembly and subassembly subcontractors

As mentioned earlier, SMC purchases capacity for final assembly from two subcontractors at Tampere region and one at Kurikka, 200km from Tampere. At the moment the thesis was written half of the final assembly capacity was purchased outside of the company and near future plan is to add volume so that SMC's own capacity stays approximately similar but still it would be one third of the whole production capacity. All of these final assembly subcontractors are also subassembly subcontractors or item suppliers. There are also pure subassembly subcontractors which are located in Tampere region. All of these final assembly and subassembly subcontractors in network are logistically named as satellites (figure 5).

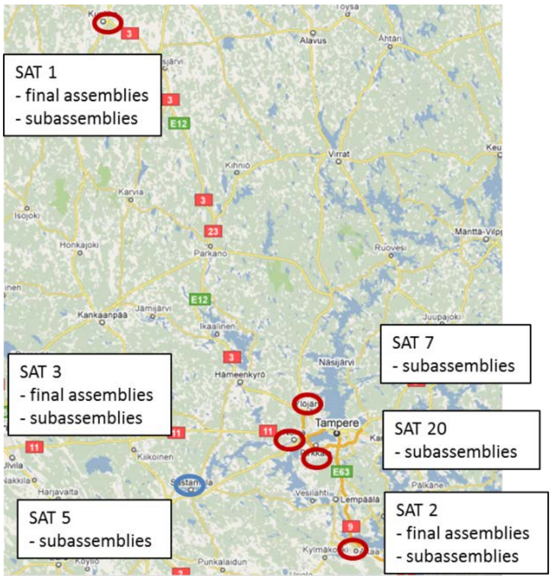


Figure 5: The network of SAT's (satellite companies, Final assembly and subassembly subcontractors).

SMC takes care of sourcing, purchasing and logistics for practically all the items for all of these satellites. Management of material flows into, from and between these satellites is one of the principle duties of logistics function and one of the principle development targets in the thesis. Demands and problems of this material flow management are dealt later in this chapter.

2.4 Material logistics

Material logistics is now studied as an operational function in supply chain. Environment, equipment and processes are purposely illustrated with many pictures so that reader can better visualize the topic.

2.4.1 Infrastructure

The factory at Myllypuro in Tampere was built in 1972 (SMC a, 2011.) and after some modifications and enlargements the basic structures are still original. Today that causes challenges to altered modern assembly production as production line and logistical processes today have different demands than four decades ago. Even if some old infrastructures are not as functional for today's functions as modern buildings would be, it is still possible to use them with more modern solutions.

Physical storage spaces

At Tampere site there are three actual building complexes named MP1, MP2 and MP3. MP1 and MP3 buildings and outdoor areas between them (figure 6 below) are the main areas where inbound material flows for SMC's supply are physically operated.

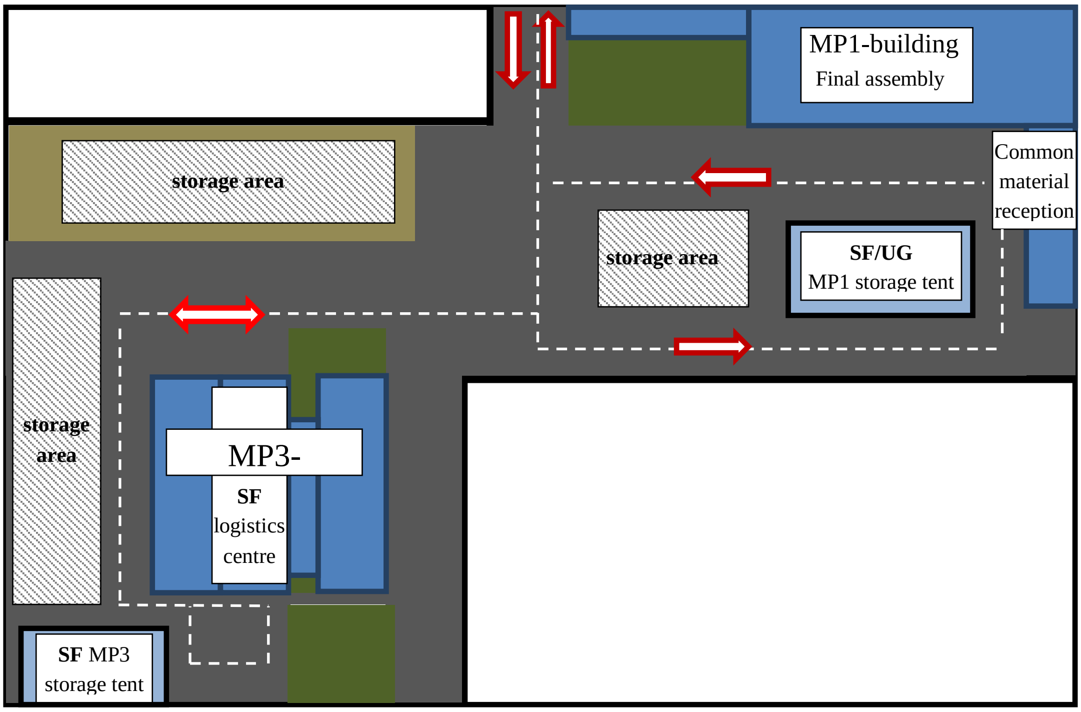


Figure 6: Physical material logistics environment in SMC's area. Diamond-lined storage areas are in reality undefined and messy. Arrows show the driving direction for truck traffic.

- **MP1** building is the main building including; most of the common functions between SF and UG, SF's Tampere site's final assembly and testing, UG's main assembly, administrative and support functions, and common material reception. As a logistical detail, there is an automated pallet shelf system which is not integrated to ERP system and is fairly slow for effective collecting for volume production.
- **MP2** building (not shown), from SF's point of view, mostly includes drill workshop where drills are manufactured and assembled. From this project's and thesis' point of view, drill workshop can be considered as a drill supplier for SF's supply as their inbound logistics are mainly separated from SF's logistic operations.

- The main storage space and logistic functions for SF's operation has been transformed to **MP3** building (figure 7 below). Product development, sourcing and order office are also located in MP3. The building is located separately, about 250 meters away, from the Tampere site's final assembly in MP1. The distance is fairly easily accessible with big outdoor forklifts, but not that easily with smaller electric forklifts. At the winter it is forbidden to use these small electric forklifts between these buildings. There are high pallet shelves with approximately 600-700 pallet space operated with electric forklifts and new high level order picker.

Figure 7: The main indoor storage of SF operations in MP3 building.

There are one and half cold storage tents for SF organizations use with approximately 900m^2 floorage and both have pallet shelves. The storage tent (figures 8 and 9) which is entirely in SF use is located near to main indoor storage in MP3 and all the shelves are accessible with big 4,5t-5t outdoor forklifts (figure 10).

Figure 8: SF storage tent pictured from MP3-building.

Still, there is a lot of floor space in the middle of the tent which is too often full of items and shelves are not any more accessible (figure 9 below).

Figure 9: Items stored in front of shelves in SF MP3 storage tent.

Figure 10: Forklifts used; 4,5t outdoor diesel forklift in front and 1,6t indoor electric forklift further back.

The other tent which is nearer to MP1 building is divided in half for the use of SF and UG. There are high shelves which are not accessible with big outdoor forklifts and, due to uneven floor, dangerous to use with small electric forklifts. Reception uses mainly those big outdoor forklifts and as they cannot position the items on shelves, they leave them on the aisle floor and shelves are no longer accessible. Some hazardous situations have occurred as the condition of the space gets occasionally chaotic and small forklifts have been forced to use.

Figure 11: Pallet shelves on the SF side in MP1 storage tent. Outdoor forklifts do not fit to operate on isles and items are therefore left on isles.

It would seem like there is a great demand for additional indoor storage as there are quantity of items and production material under the open sky, exposed for weather conditions. Added to this, all the items are not in systematic order. This is problematic especially at snowy winters when items must first be searched under the snow layer and then they must be cleaned and dried before assembly, shipping or delivery.

Figure 12: Items exposed for weather and snow.

Snow and water adds corrosion in metal parts and rust needs to be removed before use. Electrical components and different filters may also get destroyed if they are affected by water longer period of time.

Final Assembly

Production at SMC plant was changed from place production to six phase production line at the time when logistics project and this research were launched. At one time, the material logistics for the production line was developed and buffer stock for five final assemblies was placed in the same layout next to workstations. Large modules and assembly-phase-related collections were located directly next to workstation where they are always demanded (figure 13).

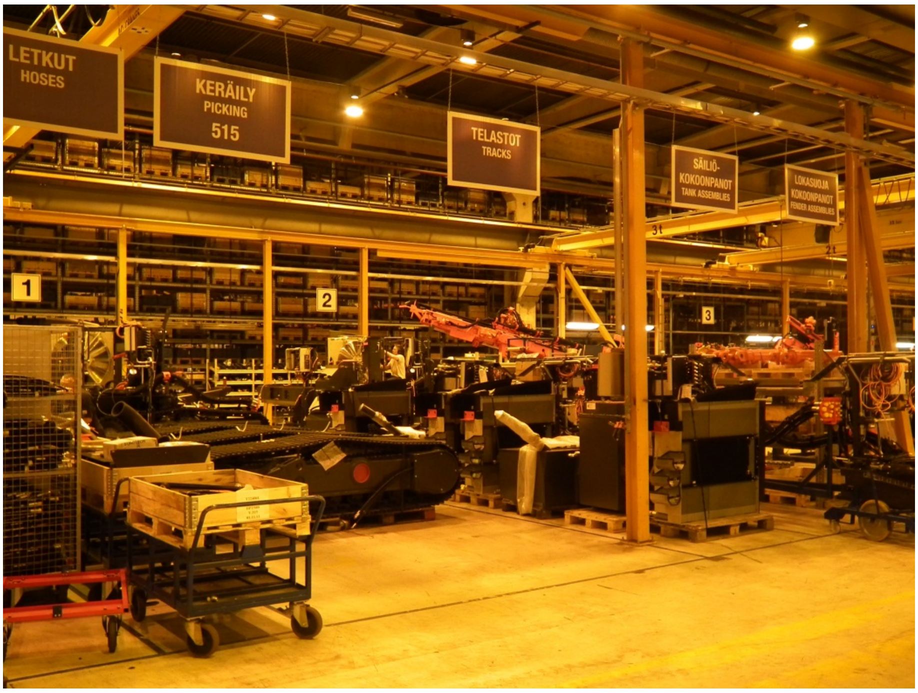


Figure 13: Large modules stored next to workstations in production line.

In final assembly there are still numbers of single items used which are not part of any module or are not directed to workstations as collected. For those items there was separate storage area founded next to production line. The placement of the large modules was defined mostly by the production development project, but material logistics project was involved in developing the processes and practices, information management and equipment affiliated to material management.

2.4.2 Material information management

SMC Oy uses enterprise resource planning system (ERP) to control its operations and manage material. System is used as a client with normal PC's. The automated pallet shelf in MP1 has its own software to manage the balance and integration to ERP is performed manually. Assembly subcontractors use web based ERP extranet extension to manage the operations and, in one case, the SMC owned material stored on their site. Any other device or systems are not used for material control.

Final products going to production are considered as individual works with work number. The work number they get already in production planning process as the work is founded in ERP system with planned -state. The use of items is operationally defined basically by production controller and aftersales controller. Production controller checks the product structure of the ordered products ('works') and enrols the material reservations for the work in to ERP. Options are recorded as a list on text field note for production. Most of the material sent to final- or subassembly subcontractor are either collected and marked for specific work, or ordered directly for specific work as T-items with work number. Modules, defined earlier in chapter 2.2.2, are the main T-items. Work direction has great benefits and it is easy to understand why work direction is used as it enables or eases:

- control of the certain module as they have often have individual options
- checking of the initial eligibility of the final assembly
- purchasing for the demand JIT (Just in time)

2.4.3 Identification and marking

Items are identified with Sandvik-specific ID number. In addition, T-items have work number to specify the work they belong to. Names of the items are informal extra information in ERP system and items do not have name physically attached to them. Informality here means for example that name can be written in English, Finnish or German and naming is difficult to use as a search method in ERP or visually. ID number is a 'dumb number' and it does not give too much hints about the item type or product it belongs to. From historical reasons old Austria designed DTH products have mainly six digit ID numbers and Finnish TH products have mainly eight digit ID numbers and that helps visual recognizing a little bit. Still, as it is only mainly, this separation is not always reliable. New DI550 DTH product model uses items from old DTH and TH products so there are both six and eight digit item numbers.

Purchased items are often inadequately marked. Almost all the items are remarked with hand written, staple-attached Sandvik patch to have clear ID marking (figure 14).

Figure 14: Remarking items with staple-attached patch.

The original identification of the item may be, in the worst but too common case, only in the covering note or in a small plate somewhere in the item. For example coolers are often supplied as big lots, several items packaged on the same pallet, and the packaging itself does not have any marking. So therefore, there are two alternative workarounds applied when radiators are received:

1. All the packages are opened and logistics person checks the small plate from the side of radiator. Then he or she marks the ID of radiator in to the packaging or pallet with marker pen as we can see in figure 15.

Figure 15: Unmarked supply inspected and remarked manually.

2. The packages are just received and positioned into same area. The identification happens when demand occurs and logistics person searches the right radiator from the batch. This workaround is much worse as the searching takes time at the moment when demand already occurs and manageability of the storages weakens when items are not properly identified and marked.

Both of these workarounds are time-consuming manual operations and would be avoided if the supplier would mark their deliveries properly.

2.4.4 Logistic processes

To develop logistics processes, existing key processes and approaches must be studied. Processes are not formally specified and different approaches and workarounds have formed informally in changing working environment. Therefore it was necessary to follow and observe practical logistic work and find causes and effects of different issues.

Reception

The reception of production materials is one of the common functions between UG and SF organization. Administratively the reception is still under UG supply organization. Reception is assumed to serve both UG and SF equally. Still, as the organizations are widely separated, there are some challenges in the flow of information and consistency of logistical approaches. Reception office and main functions are located in the MP1 building, where incoming truck loads are mainly unloaded. As a more and more common exception, some drivers know when they have only SF-material on, and drive straight to MP3 building where SF logistics personnel unload the truck.

Reception in a meaning of official recording to ERP-system does not happen simultaneously with unloading or storage placement. In good case the reception recording happens right after the unloading as the driver or logistical person takes the covering note into reception office and reception officer records the reception. In bad case there are items standing for days without reception recording. This means, that the items are stored in SMC area, but they are not shown in inventory balance. As a result from this:

1. Logistics cannot trust on stock balance in ERP and that causes uncertainty and manual searching
2. When items are not recorded to ERP, they do not have storage place either and that causes manual searching
3. Real stock value is higher than is shown in ERP so management of velocity and inventories gets challenging.
4. Purchasers mistakenly believe that new delivery lot have not arrived and therefore they may; a. order more these same items or b. add some buffer as the delivery time does not seem trustworthy.
5. One more reason for bullwhip effect. (explained in chapter 3.4.2)

As explained earlier the big forklifts that also reception is using cannot reach the shelves in the tent of MP1. Therefore the received material is often left on the aisles in the tent where they stuck the usability of the shelves. This is not allowed but still happens.

Collecting for works

Before use, items are directed to certain works. The most essential example of a work is individual final product. The collecting listing is based on BOM that production controller has generated into ERP. The logistic person checks the collecting listing for certain work (and production phase) from ERP with the filtering of his or hers own storage area. The listing and stickers for items is printed, and the logistic person collects the items to pallet, marks the items and finally marks the pallet for the work and production phase.

As collecting occurs, the items are signed out from the storage and their storage place in ERP. Items are transferred to work-in-progress storage which does not have any specified place. The items which are sent to outer subassembly or final assembly contractor are in the same work-in-progress storage than the ones which are going to SMC's own final assembly. This means that traceability of the items in ERP end to the moment when collecting occurs.

Again there are exceptions and unfortunately misdemeanours. Logistics personnel sign all the logistics transactions to ERP as they know it will ease their own work to keep stock balances up-to-date. Production personnel however sometimes take items directly from the storage without signing the items out from storage balance in ERP. Items are not then directed to any specific work either. Every work still form material reservation for all the items included to work. Logistics personnel perform collecting according to these material reservations and if foregoing take out from storage has occurred, the item is recollected for the same work. In some cases, the work (assembly) is produced before collecting has occurred and then someone just needs to sign the collecting performed by assuming that the work includes all the items that its BOM (Bill of Material) list includes. This is also an allowed workaround in certain cases, especially in final assembly, but approach has not been designed or performed reliably.

Material coordinating to own final assembly line

There are three different approaches to coordinate production material to new final assembly line in MP1 building. First is collecting for two final assembly phases of individual work which' process is explained above. Items are collected in to pallet or straight in to carrier (figure 16). These pallets or carriers are taken in to line in the order of production plan. As these items are now directed to work, they are no longer in storage balance but in unfinished production storage.

Figure 16: Collecting pallet on a carrier.

Another approach is to direct work-directed-items, mostly modules, straight into their buffer stock place next to work stations. These items are similarly in work-in-progress storage as collected items. This approach is called buffer stock, but it is not purely buffer stock in general significance. These items are all work directed and therefore cannot be used to other works so there are not items for next five works but one items for next five specific works. Items have to be reachable as individuals if the production order is changed.

Third approach is pure buffer stock next to production line. Items are stored in to separate stock whit pallet shelves, which serves only this production line. Material management in this storage was one of the development targets in this thesis.

Distribution to satellites

As explained earlier, practically all the items for subassemblies and final assemblies are purchased by SMC. Partly from historical reasons the general approach for material distribution is that items are supplied to SMC's plant in Tampere, they are stored in SMC warehouse and then they are distributed to satellites with SMC's own contracted transportation. These same SMC's trucks operate also as an inbound transportation from certain suppliers. These material flows and stocks are presented in figure 17 taken from pre-material of SMC's Logistics Development project.

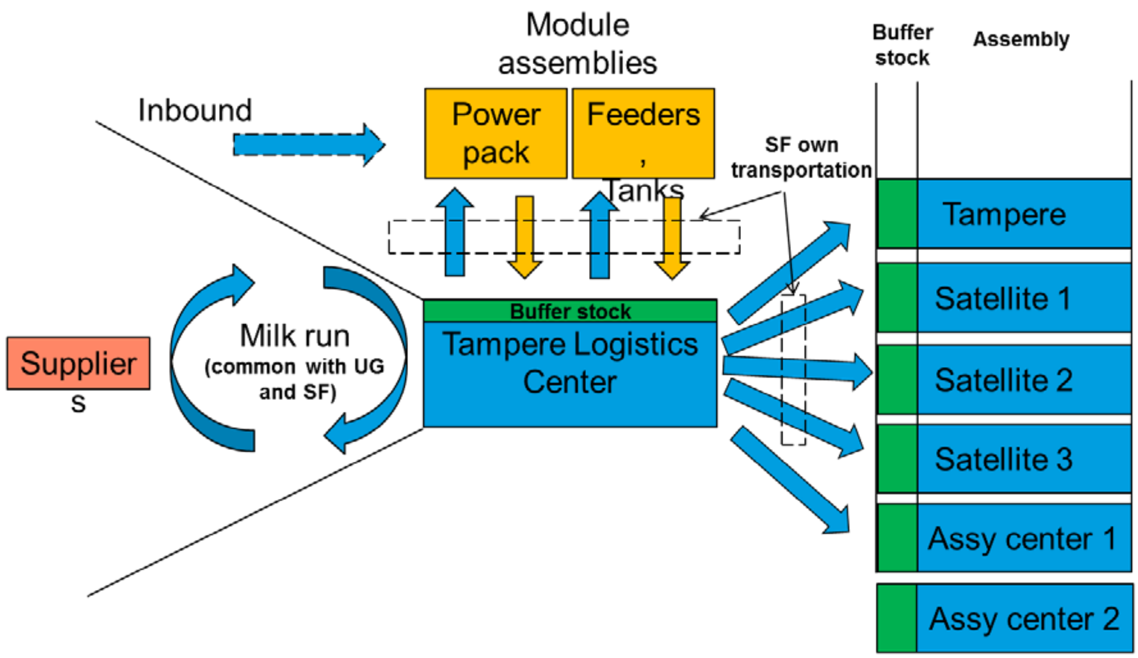


Figure 17: Logistics set-up SF Drills (SMC b, 2011).

This 'milk run' is controlled manually; trucks have routes and schedules they follow, and exceptional cases (every day) are managed with mobile phone. Items; their size, weight, shape and lack of proper marking add logistical challenges as quick changes or rearrangements are difficult to adapt without physically observing the load. This approach has been workable as material flows have been smaller and more linear. The control of this 'milk run' has however been manual and informal work. Effective management of increasing material flows in widening supplier network is impossible without more transparent and formal actions.

Buffer stocks in final assemblies are not controlled as buffer stocks in general meaning. There are not separate satellite-specific storages in ERP-system (except in one subassembly satellite). Therefore items at satellites are either: 1. collected for certain works, 2. recorded to exist in SMC's own storage, or 3. they just do not exist in ERP system. The first approach of these is preferred as then there is quite reliable information about the use and existence of these items. There are still certain problems in this workaround too:

1. When items are collected for certain works from SMC's storage in ERP, the storage for these items will be 'work-in-progress' storage which is assumed to be located at SMC's site. Therefore the actual traceability ends at the moment the item is collected from SMC storages.

2. Often there is a delivery lot of several piece and the logistics personnel knows that the item is used only in certain satellite. So, the whole lot is delivered to the satellite and items are signed for certain works according to the material reservation. However, if there are not as many reservations as there are pieces in lot, the rest of the lot is still sent and informally marked or remembered to be existent.

Because there are not storages for satellites in ERP, it is impossible to reliably and effectively manage the material flows linearly into the satellites. Even the distribution from logistic centre (SMC's storage) is challenging and unreliable with these inappropriate instruments.

2.5 Logistical Problems and demands

Many important logistical demands and problems have been raised in this chapter. It is good to collect and underline some issues, and mention some other reasons that cause logistical problems.

2.5.1 Storage areas and equipment

Items are stored outside and they are exposed to a weather conditions. This is problem especially at the winter time when items are covered with snow. Snow adds corrosion, complicates the finding of the items and items require to be dried before assembly or shipping. According to near future forecasts and plans, the amount of production should be tripled. With old processes that would mean that storage space and amount of transportation should have been tripled too.

Storage areas do not serve today's demands effectively. Big outdoor forklifts cannot reach the shelves on the MP1 tent and there is no space for large modules. Redundant and obscure OSMI items are taking most of the space and demands have not been prioritized. Inaccurate storage places also weaken transparency and traceability.

2.5.2 Logistical information management

Places for the items at the warehouses are not very exact. In ERP, identification of the more exact locations is almost non-existent. In ERP, there is only one storage at Tampere site and both, UG and SF uses the same storage. Storage places are inaccurate as there have not been mobile computers or other flexible equipment to operatively manage more accurate places. Locking storage places for certain items would have been solution, but then the flexibility of limited space would've been lost. Informal practise has been that more accurate storage place is written in text field at items basic information in ERP. This data is not updated automatically with storage operations and there are no formal processes to keep this data updated. Therefore it is not possible to manage items effectively.

As pointed out in section 2.4.4., traceability of the items is lost when items are collected. All the collected items are transformed to work-in-progress storage, which does not have any specific location.

As already pointed out in section 2.4.3., the information about items in ERP is in many respects informal which weakens searchability and transparency, and hence logistic operations and management. The case below reflects this issue.

Case caterpillar tracks: New storage solutions were designed for caterpillar track pairs within logistics solutions development and idea of setting pairs on top of each other in shelves was presented. Project team inquired the maximum weight of a pair as information is not available in ERP. Guesses (presented as sure knowledge) from several parties were between 800 to 2000 kilograms but inquiry from product development secured that the actual weight was 3600 kilograms. Serious mistakes and security risks would have occurred if those guesses would have been trusted. The risk included to wrong weight information unfortunately realized in situation where the power unit assembly was unloaded from truck. The work had been performed similarly many times but forklift driver did not know that the weight of that individual assembly was just on the limit of the forklifts maximum lifting capacity. Therefore small downhill location and incautious move caused accident where forklifts rear wheels took off from the land and forklift leaned against truck. The power unit was slightly damaged but more serious accident was avoided fortunately and because the reflex of the driver.

It is also one of the Sandvik’s main values that the most important thing is to secure safety and safety risks have been taken deep consideration. From logistics point of view the transparency of weight and other dimensional information or supplier information would be highly appreciated to also ease, secure and speed up the processes.

2.5.3 The opacity of the material flows in subcontractor network

More exact managing of the items in subassembly and final assembly subcontractor network is demanded as material flows are complicated and production amounts should be tripled. To direct all the items to their demand place in time reliably is difficult manual work and traceability is lost in to inaccurate stock information. Material deliveries can be traced only into one subassembly subcontractor as they have SMC storage (integrated into SMC’s ERP system) in their site.

2.5.4 Complex material flows

Clear picture from material flows, was one the hardest subjects to figure out during this thesis. As it proved to be too slow and manual work to get reliable information, the more effort was put to figure out why that information is so difficultly available, does that information exist somewhere, and how it would be made more easily available.

If we view the supply chain and its different parts on graphs and presentations, flows seem somewhat understandable. Still, there are numbers of to-and-fro flows, impure buffer-stocks (explained in 2.5.6) and numbers of informal practices and cases that make exceptions to system. The opacity explained earlier is one of the main reasons for difficulty to get information but the complexity of the physical flow is another reason. The history explains why the material flows are so complex. SMC has earlier assembled and even manufactured most of the parts and items for drill rigs. Outsourcing has raised material flows little by little and informal practices and workarounds have been formed.

It is worth considering is the present way to purchase material for module assembly centres and final assembly centres the most functional. At the moment material flows are very complex. From logistical view, most of the materials are purchased by SMC and they are transported via SMC where the material is often also stored. From SMC, most of the material sent to module or final assembly centres is sent as collected for work but some material is sent as a whole delivery lot. Still, follow up in ERP-system usually ends to the point where the material leaves from SMC. It’s in some people’s memory and trust that those items actually exist at subcontractor’s store. Some material is ordered directly for particular work, some are ordered by use, and some are ordered by forecast directed planning.

2.5.5 Change management

The changes in to produced products are brought from product development into production continuously without year model stages. Greater structural changes are still brought into production as a new tier. These continuous changes cause challenges for material management and production. Because of the continuous changes, the production is all the time producing products which are never made before. Even if the change is small, it may cause delay if installation and interface relations are not properly designed. Some small washers or nuts may intervene and different looking items may cause confusion. The production controller must take in notice all the changes that effect to assembly process or item purchasing.

2.5.6 Impure buffer stocks

The general meaning and idea of buffer stock is that there is certain amount of items continuously available to ensure the continuity of production or supply. In SMC the name buffer stock is used in cases where the modules are directed for certain individual works. Organizations can use terminology as they want but it is important to understand that this kind of ‘buffer stocks’ act differently than buffer stocks in general ‘pure’ meaning:

- Even if there would be five pieces of power units, feeder assemblies, cabins and pairs of caterpillar tracks available, there still would not be these parts for next five individuals if these modules are not for the same final assembly individuals.

- With individual work numbers, the buffer stock will not cycle as a pure buffer stock of similar items. The usage of items is ensured as it follows the production plan, but items must be flexibly available to use in any order if there are changes or delays in production plan.

If some theories or practices are tried to be implemented from logistics or supply chain management literature, one must understand the difference of general meaning of buffer stock in literature and approach in SMC.

2.5.7 Pallet standardization

Some suppliers still deliver the items in non-standard pallets which cannot be lifted in to pallet shelves because of their unsuitable size and weakness. Too often the pallet is broken already when it arrives to SMC. This increases logistical processing time, costs, and especially safety risk. Opening of the packages is often difficult too, as the package keep itself together. The pallets of coolers are often good (bad) example.

- Two coolers are bound with metal bands on a pallet and as the bands are cut, the coolers are about to tip over. Handling, storing and transferring these items is slow and difficult.
- This is also a safety risk as the coolers are heavy.
- Often the pallet has been broken all ready when the band has been tightened

2.5.8 High inventory levels and lack of storage space

As a result from issues mentioned earlier, inventory levels especially for certain items are high. By comparing stock balance and material reservations for many items it can be viewed that in many cases there is permanent stock for 3-6 months demand. In addition to inventory costs, FIFO does no longer realize, storage space runs out and material handling gets more difficult. High inventory levels add logistical costs and makes logistical operations more difficult physically and on management level.

There are also quantities of items remained redundant as the design of the item has changed or supplier has been changed and old versions in stock have not been used before the change. Items are often purchased in relatively large quantities, even expensive ones, even if the future demand for the delivery lot does not exist. Case of option coolers demonstrates many accumulating problems.

Case hot-country-option coolers: *There were six very large coolers stored dangerously on top of the shelves in storage. From their outer appearance it was noticeable that they had been there for long term. Because of the bad labelling their ID number was not readable from storage floor, so they needed to be taken down. After slow and careful drop with forklift these coolers were finally down and viewable. The coolers belonged to hot-country-option of old DTH rigs. There were not any material reservations for these coolers and the production of the rig model they belonged to was discontinued* *and no hot-country-option was sold for remaining products in production. The purchase price for one cooler was over 8000 euros so together the cost of these six coolers was almost 50000 euros. One of the coolers was sold for after sales but others were scrapped.*

The cost of work consumed to hassle with these redundant coolers cannot be measured but should not be underestimated. In this case, many of the problems mentioned earlier united.

2.5.9 Inaccurate forecasts and poor supply

In discussion with project steering group, one major problem the steering group highlighted, but wanted to keep outside of the thesis, was inaccuracy of the sales forecast that directly complicates the planning. As production and purchases base on forecasting based production plans, the uncertainty of incorrect plans effect directly to everyday production schedule and also directly to purchasing and logistical operations. Supply weakens as certain products are delivered late. This is because information of the actual demand, orders, come late considering the structure and approaches in supply chain.

The accuracy of the forecasts is difficult to improve from logistical or operational function point of view. Dependence from forecasts can still be reduced and supply improved by overall supply chain management and logistics as a part of it. These means of overall supply chain management are studied in next chapter.

3 TOWARDS OVERALL SUPPLY CHAIN MANAGEMENT

After exploring the target organization and status quo we'll explore the concepts and theories around this subject area. This is essential to get deeper understanding for current state analysis and to get direction and guidelines for development of logistic issues as a part of overall supply chain management. It is also necessary to define the most important terms and concepts to clarify how they are understood and used in this particular study. In production and supply the lean methodologies with numbers of tools has settled in use as part of operations strategy. In this chapter it is defined concepts around supply chain management, discussed about significance of strategy for improvement, and considered different perspectives and trends in supply chain management. Paradigms of agile and lean supply chains are taken central viewpoints as they are useful to consider the most important aspects and often used in modern supply chain management literature. Logistics point of view has been taken the deepest consideration as guidelines for solutions in practise are searched.

3.1 Supply chain management (SCM) and concepts around

Different terms and concepts are used in industry and business to define approaches, theories and paradigms. Concepts often rise from one functions point of view to define approaches and solve problems. Supply chain management (SCM) has an unquestionable connect to term and function logistics, as supply chain management is often understood as a wider meaning of logistics. In production and supply the lean methodologies with numbers of tools has settled in use as part of operations strategy. Lean extended enterprise (LEE) is a supply chain management-related but manufacturing-based concept that integrates lean tools and methodologies outside of the shop floor. For comparison, product lifecycle management (PLM), studied in next chapter, has in the same way risen from product developments point of view to take further the earlier concept of product data management (PDM).

Some professionals are minded to use terms logistics and supply chain management as synonyms. For example Boyson et al. (1999, p.3) define both words meaning synchronized movement of inputs and outputs in the production and delivery of goods and services to the customers. As the term and concept of supply chain management has searched its form on last decades, Krajewski, Ritzman and Malhotra (2007, p.372) make separation between terms supply chain, supply chain management and supply chain strategy. First, supply chain is the network of services, material, and information flow's that link a firm's customer relationship, order fulfilment, and supplier relationship processes to those of its suppliers and customers. Supply chain management is about developing a strategy to organize, control, and motivate the resources involved in the flow of services and materials within the supply chain. Supply chain strategy is about designing firm's supply chain to meet the competitive priorities of the firm's operations strategy. (Krajewski, Ritzman & Malhotra, 2007. p.372)

However, definition and separation of the terms logistics and supply chain management has commonly unified in latest literature. Emmett and Crocker (2007) describe the ultimate idea of the supply chain management quite descriptively in their introduction.

"Supply chain management is a philosophy and a way of looking at how to better manage across functions. If supply chain management is tried to be made a functional department, there's a risk of subordinating the benefits of the approach and getting locked into power plays and the playing of serious schoolyard politics; such matters being commonly found in and between existing organizational functional departments. Supply chain management by definition is all about integrating, coordinating and control, across internal and external functions." (Emmett and Crocker, 2007. p. xvi)

Stevenson (2009), among many others, share the similar view on dividing supply chain management and logistics by underlining that supply chain management is the strategic coordination of business functions within a business organization and throughout its supply chain for the purpose of integrating supply and demand management. Supply chain management is the process of planning, implementing, and controlling supply chain operations. The basic components are strategy, procurement, supply management, demand management, and logistics. The goal of supply chain management is to match supply to demand as effectively and efficiently as possible. Key issues in supply chain management according to Stevenson relate to: 1. determining the appropriate level of outsourcing, 2. managing procurement, 3. managing Suppliers, 4. managing customer relationships, 5.ability to quickly identify and respond to problems, 6. managing risk.

Logistics is the part of a supply chain involved with the forward and reverse flow of goods, services, cash and information. Logistics management includes management of inbound and outbound transportation, material handling, warehousing, inventory, order fulfilment and distribution, third-party logistics and reverse logistics (the return of goods from customer). (Stevenson, 2009)

Lean Extended Enterprise (LEE)

Lean manufacturing is widely followed and written about, especially in reference to the automobile industry. (Basu & Wright, 2008) In the past couple of decades manufacturing industry has implemented different methodologies or tools like ERP, SCM, Six Sigma, Kaizen, Lean etc. to find improvements to their performance and expectations to single methodology or tool have been high but final results often remain low, particularly when considering the effectiveness and savings in the total value stream. (Burton & Boeder, 2003) Burton and Boeder (2003) find the reason in concentrating to single tool or methodology alone and not in overall processes. They recall that the problem is not in the tools or methodologies but they just do not work alone by picking just one of them. Gentlemen underline the meaning of understanding the processes in extended company and finding the right tools or methodologies in right demands. They call this concept Lean Extended Enterprise (LEE) but recall that there are other names for concept with mainly same doctrines, depending on the view and writer.

It is easy to see connection to modern supply chain management literature as the guideline underneath is about integrating functions and suppliers, and managing operations and supply chain as a whole. In section 3.6 the lean supply chains are to be taken deeper consideration in comparison to agile supply chains to understand what the difference of leannes and agility in supply chain context means.

Burton and Boeder (2003) define reasons and factors for why this kind of development, taking concentration from inside the function to overall processes and integration, is now topical. Reasons and factors are similar than those for supply chain management but the view point for changes comes from the traditional use of lean methodology at the factory floor.

1. The manufacturing landscape has changed dramatically in the past few decades. There is much larger electronics and software content in most production operations, resulting in less intensive, smaller shop floor activity and much more knowledge-based activity. Another factor is globalization and move to smaller nimble operations more contiguous to the markets they serve. A third factor is the whole offshore movement. A fourth factor is shorter life cycles and a much faster paced, much more competitive industrial world.

2. Most improvement programs typically begin in production and materials management because people can see, touch and measure the product or inventory levels with ease. Another factor is the previous absence of supply chain collaboration, which led organizations to do their own thing internally with little thought about the total value stream. Quite frankly, most organizations have made great progress during the past decade in improving production and quality. However, many improvement programs have run out of steam and failed to deliver real bottom-line results. Shop floor is only a small part of the whole in improvement.

3. Most organizations are now overloaded with conflicting data and starved for high-quality factual information. Few companies are confident in the quality of their own information and even less confident in their trading partners' information. ERP, e-business and other information systems were supposed to simplify and define processes but they have complicated many aspects of total value stream.

4. Time to market, innovation, velocity improvement, flexibility, responsiveness cost and quality are all key factors that make company successful.

(Burton & Boeder, 2003. p.10)

Whether the original view point or term used differs, the guideline and doctrine underneath is the same. Integration and concentration to overall processes has become more and more important. Supply chains are to be developed and managed as a whole. Logistics has important role as a physical, informational and investment integrator all the way in supply chain, and it is to be developed as a part of overall supply chain considering the strategy for supply chain management.

3.2 Strategy for improvement

Many organizations skip the strategy of improvement, which is the most important element of improvement. Organizations go with the wind and implement new trend following tools and systems but results are not as satisfying as expected. (Burton and Boeder, 2003) Operations strategy consists of decisions at many levels related to own production and outsourced production. Key production location decisions and general capacity and production technological questions are often solved in Group executive team with the assistance of business unit management. Business units are pondering how business strategy is realized in operations of the factory and supply chain. Business units are also considering integration of product development, production and supply chain to working ensemble with other functions in the company. (Heikkilä & Ketokivi, 2005)

In this thesis we focus on business unit level strategy, decision making and operations in relation to supply chain management and logistic development. Some essential questions considering operations strategy in business unit level are (adapted from Heikkilä & Ketokivi, 2005):

- What kind of know-how are our operations basing? Do we develop our own technology or do we modify newest existing technology to our own needs? Can we separate from our competitors with our operations-know-how?
- Do we manage our operations right? Do we have right co-operation with the companies which operations we are dependent of.
- What kind of co-operation there is in this company between different functions like sales and marketing, supply and product development? Does cross functional co-operation support our business?
- What kind of strategic choices can be done in our operations system including organization structure, production practices, resources and technologies? Are these alternatives actively estimated? Do we make choices that guide our operations to support the goals of our business? What kinds of factors limit these choices?

Because of uncertainty and discontinuity in business environment, business strategies can change very quickly (Christopher, 2005). According to Heikkilä and Ketokivi (2005) operations strategy does not work harmonically with business strategy. This is because, due to structural inertia, the operations cannot keep up with all the changes in business strategy. Business strategy should always regard the schedule that operations level, and supply chain, is able to adapt on changes. Good business strategy does not predispose operations level for all the outer effects. The other reason for lack of harmony is that integration is not drawn enough attention. Another point of view for this issue could be, that operations strategy must be enough flexible to be able to support at least less dramatic changes in business strategy.

3.3 Braking down the barriers in supply chain

The role of the supply chain management is to remove the barriers between the company and its suppliers and even perhaps its suppliers' suppliers. If the formal structures are not developed, there are going to be different kind of complicated informal ways to get things over and through the barriers, but the barriers will stay. (Emmett & Crocker, 2007. p.7-9) Emmet and Crocker, as well as many other writers in modern supply chain management literature, underline the effects in supplier network outside the company's four walls. Depending on writer and emphasis, the terms integrated supply chain, value stream and virtual corporation are used but they all essentially mean the same thing. Businesses must work together to form an integrated supply chain focusing on meeting the demands of the end-user or final customer no matter what supply chain paradigm is adopted. The goal of an integrated supply chain is to remove all boundaries to ease the flow of material, cash, resources and information. Both the information and material flows will be simplified, streamlined and optimized with the integrated supply chain to reduce waste and lead times. (Naylor et al, 1999)

3.3.1 Horizontal co-operation

Supply chains are still often defined by the decisions and actions in different functions inside the company. Heikkilä and Ketokivi (2005) emphasize the co-operation between the functions inside and outside the company. To research and develop ones operations in changing business environment, it is necessary for company to continuously develop its own production system to correspond the business environment. Instead of just focusing on their own area, marketing focusing on developing demand and sales, product development focusing on new technical solutions, and production focusing on optimizing efficiency, the co-operation between these company's basic functions must be vital to coordinate demand management, new product launch and continuous production development. In decentralized company networks this means breaking the company's borders to co-operate with all stakeholders. (Heikkilä & Ketokivi, 2005. p.100) Stevenson (2009) shares the similar views and emphasize that supply chain management is not on one functions responsibility. Supply chain managers are people at various levels of the organization who are responsible for managing supply and demand both within and across business organizations. They are involved with planning and coordinating activities that include sourcing and procurement of materials and services, transformation activities, and logistics. (Stevenson, 2009)

The co-operation and information sharing between company's different functions and between productions units is often challenging. If division of labour is implemented based on traditional functions (marketing, R&D, production, finance) and individuals specialize clearly to serve one function, the challenges in coordination and integration can be significant. Coordinating does not happen through hierarchical decision making but through co-operation in horizontal organization. (Heikkilä & Ketokivi, 2005)

1. Multinational strategy (local)
2. global strategy (centralized)
3. international strategy (balanced)
4. transnational strategy (integrative)

The situation where "sales people do not understand the production and vice versa" is common for many organizations. Often the actual situation is that people working on these functions do not understand each other's working environment. The high level environment heterogeneity needs stronger integration between functions so that friction is avoided. The need for this integration is generally high in innovative high-technology industries. (Heikkilä & Ketokivi, 2005)

There are different ways to practically organize supply chain management roles depending on company's size, organization structure and industry. Sisu Axles Inc. as a smaller engineering industry company provides a good example.

Benchmark excursion to Sisu Axles

Sisu Axles Inc. is a Finnish metal company which produces vehicle axle systems in Hämeenlinna, Southern Finland. The company focuses on niche markets to provide custom products for their customers. The company is reasonably small, about 100 employees, but their industry and business environment is relatively similar to SMC's.

Sisu's logistical processes and supply chain management approaches were benchmarked on the basis of this study and project in May 2011. A title and position of excursion host at Sisu was Supply Chain Development Manager. He demonstrated the products, processes in supply chain, relations to suppliers and customers, and logistical processes. Sisu had had mobile handheld computers in use for logistical operations since 2006. The mobile computer and its portal was one of the main interests in visit, as demands and circumstances were fairly similar to SMC's, and Sisu had the same ERP system and IT partner as SMC. Logistical processes were systematic and storages for items were clearly separated. Items were also labelled clearly with ID, barcode, and item name. There had been some implementation problems and poor approaches but as a conclusion company had been very satisfied with these devices and IT partners.

One must be critical when host company representative gives presentation on excursion. The main attention of the researcher was still put on the hosts expertise of the overall supply chain, its operations and relations, and cross influences. As a Supply Chain Development Manager his role was to maintain clear picture about overall supply chain management and develop found matters in co-operation to related parties, internally and externally.

SMC lacks that kind of cross-functional roles and thinking that would maintain and develop the overall supply chain management. It is not enough that representatives from different functions sometimes discuss together or teams are collected from different functions. It is essential that there is tendency in these teams to actively get into effective integration and consensus is achieved about goals and about methods to reach these goals. In production unit level, it is essential that there is consensus about the goals and employees understand the priority of the goals. Different goals or priorities can lead to wrong actions and frustration. (Heikkilä & Ketokivi, 2005)

One common example of organizational integration is purchasing which as an action or function has big impact on production, logistics and inventories. Purchasing, as a function in a business context, involves acquiring organizations raw materials, components, goods and services needed to produce a product. In many organisations purchasing is still part of segmented departmentalized structure in which the procurement of supplies is a discrete activity in the sequence of activities from acquisition of supplies to delivery of a finished product to the ultimate user. The challenge of global competition is, however, increasingly leading organisations to replace segmented structures with integrated structures in which purchasing is part of larger grouping such as materials, logistics or supply chain management that emphasise the importance of cross-functional decision making. (Lysons & Farrington, 2006. p.4) At SMC the actual purchasing is performed by material controllers organizationally and operationally integrated in to supply function. They are also the key connection and relationship builder in relation to subassembly subcontractors though the use of automated and web-based auctions has increased.

Vicious cycle of supply and demand

Burton and Boeder (2003) have presented the model of vicious cycle of supply and demand (figure X below) showing successive events that leads to another continuously.

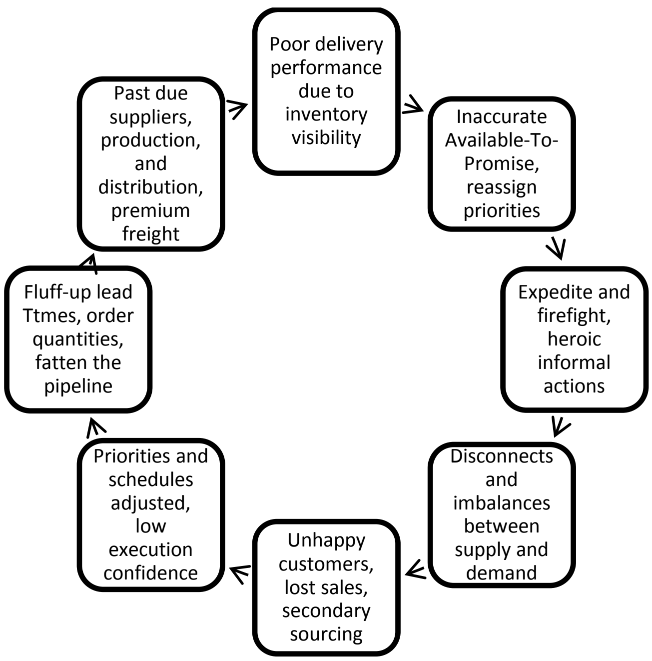


Figure 18: Vicious cycle of supply and demand (adapted from Burton & Boeder, 2003).

This cycle reflects the fact that actions of different functions in network effect to further steps and other functions in supply chain. Individual events and problems occur in certain functions and transfer to other functions causing different problems. Fire fight and everyday heroic informal actions in different functions are clear signs of an ailing supply chain. As the cycle keeps turning around and challenges accumulate, the root causes are more difficult to point out. Very often problems appear clearly in logistic or production. Still logistic or production actions can be ineffective workarounds to solve problems, if root causes are not identified by analysing and managing the supply chain as a whole.

3.3.2 Information management in Supply chain

In context of tendency to create virtual integrated supply chain it is important to understand the nature of information and knowledge before talking about information management. There are two types of knowledge: explicit knowledge and tacit knowledge. Explicit knowledge can be expressed with systematic and formal language or syntax and shared in a form of data, manuals, formulae and such a like. The processing, storing and transforming explicit knowledge is fairly easy, especially with information technology. Tacit knowledge in contrast is hardly personal and hard to formalise. Tacit knowledge is deeply rooted in action, values, ideals, routines, commitment and so on. (Nonaka et al, 2000)

Management of the supply chain and individual processes in it is far more challenging, if not impossible, when even the most practical operations are dependent on tacit knowledge of different parties and employees. Practical everyday operations should be possible to be based on explicit data and information managed centrally. There is a tradition in SMC to respect long experience and tacit knowledge and know-how that experienced employees have. Especially a long career at SMC or former company Tamrock is high valued experience. As an idea level there is nothing bad in that. Experience is respectable and these employees are highly valuable for the company. Personnel turnover is relatively low and partly therefore there are numbers of unwritten rules and practices, organizational memory and habits that affect to everyday work and operations. Lots of clearly explicit knowledge occurs only as knowledge of certain parties and therefore it is difficult to utilize and manage. This knowledge is often respected as know-how but in fact, in many cases with more formal approaches this ‘know-how’ could be transformed to easily shareable information.

Only after the explicit knowledge is transformed in the formal form of information and data, it can be managed with information system technology. Information system technology allows organizations to be connected with important partners in their supply chain networks. Capabilities to exchange reliable information with these partners quickly and cost effectively are essential for the improvement of supply chain performance. (Leenders et al, 2006. p.92)

ERP systems and lean are claimed on being at cross purposes so that you cannot achieve one with the other. According to Burton and Boeder (2003) ERP systems enable lean and vice versa. The problem on implementing the ERP has been that the processes have not been rethought and ERP has been forced to perform the same operations that were manually performed. To make improvements can be difficult afterwards when ERP is tuned to serve existing processes. That may lead to informal, and often heroic, actions. For many organizations there is opportunity to go back and pick up the low hanging fruit of their ERP implementations. Goal is on identifying the root causes of ERP ineffectiveness and going after these opportunities one by one. ERP should be realized and maintained as a clear window to real environment. Important aspects to maintain and improve also in SMC are (Burton &Boeder, 2003):

- **Master data integrity and accuracy:** including clean-up in the areas of part numbers, inventory balances, part locations, bill of materials, routings, and other data elements.
- **Kluge clean-up:** concentrating on workarounds and informal practices that people have created when ERP has not been working. The change is often small to eliminate these workarounds and bring people into the formal system.

Leenders et al (2006) present seven important supply chain management related benefits of the information systems to the organization. Current situation in SMC is mirrored to relevant matters:

1. Cost reduction and efficiency gains can be achieved by streamlining the purchasing processes and freeing up supply staff to do more value-adding work.
   At SMC cheaper or non-critical items are purchased by Electronic Data Interchange (EDI) in ERP. Still, the number of options and variations in wide amount of items makes wider automating difficult or impossible.
2. Quick and easy access to critical data in real time is helpful for sound decision making, eases the earlier identification of supply problems, and provides useful information for negotiations with suppliers.
   At SMC ERP would enable this but access in critical data is not always quick and easy especially in mobile actions like logistics as there are no equipment for mobile connection. Depending on the data sought the reason may be in ERP-system, in the structure of the product and in information sharing approaches of SMC (tacit more than explicit).
3. Speedier communication with suppliers improves supply chain effectiveness and efficiency, especially when dealing with international suppliers. Faster turnaround times can lead to increased market share and lower inventories.
4. More time can be spent on strategic purchasing initiatives and focusing on important suppliers and supply projects because less time is required for administrative and tactical supply activities.
   Purchasers are often spending their time to solve operative everyday issues and problems.
5. Improved information accuracy can be achieved by replacing manual systems with automation. The benefits can include lower inventories (e.g. safety stock), reduced stock outs, lower expediting costs, and improved customer satisfaction.

Good example of lost accuracy is the reception of materials at SMC. The reception as an information process includes manual steps that delay and risk the update of storage balance.

6. Integration of systems with other departments, suppliers, and customers can provide accurate information on a timely basis to assist with decision making in the areas of production planning and material requirements planning.

   The main assembly subcontractors of SMC have web extension of the corporate ERP that enables the interaction. Only one subcontractor has SMC storage officially at the ERP and therefore the material sent to other subcontractors cannot be reliably and timely controlled.

7. Enterprise systems provide control over how and where the money is spent.

   At SMC the ERP itself provides this information centrally but the information would be more accurate if the data input approaches would be more accurate. At the moment there is not quick and easy way to reliably check which materials are spent where.

The use of information technology to share data between buyers and suppliers is, in effect, creating a virtual supply chain. **Virtual supply chains are information based rather than inventory based.** Conventional logistics systems are based upon a paradigm that seeks to identify the optimal quantities and the spatial location of inventory. These are inventory-based business models supported with complex formulae and algorithms. Paradoxically, once we have visibility of demand through shared information, the premise upon which these formulae are based no longer holds. Electronic Data Interchange (EDI) and the Internet have enabled partners in the supply chain to act upon the same data. This data points the real demand and partners will not be dependent on distorted and delayed picture that emerges when orders are transmitted from one step to another in an extended chain. (Christopher, 2005)

Burton and Boeder talked about low hanging fruits in ERP exploiting. At SMC, one of these low hanging fruits could be the improvement of shipment and delivery visibility. The ERP would already enable more accurate and transparent material visibility, but tools and approaches will not support them and therefore informal workarounds are performed.

3.4 Inventory management

Inventories are key component of supply chain and basically all the logistics processes are related to inventory management. From business perspective, inventory levels are tried to be kept low and storing is often seen as a negative use of money. In recent years companies have almost universally began to reduce their inventories of raw materials, components, work-in-progress and finished products. The pressure has been to release the capital locked up in stock and hence simultaneously to reduce the holding cost of that stock. (Emmett & Crocker, 2007; Stevenson, 2009; Christopher, 2005)

The location of inventories is an important factor for effective material flow through the chain and for order fulfilment. Centralized inventories generally result in lower overall inventory but conversely decentralized locations can provide faster delivery and generally lower shipping costs. The rate at which material moves through a supply chain is referred to as inventory velocity. The greater the velocity, the lower the inventory holding costs and the faster orders are filled and goods are turned into cash. (Stevenson, 2009) In manufacturing, upwards of 60 per cent of the cost of finished goods comes from purchased parts and materials. Still, the issue is not only the cost of goods purchased, but also the quality and right timing of deliveries, both of which can have significant impact on operations. Web-based auctions and managed inventory relationships are expected to grow within decade even if traditional buying relationships are still predominant. (Stevenson, 2009)

The flows of goods, money and information need coordinating to minimize inventory levels. High levels of inventory can be viewed as a major symptom of an ailing supply chain. By lowering the inventory levels in ailing supply chain it is possible to reveal the problems that cause the inefficiency of the supply chain. (Emmett & Crocker, 2007) For example in industrial assembly company high inventories in all items can be used to ensure the stability of the production, even if the problems might appear at the delivery of just couple of items.

Improved flexibility and responsiveness to their customers have been recognized benefits for the same companies that have reduced their inventories as described above. The object of lean methodology and approaches is to minimize inventory of components and work-in-progress and to move towards ‘just-in-time’ environment wherever possible. As a knock-on effect upstream in supply chain has been that it is now imperative that suppliers can provide a just-in-time delivery service. As a criticism or counter-argument to lean practices learned from Toyota it can be said that all the doctrines learned from Toyota or other huge company following lean methodologies are not directly applicable or recommendable for example in SMC’s case. Supplier related lean approaches that Toyota uses, often base on the fact that Toyota is larger than any of its suppliers and it’s a vital customer for most of them. This means that Toyota can dictate the rules and suppliers will follow. (Burton & Boeder, 2003; Christopher, 2005) In Toyota’s and some other huge company’s case the inventory, and thereby costs, are often transformed to suppliers responsible. Many b-2-b companies still believe that the only way to serve a customer who requires just-in-time deliveries is to carry the inventory itself instead of the customer. Cost should not be just shifted upstream in chain as the cost can be even higher. Requirements of such customer could always be met by the supplier carrying inventory close to the customer(s). (Christopher, 2005) Transparency in a meaning of actual customer demand visibility through the supply chain secures that risks and costs are not just transformed to another step in chain causing bull whip effect.

Without careful management, demand variations can cause uncontrolled inventory fluctuations called bullwhip effect, dealt in section 3.4.2. Variations in demand at the customer end of supply chain tend to ripple backwards through the chain and periodic ordering and reaction to shortages can magnify variation, causing inventories to oscillate in increasingly larger swings. Good supply chain management can manage these challenges beforehand and decrease the gap between the actual demand and derived demand. (Stevenson, 2009)

3.4.1 Risk management in supply chain

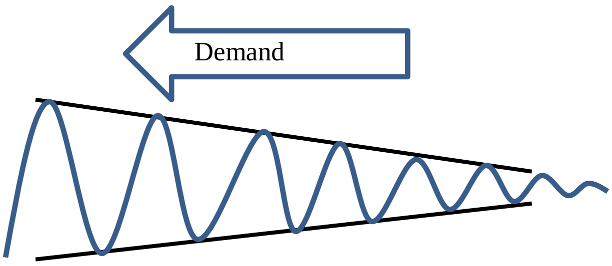
One main tasks of supply chain management is to secure the supply and minimize risks included in supply chain. Risk management in business literature can give a picture that risk management is about managing and avoiding big events that would be very harmful or catastrophic for the organization. Smaller everyday disturbances in practical business are often accepted as normal challenges that just exist and not seen as a risk. These everyday events can however be even more harmful and include great risk when disturbing everyday operations and accumulating. Supply chain and inventory risk management involves designing and implementing a robust and agile integrated supply chain network and operations in such a way that it is capable of anticipating, coping with, and recovering from disruptions (Lin & Wang, 2011).

Inventories are used as an instrument to avoid disruptions in production but high inventories itself includes high economical risks. Risk management in many businesses is management of uncertainty as risks are caused by uncertainty. Uncertainty is mainly caused by difficulty to forecast demand and production systems own operation. Demand uncertainty is managed with decisions concerning production systems structure and production approaches. These decisions concern company’s own production system and other factors in supplier network. (Heikkilä & Ketokivi, 2005. p. 110) Event management capability means the ability to detect and respond to unplanned events such as delayed shipment, or a warehouse running low on a certain item. It is important to have means, automated or other approaches, for monitoring the system, notifying when planned or unplanned events occur, simulating potential solutions and measuring the long-term performance of suppliers, transporters and other partners in supply chain. (Stevenson, 2009) Rather than pessimistically reacting to uncertainties in the source of supply chain disruptions, mitigation strategies can proactively be deployed and executed in a supply chain network to alleviate supply chain disruptions. (Lin & Wang, 2011)

3.4.2 Demand uncertainty

Demand in supply chain is derived in **consumer demand** (downwards to final product sales) and **derived demand** (upwards in supply chain). Most of the demand in supply chain is derived demand. Consumer demand is original factor affecting to derived demand but it is also affected by characteristics of products, product structure and supply chain. Balancing with demand and offer is significant factor on managing uncertainty in every industrial company. Supply chains are usually forced to be prepared for upcoming demand much before demand actualizes for own company as an order. Commitment to capacity and storage decisions include significant risk for company's economic success. Derived demand for subcontractors form from final consumer demand. If there is a big delay from final consumer demand to subcontractor demand, the risk for subcontractors, and hence for main company, will rise. The basic phenomenon for long supply chains is bull-whip effect or Forrester phenomenon. It effects to companies uncertainty significantly. In the researches made during the last thirty years the bullwhip has been detected to occur basically in every industry with long supply chain. The further we go from final consumer demand in chain, the more the demand varies. (Heikkilä & Ketokivi, 2005)

Bull-whip effect (or Forrester phenomenon) (figure 19 below) is a phenomenon of increasing distortion in demand information which moves upstream in demand-supply chain. Reasons are for example intentional distortion to secure supply, large lot-sizes or delays in demand information flow. Cures for bull-whip effect can be sought from demand information transparency and trustful relationships in supply chain. (Lee et al, 1997) (Emmett and Crocker, 2007) (Burton & Boeder, 2003) (Christopher, 2005)



Suppliers/subassemblers	Manufacturer	Sales company	Customers

Figure 19: Bull-whip effect. Demand information is delayed and distorted increasingly upstream in supply chain. Suppliers far upstream in supply chain are often basing their actions to totally different demand information than sales company next to customer.

Delays and distortions are often caused by: 1. the structure of the chain, 2. wrong forecasts and conscious manipulation of the information of demand, 3. campaign pricing. (Heikkilä & Ketokivi, 2005) At SMC's case, the campaign pricing does not really happen but the two other reasons are worth opening.

The structure of the chain: The middleman in the chain, the acceptance processes of the orders and deliveries, and slow incompatible information systems slows down the information flow of the demanded information. Delays can be days or weeks and therefore the material and component supplier work with different demand information than the actors near the final customer.

Wrong forecasts and conscious manipulation of the information of demand: Giving the wrong demand information means local partial optimizing and wrong decisions to invest and act. Wrong forecasts are given for example during strong growth, when demand exceeds the existing supply capacity. Researches have proven that customers and even the own sales organization of the industrial company tend to distort their future demand upwards to secure their own material availability. (Heikkilä & Ketokivi, 2005)

Large lot sizes are some of the practical causes of high inventories, bullwhip effect, and supply problems. Producing or ordering large lot sizes yields benefits in terms of quantity discounts and lower annual setup costs, but it increases the amount of safety stock carried by suppliers and, hence, the carrying costs. Waiting for sufficient orders to achieve a full load increases lead time. It can also create bullwhip effect. Periodical batches create “lumpy” demand for suppliers and, hence, high variability demand, which causes suppliers to carry relatively large amounts of safety stock. Starting with the final customer and moving backward through the supply chain, batch sizes tend to increase, thereby increasing the level of safety stock carried. What is so striking about this phenomenon is that any demand variations that exist at the customer end of supply chain get magnified as orders are generated back through supply chain. There can also be conflicting objectives. For example, to reduce their inventory holding costs, some companies opt to frequent small deliveries of supplies. This can result in increased holding costs for suppliers, so the cost is merely transferred to suppliers. These conflicting objectives can only be managed effectively when there is a trust between major trading partners. Effective communication requires integrated technology and standardized ways and means of communication among partners. (Stevenson, 2009)

3.4.3 Managing demand uncertainty

A continuing problem for most organizations is the inaccuracy of forecasts. It seems that regardless of the sophistication of the forecasting methods and techniques employed, the volatility of markets ensures that the forecast will be wrong. Christopher (2005) Naylor et al (1999) present the studied forecast accuracy from a group of experts in the electronics product industry in table 2.

Table 2: Forecast accuracy from a group of experts in the electronics product industry (Naylor et al, 1999).

Future prediction	Forecast accuracy
1 month	± 5 %
2 months	± 20 %
3 months	± 50 %
Beyond	Toss a coin

In heavy engineering industries like SMC’s case the time periods and predictability may be a little higher than in table 2, but practise have shown that forecasts are far from reliable. Demand in innovative products and in the SMC’s business environment, is difficult to forecast which needs to be accepted as a base for supply chain. Companies have four ways to handle demand uncertainty in their own operations (Fisher, 1997):

1. acceptance
2. reduction
3. avoidance and
4. protection against

First way to handle uncertainty is to simply accept it. Globalization, rising competition and changes in markets are adding uncertainty. After accepting uncertainty it is possible to try to reduce, avoid or protect against uncertainty. Reducing is possible by trying to get into near co-operation or partnership with biggest customers to learn to better understand the nature of uncertainty and to get reliable future demand information from customer. It is also possible to reduce uncertainty between different products by designing product structure to enable wide product range with common key-modules or common product-frame. Avoiding uncertainty means shortening delivery times and enabling late customization. Late customization makes it possible to assemble wide range of final assemblies at the last moment based on reliable customer order, not based on forecast. **The faster the company can react on demand, the shorter it needs to plan the future demands.** As the company has done everything it can to reduce and avoid uncertainty, it needs to protect against remaining uncertainty with stockpiles and extra capacity. With these ways company can be prepared to changing and difficultly predictable demand. Nokia Networks for example has used all of these chances in their reactive supply chain. Nokia got into near connection with its customers to better get and understand the information of factors affecting to future demand. It also developed the product structure of the access point devices to enable module testing instead of testing final assemblies. (Heikkilä & Ketokivi, 2005)

At SMC, there are still possibilities to focus on reducing and avoiding uncertainty caused by demand. The uncertainty is not fully accepted as there are long twelve month forecasts to predict the demand. Even if these forecasts are not trusted, they are used as a base for relatively precisely defined production planning. Often it has directly been protected against uncertainty with stockpiles and extra capacity, before it has been tried to reduce or avoid uncertainty instead.

Many forecasting errors may be result of inappropriate forecasting methodology, but the root cause of these problems is that forecast errors increase as lead time increases. All forecasts are prone to error and the further ahead the forecast horizon is the grater the error will be. The conventional response has been to increase the safety stock to provide protection against such forecast errors, but it is surely preferable to reduce lead times in order to reduce forecast error and hence reduce the need for inventory. (Christopher, 2005)

3.4.4 The concept of lead time

Today’s customers living in fast “real-time” information society are expecting fulfilment of the orders almost instantly. Same phenomenon is detected in business-to-business environment. Lead time compression has become a major order winner. The risk attached to traditional forecast driven lengthy supply chain has been recognized and quicker reaction ability with less assets is demanded. Market and customer requirements change for sure. Rather than putting the efforts into an accurate forecast, organizations must instantly adjust to these changes across the entire value stream. (Burton & Boeder, 2003; Naylor et al, 1999) For leannes it is important to eliminate anything that is not adding the value to a product, process or service, and this includes waste time. Agility requires a responsive supply chain and thereby lead time compression in terms of information flow as well as material flow. (Naylor et al, 1999)

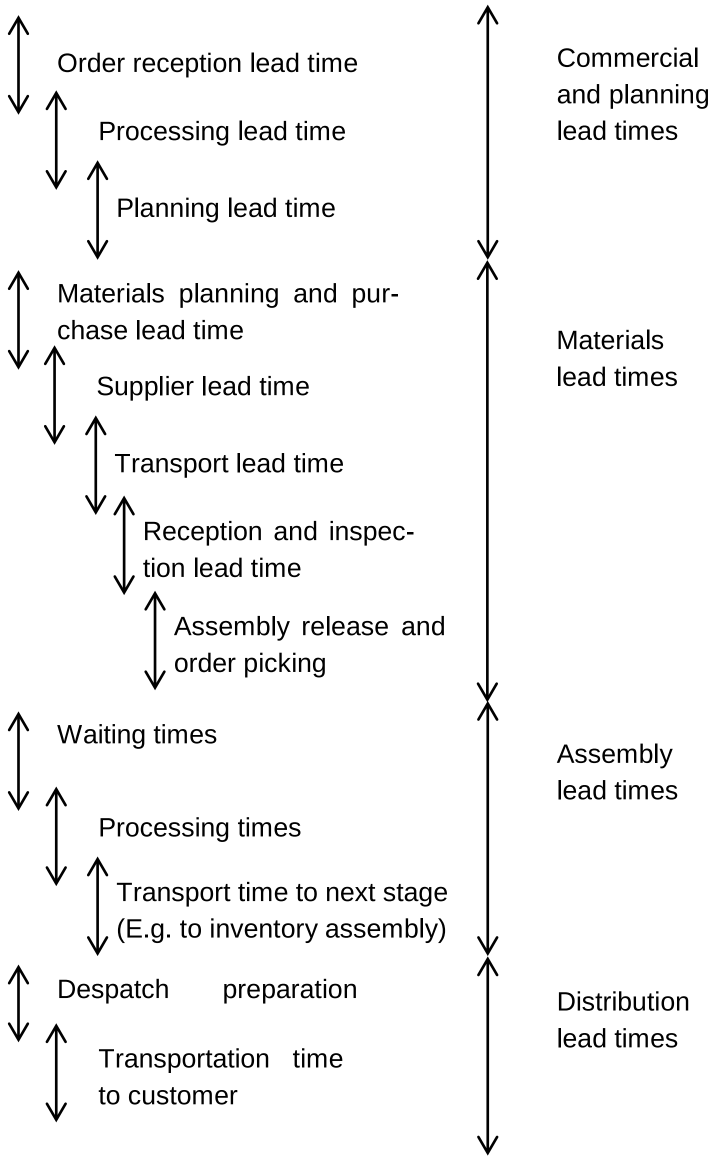


Figure 20: Lead-time components (adapted from Christopher, 2005).

The concept of lead time appears differently for customer and supplier. According to Christopher (2005) there is only one lead time from customer's point of view: the elapsed time from order to delivery. Though being very important point of view, the supplier views just as important the cash-to-cash cycle: the time it takes to convert an order to cash and the total time that working capital is committed from when materials are first procured through to when the customer's payment is received. The longer the pipeline from source of materials to the final user (figure 20) the less responsive to changes in demand the system will be.

It is the basic fallacies of management, that long lead times provide security and cover against uncertainty. According to Christopher (2005) the reverse is true in fact. The target for any organization should be to reduce lead times at every stage in logistic pipeline to as close to zero as possible. Remarkable reduce opportunities can often be found through some very simple changes in procedure.

As far as cost is concerned there is a direct relationship between the length of the logistics pipeline and the inventory that is locked up in it; the product incurs an inventory holding costs every day that it's in the pipeline. Secondly, long lead times mean a slower response to customer requirements and therefore increased importance of delivery speed. In today's internationally competitive environment, this combination of high costs and lack of responsiveness provides a recipe for decline and decay. (Christopher, 2005)

Order penetration point (OPP) is the point in production where customer order conducts process down-stream. Up-stream from order penetration point, the process is conducted by forecasts and plans. Order penetration point defines the delivery time for the customer delivery. The higher amount is produced based on order conduction and not on forecasts, the smaller is the risk for unsold storage. The wider the product range the more expensive is delivery from storage. On the other hand, delivery from storage fastens the delivery. (E.g. Christopher, 2005; Heikkilä & Ketokivi, 2005)

The lead time gap

A fundamental problem faced by most organizations is that the time it takes to procure, make and deliver the finished product to a customer is longer than the time the customer is prepared to wait for it. That is a basis for lead time gap presented in figure 21.

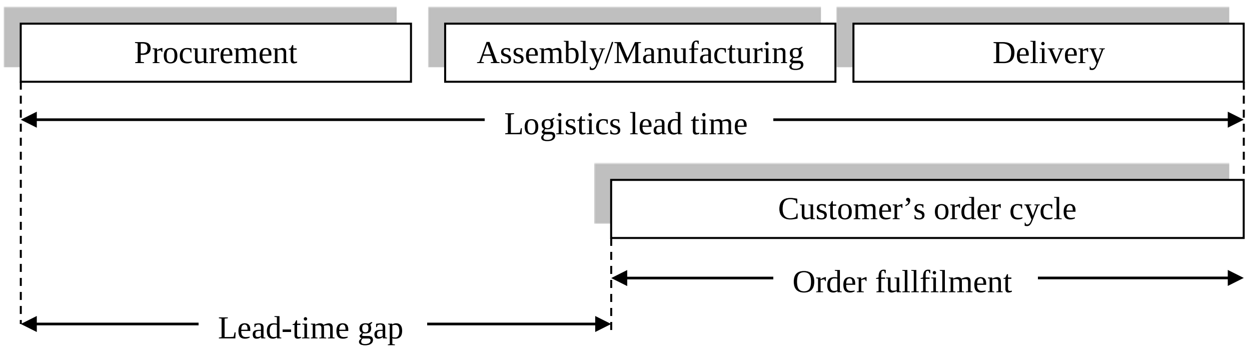


Figure 21: The lead-time gap (adapted from Christopher, 2005).

The customer's order cycle refers to the length of time that the customer is prepared to wait, from when the order is placed through to when the goods are received. This means that the customer's order cycle is also the maximum period available for order fulfillment. The conventional way to close or reduce this lead time gap between logistics lead time and customer's order cycle is by carrying inventory, which normally implies forecast. Companies seek to forecast market's requirements and then build inventory ahead of demand. Still, forecasts are not ever perfect, no matter how sophisticated they are. Forecast mistakes always end up as an inventory problem. If company would manage to close the gap by reducing logistic lead time or by extending the customer's order cycle, there would not be need for forecasts and all the inventories would base on usage. Extending the customer's order cycle is possible by gaining earlier warning of requirements through improved visibility of demand. Closing the gap totally is not always achievable, but heading towards ever shorter gap is a profitable goal. (Christopher, 2005) In addition to quicker response and cost savings, the other risks than costs associated with inventories are reduced.

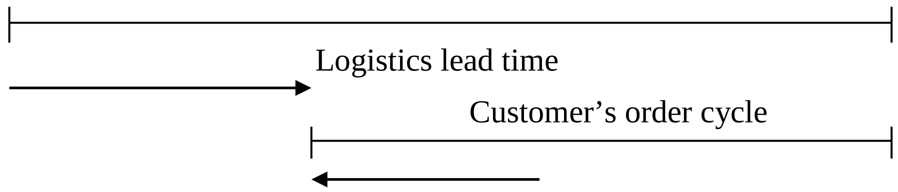


Figure 22: Closing the lead-time gap. (Adapted from Christopher, 2005)

Companies have typically not managed well the total flow of materials and information that link the source of supply with the ultimate customer. There is a big opportunity for efficiency improvements in that process. The case, in companies that do not understand the importance of managing the supply chain as an integrated system, is that considerable periods of time are consumed at the interfaces between adjacent stages in the total process and in inefficiently performed procedures. Major opportunities for time reduction across the logistic pipeline as a whole are not recognized because no one department or individual manager has complete visibility of the total logistics process. (Christopher, 2005)

3.4.5 Flexibility

Managing uncertainty with flexibility is one of the main sources of sustainable competence in developed country industrial companies. Flexibility combines the ability to understand wide range of customer demands and ability to satisfy these demands with versatile, constantly evolving products or services, quick and effectively. Flexibility is needed in every four layers of the operations system: company's highest strategy level, business level, operation level and production level. Some industrial companies are in position where they can reset industry principles, but often companies need to adapt their own principles to industry environment. Two factors, scope and time, are essential to survey relative to competitors (Heikkilä & Ketokivi, 2005):

- The wider uncertainty the operations system is able to handle the more flexible it is.
- The faster the operations system is able to handle uncertainty the more flexible it is.

Flexibility is company's benefit, not customers, and customers are not usually willing to pay about company's flexibility. (Brown, 2003) Flexibility in operations means ability to adapt in to changing environment or encountered surprising situation. There are four types of flexibility to recognize in operation related flexibility (Heikkilä & Ketokivi, 2005):

- Volume flexibility, meaning company's operations ability to manage uncertainty in customer demand. Capacity decisions (own and subcontracted) are essential.
- Mix flexibility, meaning operations ability to manage wide product range and uncertainty related to customer's choices between products. The decision between effective production of narrow product range and more expensive production of wide product range is essential decision of mix flexibility.
- Material flexibility, meaning ability to manage uncertainty related to supply chains ability to survive from demand addressed for it. Essential strategic decisions relate to supply networks structure and control.
- Changeover flexibility; ramp-up/ramp-down flexibility, meaning ability to take new products quickly into production and raise the volume.

Selecting a production process is one of the first and long-acting structural decisions. Selecting a production process means long-term commitment to combination of certain production capacity and scope of product range. Relevant options of production processes for parcelled goods are job shop, batch production and line production (Heikkilä & Ketokivi, 2005):

- Job shop bases on resources able to produce very different or customized product individuals. Material flows are moving from resource to another depending on produced product.
- With batch production it is possible to achieve higher volume than with job shop by arranging production economically according to batch sizes. Production is often arranged into cells that enable flexibility management according to product range and volume. Product change and batch size definition are challenges in batch production.
- In line production, the investment on fixed production line is goaled to achieve higher efficiency in the limits of suitable product range. Ensuring trouble-free operation is significant for line production as disturbances can stop the whole line.

In the supply chain of SMC, all three types of production processes are used. Even if the final assembly is based on line production, subassemblies are produced as a job shop or batch production. Therefore it must be understood the different demands and principals in the different phases on the supply chain. To have all three types of production processes can be an advantage to achieve both flexibility in a sense of agility and costs efficiency in a sense of leannes as section 3.6 presents.

3.5 Measuring logistic costs and performance

According to the International Monetary Fund (IMF), logistics costs average about 12 per cent of the world's gross domestic product and seems to be increasing (Ballou 2004, p.13-14). Logistics costs can be seen as one of the reasons for movement towards modern supply chain management. Companies' supplier and subcontractor networks have widen, companies operate more globally and compete by dint of customer service. All of this increase need for logistical operations and hence logistical costs. Logistics was the enabler for all of this but it was viewed as a superfluous time and money consumer. True costs of logistics are still often misunderstood. Managers and experts have started to question traditional approaches to accounting based upon full-cost allocation as they can be misleading and dangerous. (Christopher, 2005; Heikkilä & Ketokivi, 2005; Emmett &Crocker, 2007)

According to Heikkilä and Ketokivi (2005) there are generally three essential performance categories on measuring the performance of industrial company: productivity, profitability and solvency. The most important from operations point of view are productivity and profitability. Productivity means output per input. To add productivity, outputs need to rise relatively more than inputs, or inputs needs to be reduced relatively more than outputs. Productivity and profitability does not have unambiguous correlation and productivity should not be concentrated alone without considering efficiency and added value. Efficiency means realized output per planned output or capacity. 'Added value' is the value that 'operation systems' 'change process' produces. Productivity and efficiency are often measured by amounts of production and not by added value. For example according to just-in-time-philosophy, productivity can be wrong and misleading goal. According to JIT-philosophy production system should never produce for anything else than for actual demand. (Heikkilä & Ketokivi, 2005)

The pressure in most organization is to improve the productivity of the capital and so the concept of return on investment (ROI) is utilized in this regard. (Christopher, 2005)

$$ROI = \frac{Profit}{Capital\ employed}$$

Ratio of ROI can be further expanded with sales considered:

$$ROI = \frac{Profit}{Sales} \times \frac{Sales}{Capital\ employed}$$

Logistics in a ratio of ROI is generally placed as a cost in capital employed. Logistics activity does not just generate cost, it also generates revenue through the provision of availability – thus it is important to understand the profit impact of logistics and supply chain decisions. There are various and many ways in which logistics management can impact on ROI. Figure 23 underlines major elements determining ROI and the potential for improvement through more effective logistics management. (Christopher, 2005)

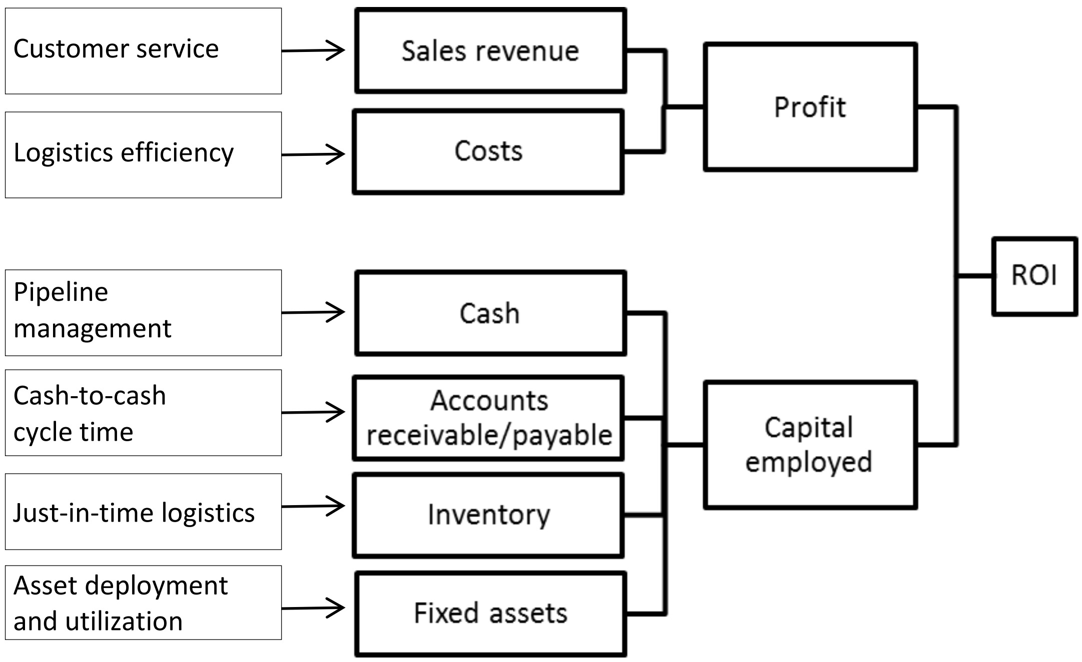


Figure 23: Logistics impact on ROI (adapted from Christopher, 2005).

As the figure above presents, logistics have impact on both factors in a ratio of ROI. Because logistics management is a flow-oriented concept with the objective of integrating resources across a pipeline which extends from suppliers to final customers, it is desirable to have means whereby costs and performance of the pipeline flow can be assessed. (Christopher, 2005) End-user focusing business has many metrics in supply chain that can be considered but they can also be aggregated as Service, Quality, Cost and Lead-time in relation presented in figure X. This presents the total value of a product to the end-user. (Naylor et al, 1999)

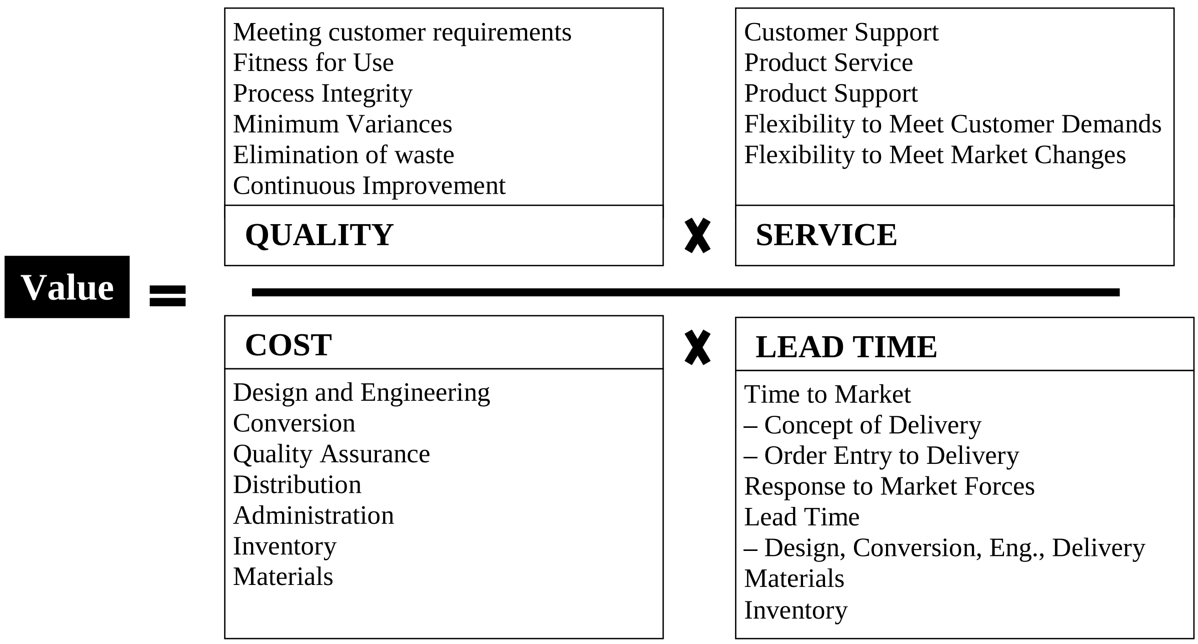


Figure 24: Total value metric (adapted from Naylor et al, 1999).

There can be need for higher quality and better service or lower costs and shorter lead times will arise and the metrics are to be gauged differently. Logistics is increasingly being recognized as having significant impact on economic and customer experienced added value. Decisions on logistics strategies must be made based upon thorough understanding of the impact they will have on the financial performance of the business.

Activity-based costing methods provide some significant advantages to identify the real costs of serving different type of customers or supplying certain individual assembly. Once the cost attached to each level of activity is identified then a clearer picture of the true cost-to-serve will emerge. Many problems at the operational level in logistics management arise because all the impacts of specific decisions, direct and indirect, are not taken into account throughout the corporate system and supply chain. Changes in sourcing decisions, production decisions or product related decision have often impact on indirect logistic costs in a form of added fluctuation. (Christopher, 2005; Naylor et al, 1999)

Measurement methods are not taken deeper consideration within this study. Development of reliable real costs measurement method in practise would be a topic big enough for a whole thesis. The idea here was to get understanding of the nature of logistic performance and costs, how they form and how they are affected by different events and decisions throughout the organization.

3.6 Lean and agile supply chains

Lean and agility have become common concepts in business sciences and operations in recent decades. Lean has traditionally been considered as a manufacturing philosophy and agility as a wider business philosophy. (Christopher & Towill, 2000; Burton & Boeder, 2003; Naylor et al, 1999) Extending and integrating these concepts to supply chain makes it essential to compare their characteristics. Some strategic decision making must be done as characteristics of these philosophies are sometimes opposed. (Basu & Wright, 2008)

3.6.1 Difference of leanness and agility in supply chain

Lean is not just systems and tools but a manufacturing philosophy began with Japanese automobile manufacturing in the 1960’s. (Christopher & Towill, 2000; Burton & Boeder, 2003; Naylor et al, 1999) Just-in-time (JIT) scheduling is probably the best known logistics operating philosophy applying lean principles. As a simplification JIT is an alternative to the use of inventories for meeting the goal of having the right goods at the right place at the right time. (Ballou 2004, p. 428) As an American operations management expert Stevenson (2009) emphasizes the benefits of lean methodologies in supply chains. According to Stevenson many businesses are turning to lean principles to improve the performance of their supply chains. In too many instances, traditional supply chains are a collection of loosely connected steps, and business processes are not linked to suppliers' or customers' needs. Applying lean principles, supply chains can overcome this weakness by eliminating non-value-added processes, improving product flow by using pull systems rather than push systems, using fewer suppliers and supplier certification programs, which can nearly eliminate the need for inspection of incoming goods, and adopting the lean attitude of never ceasing to improve the system. (Stevenson, 2009)

Christopher and Towill (2000, 2005), Basu and Wright (2008), Naylor et al (1999) and Stratton and Warburton (2003) as supply chain management specialists criticise and question the concentration on lean methodologies in relation to supply chains. Organization needs to be able to respond in shorter timeframes both in terms of volume change and variety change. Agility is a business wide capability that embraces organisational structures, information systems, logistics processes and, in particular, mind sets (Christopher & Towill, 2000). Agility in the sense of ability to match supply with demand is not necessarily synonymous with 'leanness'. Lean manufacturing is widely followed and written about, especially in reference to the automobile industry. Still, many companies that have adopted lean manufacturing as a business practice are anything but agile. Whilst leanness may be an element of agility in certain circumstances, by itself it will not enable the organization to meet precise customer demands more rapidly. (Christopher & Towill, 2000)

Basu and Wright (2008) make division of three models of supply chains; traditional, agile and lean in table 3. Supply chains often have characteristics from both models but it is still important to understand the differences and the application of each model and the application of each model and application whether pure or hybrid.

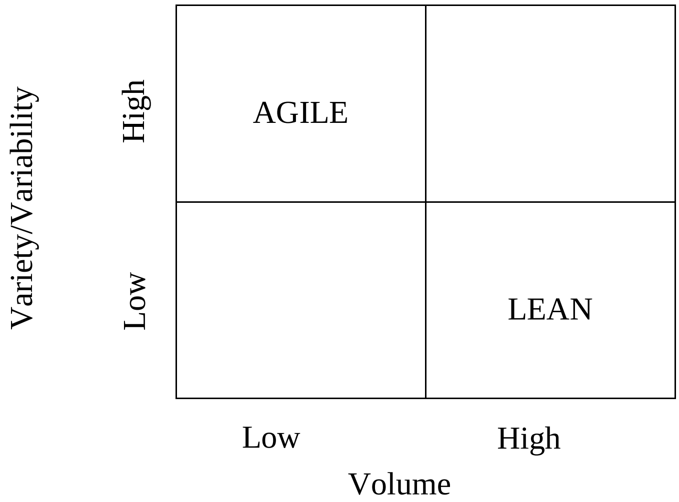
Table 3: Three models of supply chain (Basu & Wright, 2008).

- Traditional – known for:
  - Protection of market, aims for leadership
  - Forecast driven
  - Higher emphasis on customer service than cost
  - Inventory held to buffer fluctuations in demand and lead times
- Lean – Characteristics are:
  - Integration upstream with suppliers
  - Integration downstream with customers
  - High emphasis on efficiency
  - Aims for minimum stock holding
- Agile – Noted for flexibility and speed in coping with innovative products and unpredictable demand.

As a simplification:
Leannes means developing a value stream to eliminate all waste, including time, and to ensure a level schedule.

Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place. Flexibility is a key factor.
Both demand high levels of product quality and require minimum total lead-time (Naylor et al, 1999; Christopher & Towill, 2000)

The most essential difference between leanness and agility in the terms of the total value provided to the customer is that service is a critical factor that requires agility whilst cost is clearly linked to leannes. (Christopher & Towill, 2000) The type of supply chain is highly related to products market environment as clarified in figure X.



’Lean’ works best in high volume, low variety and predictable environments

‘Agility’ is needed in less predictable environments where the demand for variety is high

Figure 25: Contexts for lean and agile methodologies (adapted from Christopher, 2005).

The agile supply chain is *market-sensitive*. This means that supply chain is capable of reading and responding to real demand. Most organizations are rather forecast-driven than demand-driven. Forecast-driven supply chains are forced to use inventories to control the inaccuracy and uncertainty of the forecasts. Actual customer requirements and demands should be the driving force and principal information to plan and control the supply chain. (Christopher & Towill, 2000, 2005; Naylor et al, 1999; Stratton & Warburton, 2003)

If lean and agile -approaches are tried to be applied simultaneously without great attention to effects of the approach to the whole, there’s a risk to achieve worst parts of both worlds.

- If lean approaches (large batch quantities and forecast driving) are used for certain occasions or items at the stage of supply chain where agility is strove to be achieved, all the investments put to gain agility can be lost. Larger batches and forecast driving increase lead time and lead time for the whole is as long as it is for its slowest part.
- If agile approaches (demand driving, small batches, localized configurations) are used for certain occasions or items at the stage of supply chain where agility is strove to be achieved, all the investments put to gain agility can be lost and there’s a risk of distractions and complexity.

3.6.2 Hybrid of lean and agile supply chain

Division to lean and agile methodologies can be criticized about trying to fit one type of supply chain solution to all needs. Often, as for example in SMC's case, there is a need for both, lean and agile supply chain solutions within the same business. Some items may have predictable demand (items used in every final product) whilst for others the demand may be very volatile (option or variable items). To identify the types of appropriate supply chain strategies for different circumstances company's products (or items of final product) can be positioned in an organization's portfolio according to their supply and demand characteristics as in figure 26 below.

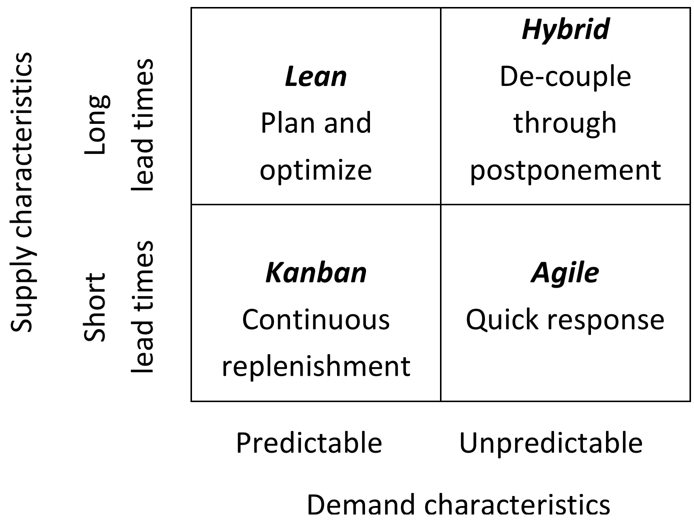


Figure 26: Generic Supply Chain Strategies (adapted from Christopher, 2005).

Let's put our concern to top right corner where lead times are long and demand is unpredictable as this is the case in SMC. In this kind of situations, the first priority should be to seek to reduce lead times since the variability of demand is almost certainly outside of company's control. Lead-time reduction would enable the application of agile solutions. If lead-times cannot be reduced the next option is to seek to create a hybrid lean/agile solution. These hybrid solutions require the supply chain to be 'de-coupled' through holding strategic inventory in some generic form or unfinished form, with final physical configuration being completed rapidly once real demand is known.

Even if the differences between lean and agile paradigms have been noted, it is critically important to understand that there are same highly important enablers for both supply chain strategies. Naylor et al (1999) present key characteristics of the agile and lean manufacturing paradigms as supply chain strategies in table 4. Characteristics occur at both paradigms but their relevance for particular paradigm can be essential, desirable or arbitrary.

Table 4: Rating the relevance of different characteristics of leanness and agility (adapted from Naylor et al, 1999).

Keyword	Lean	Agile
Use of market knowledge	• • •	• • •
Virtual corporation/integrated supply chain	• • •	• • •
Lead time compression	• • •	• • •
Eliminate Waste (time, cost, stock)	• • •	• •
Rapid reconfiguration	• •	• • •
Robustness	•	• • •
Smooth demand / Level Scheduling	• • •	•

Note: • • • = essential, • • = desirable, • = arbitrary.

It is significant to notice that characteristics can be divided to groups that have same, similar or different relevance in the paradigms. (Naylor et al, 1999)

Same high relevance

All businesses in any supply chain must focus on the end user and both paradigms emphasize the use of market and demand knowledge. If market knowledge is not exploited and the supply chain is to be made more responsive then the members of the supply chain run the risk for example producing too wide a variety of products or items at short notice when there is insufficient demand to justify the extra cost. (Naylor et al, 1999)

Shared information can be properly used only through *process alignment* meaning collaborative working between buyers and suppliers, joint product development, common systems and shared information. This kind of co-operation becomes all the time more important and prevalent as companies focus on their core competences and outsource the other activities. (Christopher, 2005) As Christopher, Emmet & Crocker, Burton & Boeder and many other professionals have underlined, new business environment sets the requirements for greater reliance on suppliers and alliance partners, supply chains need to be managed as a whole in this extended enterprise. There cannot be boundaries between actors in chain and atmosphere of commitment and trust is necessary.

Lead-time compression is a success-factor not dependent on chosen supply chain strategy. Figure 27 suggest that instead of having to choose between either lower costs or higher service, by shortening the lead-time it is possible to have the best of both worlds.

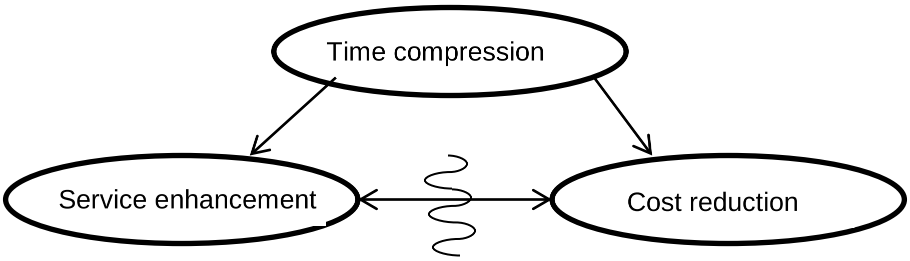


Figure 27: Breaking free of the classic service/cost trade-off (adapted from Christopher, 2005).

Similar relevance

Just-in-time (JIT) approach is probably the best known and most generally implemented lean approach related to supply chain management. In a pure JIT lean supply chain there would be zero inventories throughout a total supply chain. In practice more relevant philosophy is a Minimum Reasonable Inventory (MRI) where any further attempts to decrease stocks would not be worthwhile. (Christopher & Towill, 2000; Naylor et al, 1999) In agility the elimination of as many non-value activities as possible is also desirable. In agile system there have to be however a careful consideration of stock and or capacity requirements to ensure that the supply chain is robust to changes in the end users' requirements. The level of MRI may be set higher than for lean supply chain and additional activities might be required to provide the ability to be flexible. So the definition of what is value adding process will be expanded to include processes that are fundamentally non-value adding but necessary. The use of an integrated supply chain is essential if elimination of waste is to be achieved (Naylor et al, 1999)

Different relevance

As previous chapter highlighted, lean supply chain is a cost effective paradigm that requires smooth demand and level scheduling while agile supply chain is robust and flexible to secure service and supply on fluctuating demand. These differences are to be considered when utilizing both paradigms as a hybrid in the same supply chain.

3.6.3 Decoupling point

Basu and Wright (2008) view the utilization of lean and agile supply chain a bit differently than other lean/agile supply chain writers even if they do refer to same writers Naylor et al and Christopher. According to Basu and Wright supply chain can be lean for part of the time, agile for part of the time and both lean and agile 'hybrid' for part of the time. Naylor et al (1999), Christopher and Towill (2000, 2005) as well as Stratton and Warburton (2003) are still quite single-minded saying that lean and agile supply chain approaches should be separated timely in decoupling point and not to be applied simultaneously. Lean and agile approaches have some characteristics with similar high importance like integration and cooperation through the supply chain, utilization of market knowledge and lead-time compression. Still the 'hybrid' of lean and agile supply chain which these professionals are talking about is exactly the combination of timely in decoupling point separated, not simultaneously existing, lean and agile supply chains. The difference in opinions is probably derived from context. Argument that Basu and Wright (2008) present about simultaneous existing of lean and agile supply chain is likely to be based on a view to different items for the same product in supply chain. It is true that some of the items may still follow lean supply chain approaches when some items for the same product are already managed with agile supply chain approaches. However, benefits of lean and agile approaches will not be realized simultaneously if these items are strongly related or dependent on each other.

Decoupling point separates the part of the supply chain towards customer orders from the part of the supply chain based on planning. The decoupling point is also the point at which strategic stock is often held as a buffer between fluctuating customer orders and/or product variety and smooth production output. This is a critical fact for considering when to adopt agile or lean manufacturing techniques. Positioning of the decoupling point is associated with the issue of delaying product differentiation/customising closer to the end user. (Naylor et al, 1999; Christopher, 2005) Responsiveness is achieved through agility in supply chain. Customers can be served more rapidly and the degree of flexibility offered can be greater and yet the cost should be less because of the shorter pipeline. (Christopher, 2005)

In any operating system, there exists the phenomenon of dependency and fluctuation. Combined in a delivery system they define the fundamental characteristics of production flow, which may be viewed at the factory or supply chain level. The traditional means of dealing with demand fluctuation is to place inventory between each process, so effectively decoupling the impact of the fluctuations. In the case of agile supply there are two major distinctions (Stratton & Warburton, 2003):

1. The non-standard nature of the product will inherently result in higher levels of internal fluctuation.
2. The unstable nature of market demand precludes the effective use of finished stock inventory to decouple the supply system.

The goal of hybrid strategy should be to build an agile response upon a lean platform by seeking to follow lean principles up to the de-coupling point and agile practices after that point. There should also be the principle of seeking to reduce complexity whilst providing the requisite level of variety that the market demands. (Christopher, 2005)

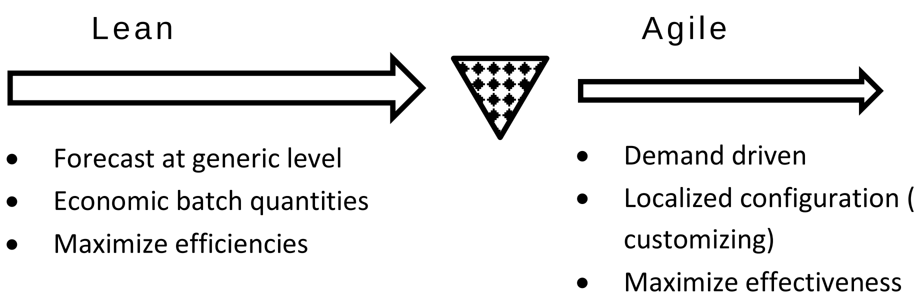


Figure 28: The de-coupling point (adapted from Christopher, 2005).

Delaying the decoupling point reduces the risk of being out of stock for long periods and holding too much stock of products that are not required. Benetton clothes manufacturer, Dell PC-assembler, and many other companies also in engineering industry have successfully applied delayed differentiation in their supply chain to reduce above-mentioned risks. Benetton has delayed the dyeing of their jumpers, which is critical differencing factor, until the end of the process. Dell has delayed the final assembly to assembly-to-order from totally standardized components basing on direct customer demand. No final products are made to stock but customers are still served quickly and inventories are kept low. (e.g. Naylor et al, 1999; Christopher, 2005)

4 PRODUCT LIFECYCLE MANAGEMENT (PLM) AS A COLLABORATIVE TOOL IN SUPPLY CHAIN MANAGEMENT

The significance of product lifecycle management (PLM) is increasing especially for companies in the manufacturing, high technology, and service industries. PLM is essential tool for today's industrial production as it helps coping with complex supply chains and discontinuing business environment, challenges with shortening product lifecycles and growing customer needs. Compression of lead-time is required in all type of supply chains and product structure is one of the key determinants of lead-time. Complex products require collaboration within large specialist networks including suppliers and partners as highlighted in previous chapter. Therefore electronic data transferring with high level information security is essential. (Young et al, 2007; Sääksvuori & Immonen, 2008) There seems to be great potential in PLM but also a substantial overhead that may void the benefits economically if potentials are not effectively realized. (Young et al, 2007) From these premises the effective utilization of PLM system and approaches is considered in this chapter.

4.1 Products role in supply chain management

It is still often the practise that product is first engineered and designed, and then production (including purchase and logistics) is designed to produce these products. The amount of relations between product and production is immeasurable. (Ruohomäki et. al, 2011) The old truth, that 80% of the cost of the product is determined during the product development phase, has not been falsified. (Sääksvuori & Immonen, 2008. p.43)

4.1.1 Modularization and late customization (delayed differentiation)

Responsiveness to win business is not just about the speed to quote the order, but speed to design and produce items as well. In many industries the design of each individual order consumes precious lead-time and requires the use of design engineers to manually produce drawings and/or production documentation. (Brown, 2003). With modular product structure it is possible to combine the advantages of mass production and wide product range. This is called mass customization.

Mass customization exploits the great efficiency of line production and great variety in final assembly range. One of the most essential benefits of modularization is that various arrangement or combinations can be done during assembly process according to customer specification. By including the customer valued variations and options into more surface level in the product structure it is possible to push the customization point later in assembly process. This is called delayed differentiation or late customization and it is enabled by designing the product structure and production model such way that customer valued variations can be attached only in certain modules and production phases. (Heikkilä & Ketokivi, 2005; Shamsuzzoha, 2011; Stevenson, 2009)

Implementing the modularity, considering all the effects and goals tried to be achieved, can be challenging. To achieve the goals of modularity, designers of the modules must have knowledge about internal principles of overall product and overall supply chain. (Shamsuzzoha, 2011) These internal principles include the lean and agile supply chain paradigms and the positioning of the de-coupling point. Differentiation of products should be delayed after de-coupling point.

4.1.2 Standardization and differentiation

In assembly industry, by standardization it is usually meant the standardization of parts, components and materials in product itself. Different customer demands satisfying product range and variation can be achieved by attaching standard items and modules. The basic idea of standardization, that affects to cost efficiency, is that as optimal amount of items as possible can be produced or purchased more cost efficiently. (Ruohomäki et al 2011) Reduction of the number of items affects directly to logistic costs caused by transports, packaging, handling and storing.

Building in increased customization or variation the complexity increases tremendously. This complexity can drive significant additional costs for the manufacturer. Still, it's good to remember that the customer does not care if the company can provide just about anything. They only care if the company can provide what they want (Brown, 2003). Christopher (2005) also adds that the product is purchased not for itself but for the promises it will 'deliver'. Putting this to SMC environment we could say as an example that customer does not care what official regulations his drill rig does meet as long as it meets those obtained in his country. At least he will not mind if the rig meets higher standards. If there is a possibility to meet all regulations with same item, then using different regulation satisfying items does not give any added value for the customer but complicates the material flow and other actions in supply chain. There are for example three types of air tanks for the same SMC rig depending on the area the rig is sold. There are no functional differences between these items but they meet the different regulations. Therefore there needs to be separate purchasing, inventory stock, BOM structure and logistical processes for these three different air tank types. It is understandable that lower regulation level items may be cheaper to purchase, but the price differential has to be significant to cover added logistical and investment costs. Ruohomäki et al (2011) declare that development of standardization should be continuous development theme in companies of all sizes. Development acquires common goals and co-operation from all the functions in company.

Standardization in packages and transport units also eases transport, handling and storage. Less item specific equipment and approaches are needed when items are standing for example in standard EUR-pallets.

4.1.3 Example from car industry

In car manufacturing industry modularity and standardization has been taken very far and even if resources and demands in SMC's type of industry are not as big as in car industry, it can still represent possibilities and profits of standardization and modularity. VW-Group can give an example about using the same items and generic structures. Twenty different car models from sports cars to SUVs, which all have different variations inside the model, still use the same platform, mostly same engines, and numbers of same items. (Prassler et al, 2009) Another example about standardization is equipment packages and readiness for options. When a customer buys a car, he can first choose whether he wants to take the car without option package or with some of the ready packaged set of equipment and add some options. With packaged options, the wide amount of options is still managed in logistics and manufacturing as a few different BOM and set of items. Added options and even the ones in equipment packages are not usually added as a whole. Especially the electrical options are often very cheap for producer and therefore it just makes almost every part of the supply chain less complex to install these options to every car, but leave the enabling button or switch unimplemented. Cruise control is a good and common example, as most of the mid-range cars today include the actual technical parts of the cruise control inside the dashboard and control unit, and the only added part according to customer's selection is the switch to enable the functionality. These facts give an opportunity to lower the amount of items. The variation of sales between the different models will not cause as big variation on demand of common parts. Need of forecasting decreases, and purchasing and logistic operations come less complex and less expensive.

4.2 The definition of PLM

PLM has formerly been noted in a narrower frame of reference as PDM – Product Data Management. Former ideas of PDM and PDM-systems have been generally viewed as tools for product development, and it is still a common approach in Finnish industry. PDM was developed in late 80's (from primitive EDM – Electronic Data Management – systems) to keep track of the growing volumes of designing files generated by CAD (Computer Aided Design) systems. PDM enabled item standardizing, document file storing, maintain BOM (Bill of Material) structures, to control item, BOM and revision levels, and to see relationships between parts and assemblies. Risk of using incorrect design versions and loose product information was reduced and reuse of existing product information was increased. (Sääksvuori & Immonen, 2008)

PLM and PLM systems should not be understood as synonyms. PLM system is a collection of tools to carry out and often enable PLM methods and approaches. PLM is still a concept and methodology that does not necessarily require PLM system to every function. With distension from PDM to PLM and to idea behind the system, PLM can be considered as wider tool in supply network to bring new products to market with less time, effort and risks. Terminology change from PDM to PLM in systems can be claimed to be a marketing trick to bring a new feeling to system. Developments from PDM to PLM, in the sense of functionality of the software offering, has extended to support users in research and development, marketing and service and to support engineering collaboration with co-developers in supply chain. (Pels & Simons, 2008) Sääksvuori and Immonen (2008) expand the use and benefits of PLM: "PLM is a holistic business concept developed to manage a product and its lifecycle including not only items, documents, and BOM's but also analysis results, test specifications, environmental component information, quality standards, engineering requirements, change orders, manufacturing procedures, product performance information, component, suppliers, and so forth." Incremental savings can be achieved by implementing tools and technologies, but wider benefits of operational PLM and real return on investment can be achieved by making changes in processes, practises and methods to gain control over product lifecycle and lifecycle processes. Groups all across the value chain can work faster through advanced information retrieval, electronic information sharing, data reuse and numerous automated capabilities, with greater information traceability, transparency and data security. The work once been done should remain exploitable, regardless of place, time or data ownership (information security considered). (Sääksvuori & Immonen, 2008)

It should be possible to change the product's design or development and production processes even if it's often for a single client. One feature of the modern business world is powerful inter-company networking. Individual products are generally born from cooperation between companies, each of which is responsible for some part of the products planning, component preparation or assembly. The management of an extensive and scattered network of subcontractors and partners is not easy and it requires very effective data management. Making changes to product designs or product implementations is also a big challenge in a networked operational business environment. All the interested parties must have access to the latest version of documentation of each product. In addition, it should be possible to see effects of changes to product elements already when the changes are planned. (Sääksvuori & Immonen, 2008. p.5)

The concept of the product lifecycle management is at its simplest, a general plan for practical product lifecycle management in daily business at the corporate level, in a particular business or product area. It's a combination of business rules, methods, processes, and guidelines as well as instructions on how to apply the rules in practise. A good PLM-concept is never static; it keeps evolving in tune with the business and its requirements.

To understand what kind of information and data is managed with PLM system and how they are managed it is important to understand the data types in the system.

Table 5: Definition of data types in PLM (adapted from Sääksvuori & Immonen, 2008).

Data type	**Definition**
Definition data of the product	Determines physical and/or functional properties of the product, describes the properties of the product from the viewpoint of a certain party (i.e. customer, presales, designing or manufacturing) and connects the information to the interpretation of the party in question. This group of information could be characterized being a complete product definition as it includes very exact technical data as well as abstract and conceptual information about the product. Includes also the images and conceptual illustrations that characterize the product.
Life cycle data of the product	Always connected to the product and the stage of the product or order delivery process. This information is connected to e.g. technological research, design and to the production, use, maintenance, and possibly to the official regulations connected with the product.
Metadata that describes the product and lifecycle data	Describes the product data, e.g. what is the data type, where it is located, when and by whom it is modified and how it can be accessed.

The core PLM processes in manufacturing business in to product process and order-delivery process. Product process means NPI (New Product Introduction), and maintenance and development process of the existing product on generic and abstract level. Order-delivery process means the lifecycle process of actual individual product. (Marchetta et al, 2011; Sääksvuori & Immonen, 2008) PLM in a concurrent engineering/virtual enterprise paradigm involves interactions between several types of entities and at different abstraction levels. Since each interaction type entails different issues (e.g. information ownership, concurrency, etc.), a structured categorization of these interactions is needed. (Marchetta et al., 2011)

Proactive reference framework

Researches have so far focused on information models, business processes and interoperability issues. Only recently, the need for putting more intelligence on products to make them proactive during their own development and management, to better support business processes, has been recognized. (Marchetta et al., 2011)

Marchetta et al. (2011) propose a proactive reference framework for PLM with also logistic information model. The framework includes product information model to define the structure and relations of information, applications architecture as a link between the data and the actions, and business process model as defining the actions and processes. Product information model has been taken as a fundamental asset as the most important bottleneck found in concurrent engineering environments within virtual enterprises is the difficulty of capturing, sharing and maintaining product information in a distributed way over time. Information models are proposed for different function in organisation. The logistics model allows the product agent to support logistic activities such as coordinating supply chain activities, determining lead times and costs, etc. (Marchetta et al., 2011)

The framework includes a business process model for PLM and supply chain management that supports concurrent engineering within virtual supply chains. The order delivery process takes care of coordinating all activities to put products in the location accorded with the customer. This process includes logistical activities. The production planning process accommodates the demand to the available manufacturing resources. As a result it forms a production plan provided to manufacturing/assembly. Demand/inventory management forecasts demand in order to support procurement and production planning. All of these processes are executed concurrently by people spread across the company. (Marchetta et al., 2011)

4.3 Concurrent Engineering

The efficiency vs. innovation dilemma in PLM has been addressed by proposing intensive use of knowledge management to involve buyers and suppliers in innovation processes. (Marchetta et al, 2011) To design product and production system simultaneously, the concept of Concurrent Engineering (CE) was developed. CE can be seen as a part of PLM concept and it is included as a function in latest PLM systems. The practical use of CE is still often actualized as different designing guides, for example DFM; Design-for-Manufacturing, DFA; Design-for-Assembly, DFC; Design-for-Cost, DFQ; Design-for-Quality and focusing on all the main qualities, DFX; Design-for-eXcellence. (Heikkilä & Ketokivi, 2005. p.103-104) The concept has widen also to supply chain management with DFS; Design-for-Supply-Chain (Sääksvuori & Immonen, 2008). New ideas in these concepts are for example continuous co-operation in cross-functional teams between company’s operations, early supplier involvement (ESI) and instrumentations to compare alternative plans to set goals. DF-designing guides have though been criticised about their bias to always adapt product to existing production system and supply chain. (Heikkilä & Ketokivi, 2005. p.103-104) According to Lysons and Farrington (2006) concurrent engineering can be seen as one of the enablers of agile manufacturing.

Supply chain can be exploited to design tailored products or different versions of the product with options as in SMC’s case, and it is often necessary to redesign production process. The latest idea in changing business environment is Three-Dimensional-

Concurrent-Engineering (3-DCE) that pays equal respect for the product, production process and supply network. (Heikkilä & Ketokivi, 2005. p. 105)

DFA-guides can bring remarkable savings as studies have shown. The averages of the change of eight most published indicators according to studies are (Curtis, 1997):

- 56% less items
- 62% shorter assembly lead time
- 45% smaller assembly costs
- 50% total costs
- 72% less fasteners
- 54% less assembly functions
- 45% shorter development cycle
- 69% less assembly tools.

According to Ruohomäki et al (2011), general DFA-designing principals can be summed up as follows:

1. The number of items is tried to be minimized.
2. Product Development takes in to consideration and tries to simplify the functions of assembly process, like
    a. Inbound logistics and storage
    b. handling
    c. installation
    d. the transfer of assembly from assembly place to another

To simplify the assembly work and logistic processes in supplier network it is essential to design all the material flows in and out the assembly line, assembly approaches and so on. One of the most essential goals of DFA is to reduce the number of items as it effects to cost reduces in numerous ways. (Ruohomäki et al (2011)

4.4 The most essential functionalities of PLM system for supply chain management

The management and maintenance of product structures is one the most important functions of the whole PLM system, because these features provide the basis for many other basic system functions. Some properties of version management, structural presentation of information, and change management as well as configuration management, are typically based on product structure management. (Sääksvuori & Immonen, 2008) PLM systems today have applications and tools to take these advantages in practise in different stages of supply chain. In Finnish manufacturing industry these are yet not widely applied but so far experiences and international solutions have proven the potentials.

The product structure itself makes the presentation of the relationships between the separate parts of products and assemblies possible. The product structure can be based on a generic product data model or directly according to a product unit based part list or BOM (Bill of Materials). ‘Bill of Materials’ as a term is a bit misleading because BOM in this context refers to a structured part list into which a hierarchy has been added to mere flat list of parts. BOM constrains enable the filtering option so that certain parts of the structure can be hidden and others are emphasized. By filtering the structure this way it is easier to examine large and complex product structures in sections. (Sääksvuori & Immonen, 2008) For different purposes and different functions in supply chain there are different needs of information about the products. If the product information cannot be filtered or structured purposely, it is difficult to use it effectively as the total amount of information is huge. (Kakehi et al, 2009) Appropriate operation-based view with filtering and structuring is information in itself. In certain cases, the system might contain only one product structure for each generic product and there will be only view of it. With different views, the same product structure is examined from different viewpoint in different circumstances.

1. The BOM view from the engineering point of view can be divided to show the items related to certain functionality of the final product.
2. The BOM view about the same product structure from manufacturing point of view shows only the items related to certain phase of assembly or only items related to certain subassembly.
3. From spare part point of view, there would be BOM view that show only the items related to certain package of spare parts.

To achieve the effective PLM it is essential to share information gathered over the entire product lifecycle in multiple departments and therefore it is essential to construct a multiple database Bill of Material (BOM) in each case for effective knowledge sharing. (Kakehi et al, 2009) This way, the updates in generic structure will be updated in to all these operation purposed views simultaneously and changes in views does not effect to generic structure.

On the other hand, modern PLM systems can handle several product structures for the same product. This approach might be practical in certain organizations with certain products, but maintenance to keep up to date several different product structures for the same product might become difficult or impossible in practise. The management of the changes, especially in the relations between different structures for same product, might become difficult to maintenance. Importance of recording and maintenance of the individual structures for individual products will increase in business to fulfil demands of After Sales services and product life cycle services. Individual product information can include the information about individual product, owner and location but this information does not necessarily have to be in too exact level as the maintenance of information would become too difficult. Therefore the first approach, to have one generic product structure and several BOM views for it, is often more applicable. (Sääksvuori & Immonen, 2008)

Here we get to the other essential functionality, Change Management, which manages changes in documents, items and structures. It is one of the key features of a PLM system as it provides broad, real time and secured controllability and visibility to the change processes for products in all the functions of organization that need the information about changes in products. It also provides traceability to performed engineering changes or design changes during product's design history. Problems in existing design can be controlled and quickly signalled to product development with engineering change request (ECR). ECR is formal and quick way to propose changes for responsible person and no middlemen are needed. Change Management tool has remarkable potential to develop all change processes of the company (Sääksvuori & Immonen, 2008):

1. The change is controlled and therefore manageable.
2. The information about forthcoming and completed changes is automatically distributed and accessible.
3. Automated functions and predefined processes speed-up the change processes.
4. **Well-controlled and timed changes to items already in distribution and production (components/documents) become possible in a wide extent. In other words, a certain change can come into force at a certain planned time or it can be triggered by some event. When a component from a particular vendor, currently in production use, runs out from the component stock, the change will come into force and the old component will be replaced with a new interchangeable component.**
5. Relations between the various pieces of product information are retained in change situations**. Conflicts with existing product information are checked.** For example, one can easily check the impact of any design change to sub-assembly in all products containing the sub-assembly in question.

PLM system also eases communication and management of tasks or messages related to product development to form a foundation for Concurrent Engineering. Automated messages about relevant information are sent to pre-define responsible people so that they are all the time informed about actions, which may affect to their own work or require action from them. (Sääksvuori & Immonen, 2008)

Another advantage that PLM systems offer is a light and quick three-dimensional <u>visual view or picture for parts and items</u> which can also be viewed from ERP with integration. As a comparison to current situation in SMC, the ERP system provides only the ID code and obscure name of the item logistics or assembly operations. Visual recognition of items eases and accelerates operations and also prevents from mistakes.

4.5 Summary of PLM in Supply Chain Management

According to Sääksvuori and Immonen (2008) the main single benefit from properly integrated PLM system is the improved communication about product related information between all the members in product related network. There would be one trusted place to record, share and maintenance the product related information. If someone disagrees or questions the information, it needs to be discussed with responsible people and changed if needed. Time spent for informal activities in information sharing could be considerably decreased, and consensus and the trust in accuracy of information would increase.

Production and manufacturing have traditionally least utilized the business features of the company’s product lifecycle management. PLM systems are blamed being very limited usable in production. The interface and flow of information between product development and production is often problematic and slow. With carefully defined and implemented processes PLM system can form a lasting connection between these two functions. Purposely and case sensitively divided BOMs have potential to simplify and visualize the assembly work. Change management tools can make the communication about changes quick, formal, controlled, easy and traceable. Production can also request changes to product to make production easier. Request is topical also when there are changes in production systems or devices. Integrated production or CIM (Computer Integrated Manufacturing) enables the integration of manufacturing systems to engineering tools. (Sääksvuori & Immonen, 2008)

Daily operations of subcontractors can be supported with tools of PLM system as the relevant information can be securely and purposely shared according to user privileges and classification of the documents and files. Purposely and case sensitively divided BOMs have potential to simplify and secure the material coordinating and assembly work related to each subassembly. Information about changes can be quickly shared in a controlled manner with change management application. Transparency and traceability between main company and subcontractors increases as informal information sharing activities by e-mail can be reduced.

If the changes in product structures are not managed centrally, and sourcing and procurement are not involved with the change there is a risk that company makes overly fast and uncontrolled changes in the design of the product. These uncontrolled changes lead to the wrong component procurements and accumulating redundant items in storages. Change management approaches and tools

Added to earlier discussed easier access to reliable integrated product and material information, the after sales function benefits from individual product life cycle information, as all the design version information, product structure and BOM of individual product are traceable. The need for study related to individual can be reduced significantly.

As a conclusion for this short presentation for PLM it is essential to understand, that all the challenges in management of product information and lifecycle are not solved just by implementing the PLM system. Badly implemented system and approaches may add complexity, ineffective workarounds and substantial overhead. When processes and approaches are defined, it is essential to understand the whole and information demands of the supply chain. As product related communication and interaction cross-functionally improves, the understanding of the whole will increase simultaneously.

5 FROM STORING TO MANAGEMENT OF MATERIAL FLOWS

The problems and demands were analysed from logistical point of view in chapter 2. As explained earlier, the research was expanded to the whole supply chain as logistical problems and demands were often just causes from earlier stages in chain. There is a lack of tools and approaches to support overall view to supply chain and therefore problems are solved inside the function. As analysed in practise and studied from latest supply chain management literature, the lack of overall understanding and common goals causes partial optimizing, inefficiency and risks in supply chain. This chapter introduces the logistical solutions taken in practise but also the approaches and paradigms in practise at SMC environment.

5.1 Strategy for logistical solutions

Logistical solutions must be designed and built to secure short and long term supply and competitiveness by understanding the challenges of discontinuity in changing business environment. The physical solutions, processes and material information management systems must be flexible to adapt for chancing requirements of the supply chain. This means that physical solutions and processes do not need to be significantly changed if the higher level business strategy changes but the system will adapt to new strategy. Meanwhile, the flow of information in logistical chains and cross-functionally, must be eased and secured by information management. Transparent real-time information systems and material management equipment are essential for functional logistics when lead times, production disturbances and stock value are tried to be reduced. Transparent and accurate information management has significant meaning to ease information sharing and collaboration cross functionally and in the supplier network.

Tendency for flexibility should not be understood here as a tendency to increase informality. Actually the opposite is true. Formal approaches are often easier to control and manage and therefore more flexible to manage than informal approaches. Informal approaches are often deep in the organization culture and, in their indefinability, difficult to manage. For example, if all the storage places are marked and managed formally with own data field and marking syntax to ERP system, rather than using informal workaround with notes in text field, the information is more reliable, readable and more centrally manageable.

Even if solutions and approaches are implemented locally to serve local needs, it is necessary to understand Tampere site's role as part of global Sandvik Mining and Construction Company and Sandvik Group. With flexible and efficient production solutions and well managed supply chain, Tampere site can feel more secure of its own continuity and competitiveness if the parent company makes location decisions. Grand location dependent and function dependent inventories can be risky in discontinuing and changing business environment, especially when they are difficult to adapt or move. In short term, it would be easy to build more indoor storage to cover all the material from weather conditions to ease and safe the handling of material. To invest in buildings and additional storages, company must have reasoned long term demand for them.

5.2 Material flow coordinating in SAT network

The handling of items at SMC has been based to traditional storing perspective. Items have been purchased, delivered to SMC, received and stored, usually without proper spatial information. When the actual demand has occurred, the item has been collected and delivered to demand place. Manual searching of the item has too often been preceded this process. Sending to satellite requires new packing list or covering, and loading to truck. Inadequate information management has made these processes difficult and informal practises have been performed.

With new storages founded in ERP for every main SAT it has been enabled the traceability and manageability for more linear and secured material flows. Storage decision and material flow coordinating decision are connected. Lean and agile supply chain approaches meet in the de-coupling point on the storing decisions, which must be understood to make right decisions. Direct deliveries and cross-docking deliveries are approaches to direct items that are used in particular SAT. The storage place is then also only in particular SAT to reduce extra inventories, logistic lead time, complexity and logistics costs.

Items that are used in several places would be too complex and expensive to order and direct directly to their place of use and multi-storing would also raise inventories. Here we can see one embodiment of lean/agile de-coupling point in practise. The use of items in total is easier to predict than their use in certain assembly place. Therefore the central storage in SMC is exploited as a terminal. Items can be ordered in bigger and more economical batches to terminal and distributed in to different SAT's according to demand. As a premise for supply approach, when items are used in several places, is that items are stored in SMC terminal only. Items are then collected for certain works and supplied as a collection for individual work, as the general approach already is.

However in several cases more economical approach in a sense of time, money and complexity, is to send delivery lot/pallet as a whole or smaller batch. This approach has been informally used but traceability of the deliveries has been lost as there have not been storages in SAT's. When multi-storing decision is made, the item must be estimated in a sense of expense, availability and velocity to secure supply and avoid high inventories from multi-storing. Table 6 gives a guideline for storing decisions.

Table 6: Reasons and arguments for storage decisions.

Storage in	Supply approach	Reasons and arguments
SAT only	Direct or Cross Docking	1. The item is used only in particular SAT. 2. The item is work directed (T-item) and can be directed directly to place of use.
SMC and SAT (multi-storage)	Storage transfers as batches	Item is used in several places but - velocity in target place of use is high, - delivery lots/pallets are easier to handle as a whole or smaller batch, - items are relatively inexpensive and - availability is good
SMC only	Collecting from SMC	As a premise when items are used in several places.

There are four ways to deliver items to SATs:

1. Direct deliveries
2. Cross-docking deliveries
3. Storage transfers
4. Collecting for work

It must be understood that as a basic concept, direct deliveries and cross-docking deliveries function similarly. In both cases, items are ordered directly to SAT storage where they are used, as it is shown in table above. The only difference is that in cross-docking approach deliveries from different suppliers are combined at SMC to reduce transport costs. Items are not stored in SMC, but only unloaded from incoming truck to SAT-transfer box (area) to be loaded to another truck that delivers items to target SAT. This approach must be quick and flexible. SAT-transfer boxes should not have material standing for days. The actual logistic processes and tools for information management in material coordinating are introduced later in this chapter.

5.3 Physical areas and their functions

Storage areas needed re-thinking as demands and problems were studied earlier. Storage space needed to be taken in effective use and OSMI items transferred away or scrapped. The use of different storage areas was defined to simplify and rationalize areas, processes and visual material finding. Storing equipment and shelves were also designed to better serve prioritized demands. Flexibility was concerned in every decision and solution and therefore standard and adaptable equipment were used. Many different storing solutions were estimated but pallet shelves were natural choice because of their adaptability and flexibility to different demands. Existing shelf and other equipment were used as much as possible to support recycling and reduce costs. A new storage tent was also considered, but it was estimated that current storage space would be enough with new arrangement when material flows are directed more effectively and inventory levels have been reduced.

5.3.1 The use of storage according to production lifecycle

There are five stages in product lines production lifecycle (not to be confused with product lifecycle) from production point of view to be taken considered in production, storage and other logistics, and other functions in supply chain.

Table 7: Logistical demands and effects in different stages of production lifecycle.

Production lifecycle stage	Logistical demands and effects
1. Proto production	Individual items, which information is not necessarily correct, marking is deficient and demand unpredictable.
2. Ramp-up production	Big lots and individual items, demand and especially time of use are difficult to predict, velocity distractions.
3. Volume production	Big lots, scheduled demand for production, high velocity, **great demand for trouble-freeness**.
4. Ramp-down production	Necessary and redundant items, material reservation errors, items difficult to repurchase.
5. Discontinued production	Redundant items remaining, use only as spare parts.

The biggest and most important to keep trouble-free is the volume production, not to say that others would not be important. Volume assembly production, especially line assembly production, bases on trouble-free operation where high effectiveness is achieved by smooth continuous operations and if not Just-in-time, then at least In-time material supply. Distractions in one point can stop or at least slow down the whole production line. Storage velocity with volume production items should be high, and storages must be easy to manage, operationally by logistical personnel and informatively by purchasers and production controllers.

5.3.2 MP3 indoor storage

MP3 indoor storage is the main collecting storage. Area and shelves were recently formed so there was no need for rearrangement of these shelves. There was still space for extra shelves which were primarily used to serve subassembly function and logistical processes. This way all the current storage shelves were simplified to be in pure storage use. Storage places were named and marked more accurately than on outdoor areas to ease the finding as shelves are high, items are smaller and there can be several items on one pallet. Shelves are to be operated with high level order picker which is to be regarded in item placement and storage place marking.

5.3.3 MP3 outdoor storage areas

Outdoor areas of MP3 building (figure 29 below) were main areas of interest as SF's logistical operations were managed from MP3 building and areas were not used effectively. Areas have been separated for different uses in new layout.

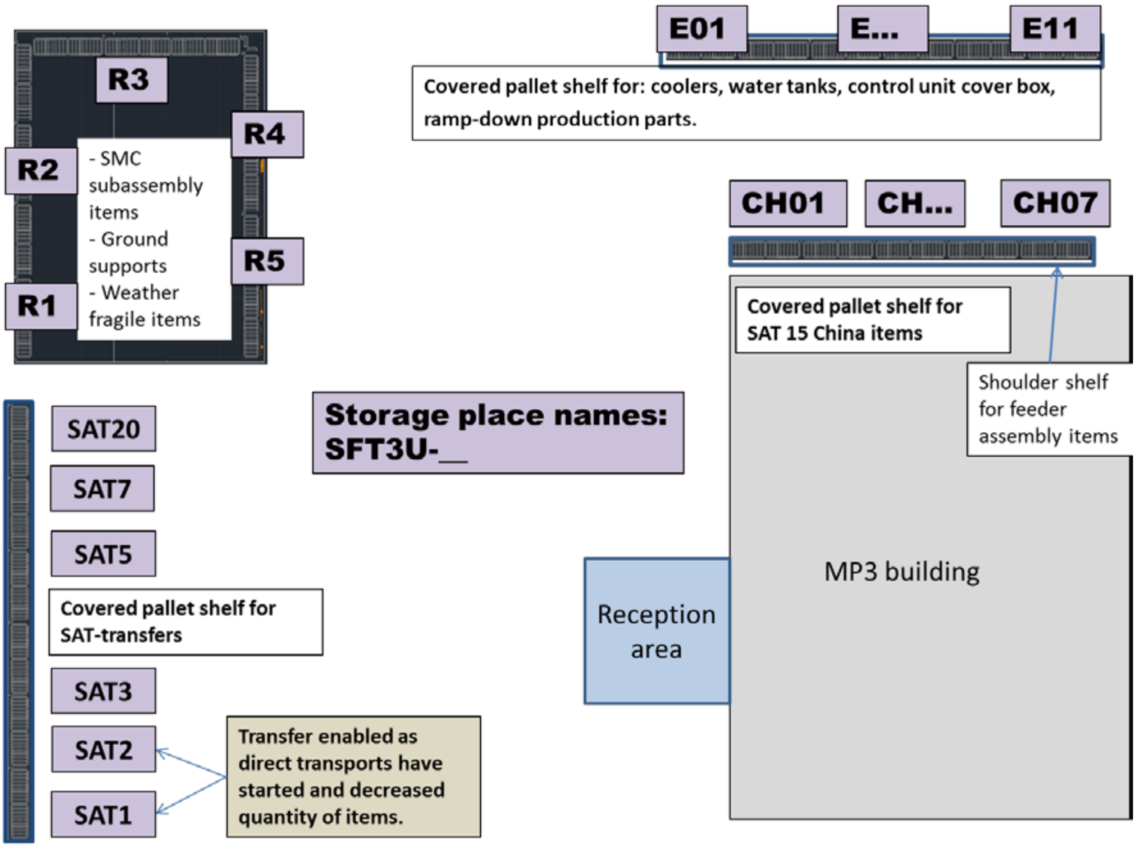


Figure 29: The use of outdoor areas of MP3 building.

SAT transfer (cross docking) boxes and shelves needed to be easy to reach from truck load/unload area. Tent was primarily used for high circulating weather fragile items used in SMC subassembly. The extra shelf was added on the back wall of the tent as the space was unused. All the outdoor pallet shelves are covered with roofing to protect items from direct rain and snow. SAT transfers are meant to be delivered daily, so items will not stay in shelves for long periods. E01-E11 shelf is meant for slower moving items. Ramp-down production items need to be well covered with the protective film and marked clearly. This way they are maintained, easily available and will not disturb volume production. As the items on outdoor areas are generally larger and multiform the storage spaces were formed on less accurate level than in indoor storage. Storage places are still accurate enough to be viewed from one position. Operating with big outdoor forklifts can be eased by putting the barcodes of storage places as a list into cabin of forklifts.

5.3.4 MP1 tent

MP1 tent (figure 30 below) was natural choice for storing items and modules for volume production final assembly; tent was next to final assembly and reception so transfer of big modules would be easiest to do.

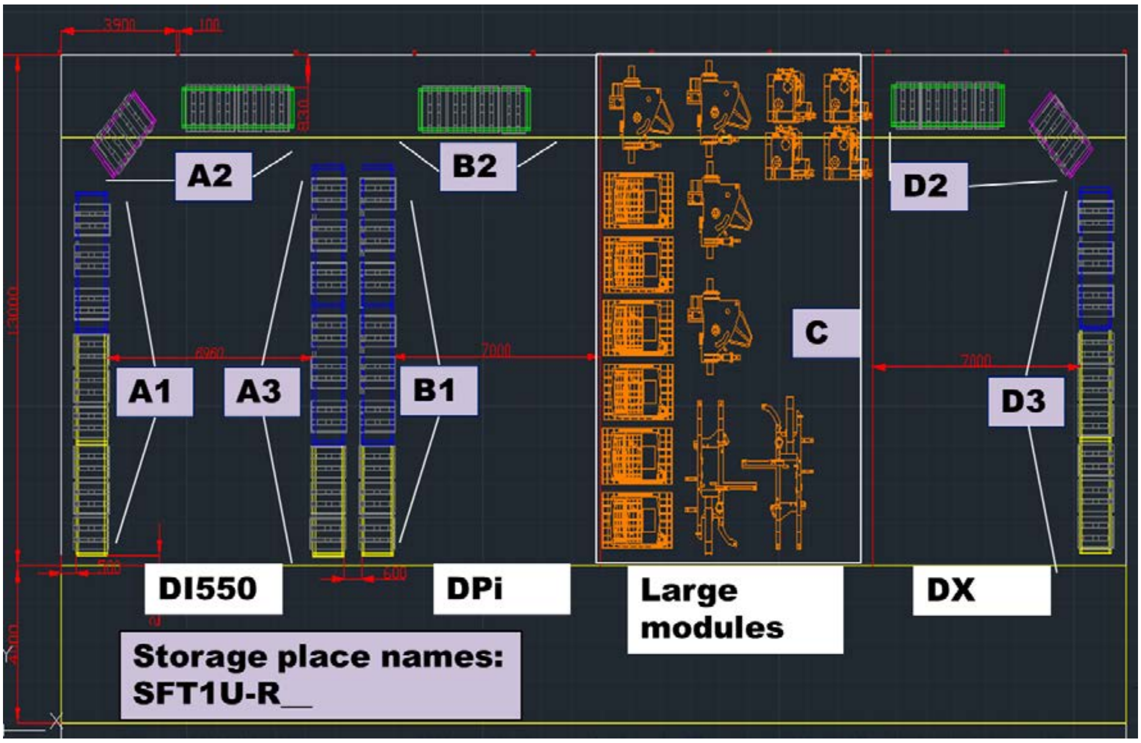


Figure 30: New layout and naming syntax of MP1 storage tent.

The shelves were re-arranged to get space for modules and to enable the use of big outdoor forklifts. The space was divided in four areas; DI550 items, DPi items, DX items and floor space for largest modules of all products. Areas were designed for certain products but they are flexibly adaptable for future products and their demands. Approach for naming is similar than with outdoor areas of MP3 building. Naming is enough accurate for quick finding but allows flexible use as items are multiform.

5.3.5 The use of production line storage

There is a high resistance from final assembly assemblers to perform logistical tasks like collecting an item and especially recording the transaction to system. There is variety of reasons for resistance sensed; logistical work and tasks are disparaged as less valued work, and there is fear of change, new tasks and complicated devices. This resistance is also supported from management level.

The resistance might be reduced if assemblers would see the use of the storage and logistics portal first accompanied with logistical person. The logistical person would be using the storage in collaboration with foreman, collecting and delivering the items for works into workstation, recording transactions and controlling the storage level.

There are two options:

1. Assemblers are collecting the item physically and sign out the item from stock balance simultaneously.
2. There is logistics person collecting the item and signing the item out from stock balance and assemblers do not ever take anything from the storage by themselves.

The person who physically collects something from the storage, signs the material out from the stocks! This should be unquestionable rule and exceptions should be well considered and argued. This is a valid rule in each stock.

5.4 Logistic information management

The logistical processes and warehouses at SMC were difficult to manage and the main reason was the lack of currant concentrated information about the items and their appearance. Therefore it was clear from the early stage that no matter what strategies, processes or storing equipment are going to be chosen, the logistic information management was going to be one of the key development subjects.

5.4.1 Demand for transparency and traceability

Stance for the maintenance of information in ERP at SMC is rather to ‘make it look good’ than ‘make it show exactly and reliably how things are’. Information is not reliably readable for all the parties when one must be aware of things related to information. From logistics point of view, the signing in and out of items from storages is one of the principal information transactions in ERP. Wrong actions cause inaccuracy in stock levels and weaken the confidence to information accuracy. Operational work is performed by sharing operational data (not knowledge) via e-mails, phone and negotiations. This kind of action is same time cause and effect to itself. When operational actions are not systematically performed in ERP, the information attached to these actions is not transferred within. Accuracy and thus reliability to the information in ERP is lost.

More formal and transparent information channel (than e-mail, phone or informal negotiations) for operational information is demanded so that all the parties in supply chain have the same operational information easily and reliably available. ERP can work as reliable, centralized and effective information channel, when operated formally and systematically. One of the principles in ERPs is that the same information is viewable for all parties. This is critical, to enable integrated supply chain where information uncertainty is minimized. ERP system is an important and increasingly coherent operative tool and information channel that integrates organizations and its supplier networks functions.

5.4.2 Development of Information management in warehouse logistics

Demand for new storages in ERP-system actualized when it was realized that Lean ERP –system allows balance-profile -managed transfers only between storages and not between storage places. New storage was decided to be founded for new production line from several reasons. First, it was definitely clearer to separate material in production line from other storages. Secondly, there was demand for profile managed balances at the production line because the space was limited but availability needed to be secured. Thirdly, it was possible to secure the balances at the production line and follow them more precisely when they were in their own storage.

Table 8: Check list of the essential aspects in warehouse logistics.

Check list of the essential aspects in warehouse logistics
- SF and UG storages must be clearly separated as the purchase, use and control (management, generally speaking) of the items are separated.
- Storage places must be active controllable fields in ERP-system so that they can be controlled efficiently and reliably with the system.
- The name of the storage place must be informative and tell o the storage it belongs to o the actual location
- All the items must be marked, preferably in advance by supplier, but at the latest when received.
- All the items should have default storage place or default storage area (rationalized use depending on the item and its use) where they are placed when received.
- All the items must be received and recorded to ERP-system as soon as they arrive in to their destination (SMC's plant or subassembly storage).
- All the items must have storage place as soon as they are received and as near as possible till the moment they are used.
- Items must be signed off from storage balance and signed for the specific work or delivery as near as possible to the actual moment of use.

The essential data of the items from logistical view are:

- Item ID
- Item Name
- Where are and how much there are these items?
- Where are these items going to be used?

The essential data of the warehouse from logistical view are:

- Where is this warehouse?
- Whose items are in this warehouse? (SMC's? SF's or UG's?)
- What is the main purpose of this warehouse?
- What items are in this warehouse and how much?

The essential data of the storage place from logistical view are:

- What is the name of this storage place?
- In which warehouse is this storage place?
- Where exactly is this storage place?
- What items are in this storage place and how much?

It is not even possible to say if right items are in the right place in the right time, if there is no reliable information about their appearance. Measuring these things can already be forgotten at this stage, as there is no essential accurate data to measure.

5.4.3 Logistics portal for handheld computers

To enable effective and real-time logistics information management simultaneously in ERP and physically, mobile devices were required. Storage places in warehouses needed to be taken into more specific level. Utilization and maintenance of space information alone required being mobile use of logistics personnel.

Technology

The device itself is not as important as the application which is used with it. As a fundamental decision in the beginning of application development there is a decision of whether to use application as an individual client of ERP or as a web based portal. Both approaches have their benefits and flaws. Client can be used without constant wireless Internet connection which would be great benefit, but there are delays in updates and application must be designed device specifically, and it must be installed to every single device. Web-based portal is easier to design and implement. Updates can be made far more flexibly as devices are only dull user interfaces to web portal. As a flaw, web-portal requires constant wireless internet connection to work, but a small break in connection does not cut the action. Because flexibility was one of the main premises in logistics development, web portal was chosen from these alternatives. Unfortunately, it was understood later that wireless printing over the web portal was very challenging.

Choosing the actual device was time-consuming work as the device needed to be flexible and cover several different demands today and in future. Compatibility to SMC's different system requirements was necessity. Several device providers were compared and reasons for selected provider were: Devices were suitable and flexible, approaches of the technology provider were confidence inspiring, support continuity was secured and prices were competitive.

Figure 31: Tough Book and barcode reader for forklifts and handheld computer.

Two types of computers were chosen. Bigger robust laptop was chosen to be installed in forklifts with barcode reader and robust handheld computers were chosen for ubiquitous logistics operations. One dimension barcode is easy to produce and it is already most commonly used by subcontractors. One dimension barcode is also easiest to read with barcode reader or a mobile computer also from further distance. Other evaluated options were two dimension barcode and RFID technology. Two dimension barcodes cannot be read from further dimensions and benefits of RFID technology were evaluated to be too small to compare the price, risk and challenge of implementation.

Barcoding: A barcode is a series of parallel rectangular bars and spaces arranged in a predetermined pattern to encode letters, numbers, and special characters. An optical character recognition device, or scanner, “reads” the information by passing a light beam across the barcode, sensing the width of the bars and transmitting the information into the computer, where it is decoded. Barcode information can include a wide array of data related to items. Barcoding replaces data key entry with automatic data capture at the point of transaction and direct transmission to a computer or storage device. In supply, bar coding is particularly useful in receiving inbound materials and order generation. The benefits in receiving operation are quick and accurate data entry, and faster checking and clearing of shipments. Radio Frequency Identification (RFID) technology is the next step on the market but today it still cannot be signified as a trend. (Leenders et al, 2006. p.96)

Functions

All the logistical processes that required mobile transaction connection to ERP were transformed to functions into logistics portal. Mobile logistics portal enables easy and transparent ERP transactions simultaneously with physical actions.

Table 9: Logistics portal functions.

Process	**Description**
Reception	Reception as an ERP transaction has to occur simultaneously with physical reception. Items also get storage place in reception.
Collecting for work	Collecting for work is performed directly with portal. The logistics person can simultaneously view the ERP stock balance and actual quantity of items which increases information reliability.
Collecting at line	This function is meant for assemblers use in assembly line storage or other assembly station. Items can be collected individually but they are still signed for certain works and collecting is not allowed if there is not reservation for particular item.
Storage transfer	This function enables traceable transactions between storages. Items are signed out from one storage and received into another as the items physically arrive.
Storage place transfer and placement	This function enables flexible arrangement of storages. Storage place information chances are made easy so that they would stay updated.
Storage place filling request	This function is meant for assemblers use in assembly line storage or other assembly station. Certain items are difficult to coordinate in to their place of use automatically so assemblers can request for certain amount of items as the demand occurs.
Collection-item creation (China supply)	Collection-item is used especially in supply to China assembly centre. Delivery of one container has to be created from several different sales orders basing on actually delivered items. Earlier this has required manual work of combining hand written lists and errors occurred.
Sticker printing	Sticker printing is enabled as a separate action from other transactions to ease material labelling.
Balance query	Balance query is enabled as a separate action to ease material searching.
Inventory	Inventory is performed storage place specifically.

All the functions to the portal were developed together with the actual logistic process. Functional flowcharts for software development (in Finnish) are attached as appendix in this document. This way the possibilities and limits of the portal and ERP were considered simultaneously with logistic processes. The actual solution was mainly based in to existing portal used in Turku site but in respect to approaches created in these flowcharts. These flowcharts are also useful for implementation and future development.

5.4.4 Naming rule and marking

Naming rule for the storages and storage places has been taken deep considering. Even if it can seem like a fairly insignificant matter, the naming can either ease or distract operations. There are two guidelines put weight on; transparency and flexibility.

Transparency in this context means that already the name of the storage or storage place gives the most essential information about the storage or storage place. Understanding the syntax should not base too much on memorizing, but the name must be logical and readable too, so it should not be too long either. It must remembered also, that Sandvik Mining and Constructions other sites in Finland are using the same ERP system, so storages should be separable from other sites. No common syntax is yet agreed in extended company in Finland.

Flexibility in this context means that the name of the storage or storage place should not unnecessarily limit the use of storage or storage place. The name should not require changing either if the use of the storage or storage place changes. Naming according to certain product, product line or item type would be strictly harmful and demand change at the moment of change in production or in supply chain. Incremental changes must be flexibly doable. Therefore it was decided to include the most essential and least changing information in to naming syntax as presented below in table 10.

Table 10: The naming syntax for storages and storage places.

Storage	**Description**
TRESF-T	Tampere SF –organizations Terminal
TRESF-SAT7	Tampere SF –organizations storage in Satellite assembly 7
Storage place	**Description**
SFT3S-H0103	Belongs to TRESF-T storage (SFT), exists inside of the MP3 building (3S), H-shelf, gap 1, height 3.
SFT1U-RD3	Belongs to TRESF-T storage (SFT), exists outside of the MP1 building (1U), inside of the pavilion hall (R), area D, shelf area 3.

Storage places needed to be marked and labelled with barcode to be able to identify them visually and with the information systems. Different technologies to read storage places were evaluated and combination of one dimension barcode and text field was chosen.

Figure 32: Labelling of the storage places. Illustrative name marked visually and as a bar-code.

Text field is visual and independent from technology so technical problems will not interfere the operation. This kind of label is also easy to make and modify so the flexibility is achieved in these means as well.

5.5 Logistic processes

New approaches, applications and devices are not developed alone to serve old logistical processes. Propriety of the logistical processes must be re-estimated and re-designed when demands and also possibilities have changed.

Reception

When items are meant to be directed effectively and transparently, the old process of **reception** was too slow and it did not support cross-docking. There was also need to enable concurrent mobile placement of items so that items would not be left just somewhere without storage place.

New process of reception is introduced below in figure 33.

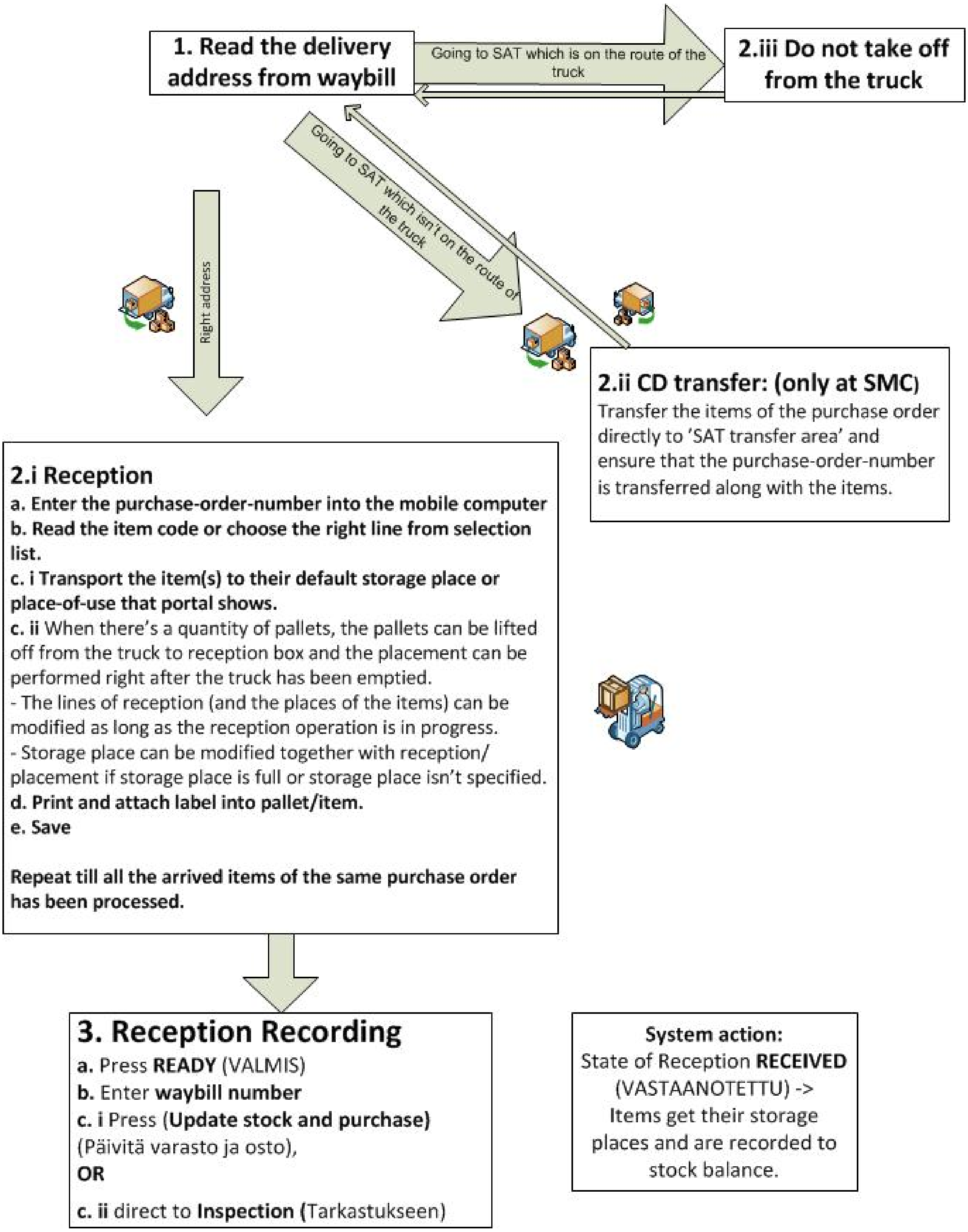


Figure 33: New reception-, cross docking- and placement process.

Collecting for work

Benefits, that mobile computer and storage portal can bring, need re-designing of **collecting** process too. The list of collectable items do not need to be printed in office as the collector can follow the duty in real-time, see the exact storage places and balances, and sign out the items when physical collecting occurs. As a system action items collected to be used in satellite company are now transferred to work-in-progress storage in particular SAT. Traceability and transparency are maintained even after the collecting of items. (Figure 34)

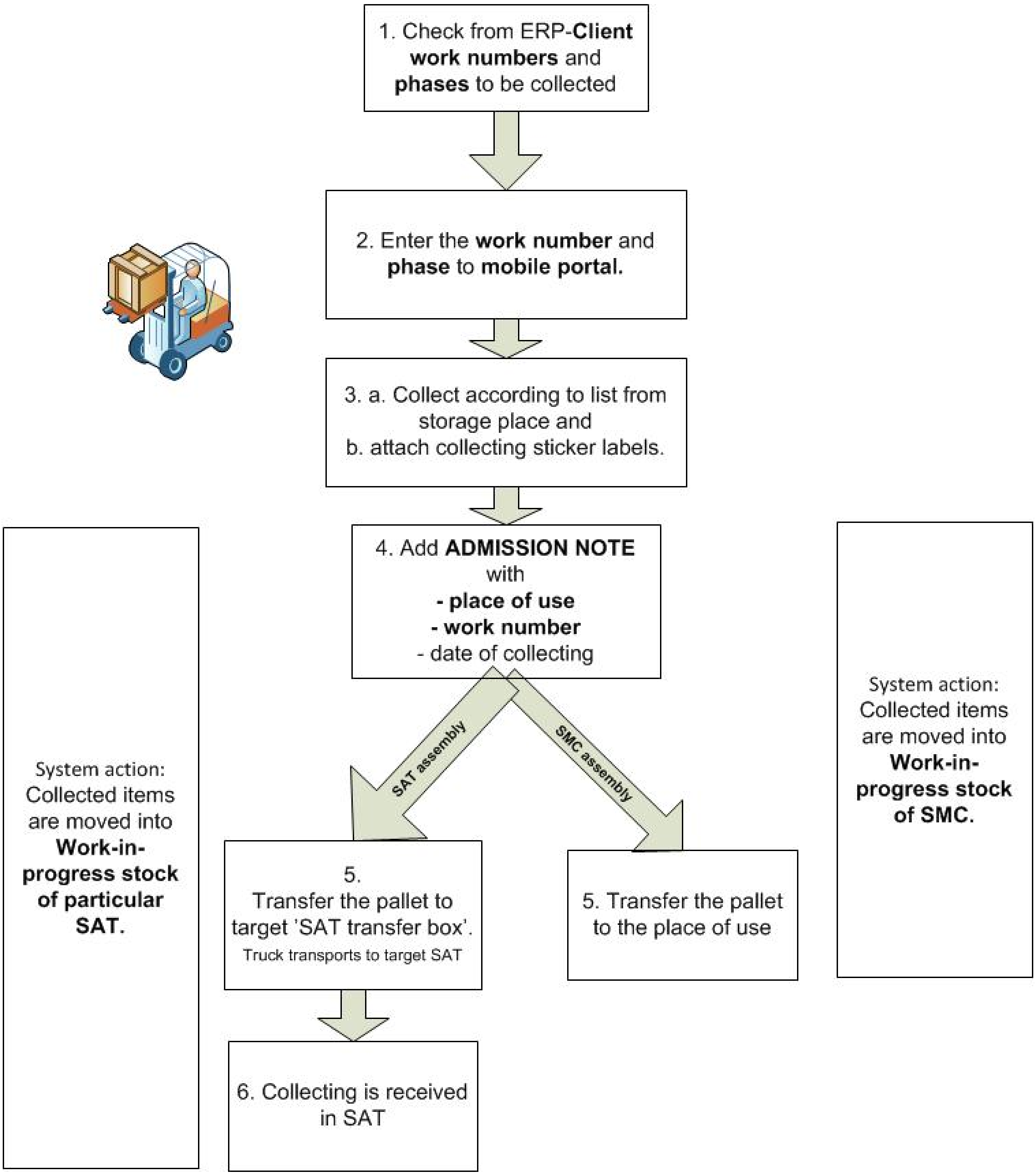


Figure 34: New Collecting for work –process.

Stock transfer process is one of the new processes that are essential to support new flexible and transparent material flow management between storages and satellites. The actual stock transfer function existed in ERP system but it was not in use as there were not many stocks earlier. Transfer function was not usable neither with portal nor with web extranet that satellites have in use.

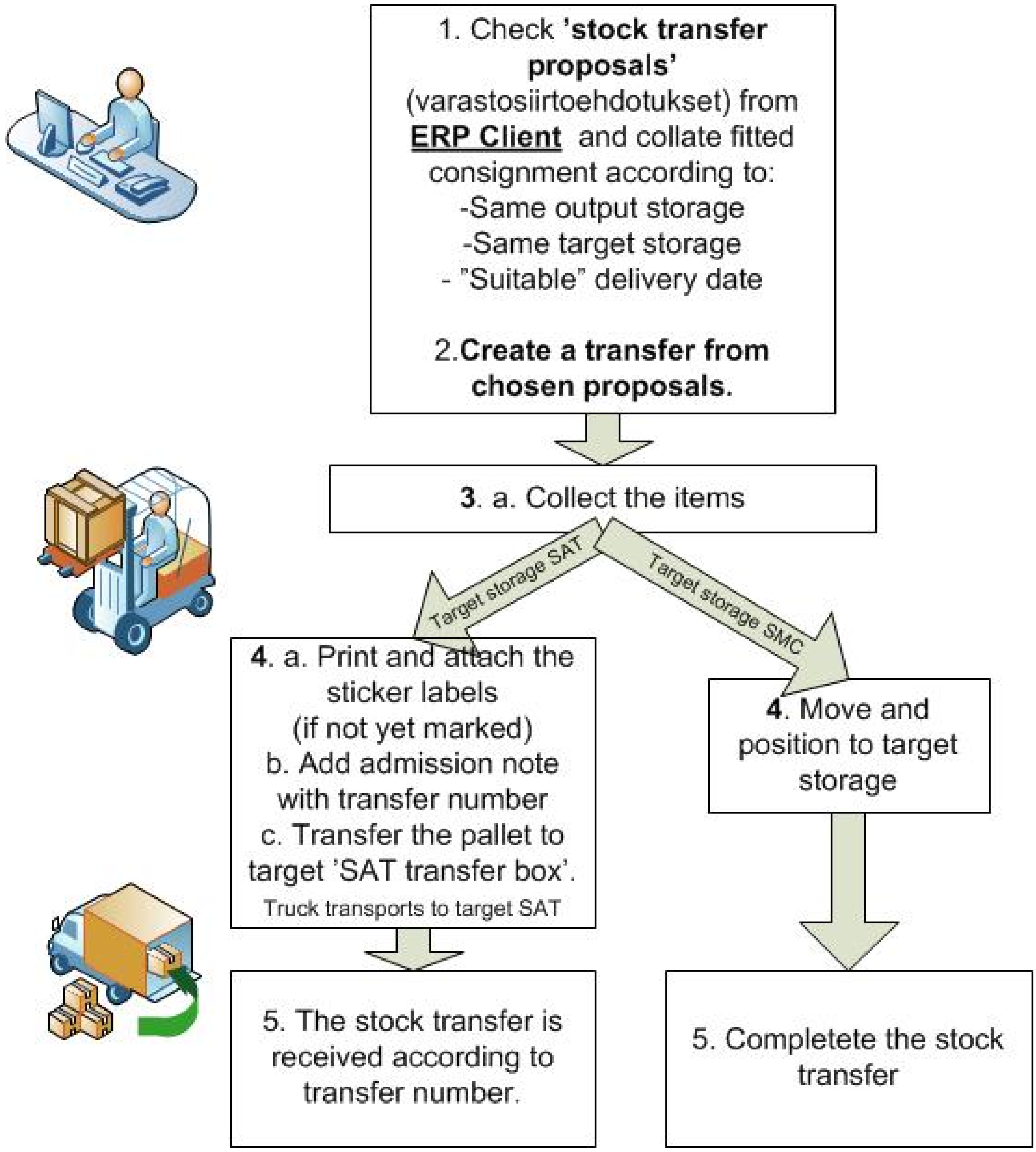


Figure 35: New Stock transfer –process.

5.6 Ramp-down production and discontinued production

From ramp-down of old DTH product lines (DIxxx) it has been learned that unconsidered and unmanaged ramp-down may lead problems and costs that affect not only to particular ramp-down production but to all supply at the site. The decision of production rundown has to be done with old products periodically. It is understandable that company does not want to put too much effort to products that are soon to die as new products are more important and productive. Still, the rundown should be managed well and not just left to die. The production of the last individuals can be very complicated and harm the volume production. As it was decided to minimize the support for these ramp-down products, it was not considered that there are numbers of structure errors and BOM errors which cause errors in to material reservations. Storages were full of unidentified redundant material making all the logistic operations difficult. As there were errors in material reservations and repurchase was difficult and expensive, the clearance was challenging and risky to perform. Logistics function has been claimed not to serve production effectively and reliably. The current-production-supporting product development function was pushed into an awkward situation as production needed their support but they were not allowed to spend time to answer that call. Supportive actions were performed informally whenever time permitted. This claim-chain proves how things are connected and why there is a need for cross functional supply chain management to get into common goal.

To solve the problem with old DTH-items, it was decided to move all of this material out from their warehouse and divide them in two sections; surely useless items and obscure items. The clearance and division of the material was made by taking the storage balance profile in ERP-system and cropping it by the time last used to 9 months and checking that there is no reservations or upcoming use. All the material was also offered for spare part retailer. By taking all this material off from their regular warehouse it was easier to clarify the quantity and need of space of the items. Big benefit was also that people involved with DTH-production got finally interested of checking the need and validity of the material, even if the reaction always was not the most positive one. The main warehouses and primary storages were decided to take in effective use for volume production for the main products, the new D550 DTH-rig and DP-, DPi- and DX-series.
The plan for all the items (excluding big subassemblies) of old generation DTH-rigs was to store them in existing secondary storage areas which are not as well accessible for production and protected from the weather as the primary storages. Material for these machines would be in a same place, marked and in order with specified storage places that are also updated to ERP system. All the material is also covered with either light roofing or plastic film on the pallet. Assembly of the old generation DTH rigs takes place at place assembly, not at the production line, and most of the production delays are caused by item searching. By taking the primary storages to effective use for volume production line it is possible to minimize volume productions material collecting and transfer times. It is also primarily important that the material for volume production line

would be in weather proofed storages so there will not be problems with melting snow or ice cold items.

Ramp-down situations repeat regularly as new models are introduced and old models production is discontinued. Ramp-down must be planned and managed carefully. When decisions about support reduces are done, there must be certainty and understanding about the current conditions of the product structure, BOM, production capabilities, correctness of material reservations and quantity of remaining items. As a preventive action logistics should separate the materials of ramp-down production from storages of volume production to avoid disturbance and confusion. To ease this separation there were new storage area and shelves built at the area of MP3 building. This area has own storage places in ERP as well. Storage places in ERP were founded under the same terminal storage that serves volume production so that there would not be extra transactions between storages which would add work and complexity. As the naming syntax and physical separation are clear, the storage is now more manageable and less risky for volume production.

5.7 Avoiding high inventories

Just-in-time (JIT) scheduling is an operating philosophy that is an alternative to the use of inventories for meeting the goal of having the right goods at the right place at the right time. At SMC most of the items are still bought to be waiting for use but certain larger items and modules are work-directed, more following the philosophy of JIT. The history in SMC tells that JIT in certain level has been implemented and used earlier, but practise showed that suppliers could not deliver items reliably enough and production breaks occurred. As a backslash, inventory levels have been re-raised and orders advanced to secure production continuity.

Tendency to gain cost savings is the main reason for big delivery lots. Cost savings are achieved from reduced transportation costs but more remarkably because the suppliers give quantity discount. Often it is heard that big delivery lots reduce logistic costs but that’s because transportation costs are easiest to see and other logistical costs, storage costs and inventory costs are not that transparent. Savings in transportation costs are understandable goal when the demand for the item is known and level, items are inexpensive and they do not cause other high costs. The situation is different when items are expensive, demand is fluctuating or probably discontinuing, and/or items cause other costs, for example great demand for roofed storage place. Transportation costs can be reduced with combined transportation and cross-docking. Obsolete and slow moving item (OSMI) list points out some of the costs of redundant items that remain unused and the number is bigger than the annual transportation costs.

Effect of a delivery lot size to supplier’s ability to supply was illustrated in a case where SMC operates as a supplier; the after sales spare-part supply.

Spare-part coordinator at SMC processes orders from Sandvik after sales company and fulfills the supply from start to finish. When order for certain item arrives, the co-ordinator checks the availability or estimates the time it takes to produce and deliver the part if it has to be purchased or assembled in SMC. There is not separate stock for spare-part supply at SMC but the same production stock is used.

There have been several situations where the supply of certain items is difficult as the availability is bad or the lead-time is long. After sales company wants to secure their own supply for demand and they want to do it by increasing their own inventory level. To increase the inventory, the after sales company increases the delivery lot they order, even if the actual need at the moment is smaller. As a result from that, SMC is practically unable to supply the delivery in time even if they would be able to supply the amount for actual demand. Flexible post-delivery option is not supported and as a manual workaround the work is increased and transparency is lost. This increases uncertainty and decreases confidence between supplier and customer.

In this case, the spare-part coordinator negotiated with after sales company and they agreed to keep delivery lots small and thus reduced lead time and inventories.

Transparency of demand information

The problem observed in JIT approach was supplier's inability to adapt quick enough to changes in volume variation. Risk for problems and disturbances in JIT approach is real-time demand information and therefore lack of confidence between supplier and customer. Transparency of demand information in supply chain can be arranged with information systems by delivering the supplier the accurate and real-time demand information. Sometimes this can be challenging to apply reliably and effectively. From supplier's point of view, the orders are the most reliable demand information. With smaller delivery lots this information is offered more constantly and risk included to own inventories is smaller.

When overall logistic costs are not the most relevant saving source the biggest reason is quantity discounts. This issue is most relevant with highest risk items (expensive, big, or obligatory items). When items are expensive, relative transportation cost has less and less Here is an opportunity for sourcing, purchasing and logistics together with suppliers to think this approach new way as the win-win-situation can be achieved with common goals.

SMC does not sell more certain products if they happen to have more certain basic items in stock. There should be relatively same amount of other items for same product to be able to produce more of them. So the consumption of items does not depend from how much at once SMC purchases them. SMC tries to build long term partnership with suppliers and avoids changing the supplier so all the extra sold once is off from suppliers later sales. Except on the situations when SMC fails to use all purchased items and rest of them remain redundant. The situation may be that the supplier is prepared to sell more too but as the order from SMC does not arrive, items remain unsold. This can be called lose-lose-situation.

Table 11: Effects of delivery lot sizes to transparency information.

The supplier type	**Big delivery lots, longer order gap variation**	**Small delivery lots, shorter order gap variation**
Both supplier types	Have to be prepared for big order from the supplier which you have not heard about for a while. To be able to supply the order in time, one must carry the inventory of the big delivery lot for the time gap of estimated first possible order date to the actual order date.	It's easier to be prepared as the order will be smaller. You've been in contact and had orders more often and more recently. To carry the inventory of smaller delivery lot is not that expensive or risky.
Manufacturer	Have to be prepared to manufacture big batch occasionally. Managing capacity and know-how related to certain item is more difficult.	Capacity requirements and scheduling is easier if batch is smaller and produced more regularly.
Distributor	Have to make big order for your own supplier in time to be able to serve your own customer.	Smaller orders can be made more accurately and quick basing on recent orders.

Sometimes the chain backwards can be longer and more complicated. Manufacturing supplier, which manufactures items specifically for SMC and which manufacturing set-up time for new batch is relatively long, can be one example. In this kind of situation the supplier may still be willing to sell big quantities rather than smaller delivery lots. Anyway, these same inventory-related regularities are valid for these suppliers as well. It is important to negotiate with supplier to get them agree about the new approach and its goals.

6 FURTHER INVESTIGATION – LEAN / AGILE SUPPLY CHAIN IN SMC

All the interesting and important research topics could not be taken in the end or under investigation within this thesis. Still, these topics that have arisen during this thesis are not to be forgotten. This chapter deals with issues of supply chain management which are not necessarily logistical but which cause challenges for logistics and whole supply chain. The purpose is to tell the logistics and supply's point of view to issues that affect to the whole supply chain management. By questioning and proposing further investigation subjects it is desired to stimulate discussion and increase common cross-functional understanding that would help managing the supply chain as a whole. The hybrid of lean/agile supply chain has been taken to major point of view as its advantages in practise have been proved in many companies and possibilities are seen in SMC's operations. Here is the list and short description of the topics.

6.1 Hybrid of lean and agile supply chain in SMC

Implementing lean/agile supply chain and finding the decoupling point: What are the practical stages that each function in the supply chain must perform or consider on their own action?

One can argument that SMC already uses lean/agile supply chain approaches and that is partly true. Many items are purchased according to level demand following somewhat lean principals and some option items are kept as inventory to meet agile goals answering to uncertain demand. These approaches are still not performed systematically and they are not supported by all the components of supply chain management. All the topics below are partially enablers for lean / agile supply chain.

6.2 Creating collaborative supply chain

How to create confidence and partnership in supplier relationships? What kind of collaboration or partnership is desired with different kind of suppliers? How to get agreement and involvement on common goals to achieve win-win situation? What is the best way (effective and transparent but secure) to interact with suppliers and speed up the flow of demand information? Could know-how clusters create competence and help managing risks?

6.3 From forecasting to actual demand based production

Forecasting definitely has its place and role in organizations operations and supply chain management and planning. Fixed investment decisions, long-term capacity decisions and securing of business continuity need forecast information to support decision making. In the hybrid of lean/agile supply chain, the lean phase of the supply chain still demands forecasts to predict level of capacity and use of common items. However, if twelve-month-term forecasts are used as a driver of operative actions for end-to-end supply chain, the smallest inaccuracy of the forecast has immediate affects to offer, production and often to whole supply chain. The concentration on improving the forecast still leaves the uncertainty and risks of wrong forecast not to mention the complexity in supply chain. By concentrating on shortening the lead time instead, the results would be more certain and satisfying for the whole chain, especially for the customer.

In SMC's case there are possibilities to reduce lead-times by certain actions in different functions. Some of them are presented in table 12.

Table 12: Actions to reduce logistics lead-time.

Function	Action to reduce logistics lead-time
Product Development	- Support assembly with concurrent engineering - Seek to standardize when possible - Seek to delay variations and options closer to surface level on product structure
Sales and Marketing	- Inform supply transparently about customer demands - Inform product development and sourcing transparently if there are certain requirements occurring for the first time.
Sourcing	- Avoid the complexity of supply chain. - Avoid oversized batches to support demand transparency.
Production/ Purchasing	- Avoid fluctuation in order gaps - Discuss and interact with the supplier to avoid bull whip - Interact with product development constantly about challenges in production.
Logistics	- Make logistic operations and storages as transparent and reliable as possible. - Seek to find linear material flows and processes

Actions can be divided for different functions but as repeatedly highlighted in this thesis, the integration and collaboration in the whole supply chain network secures the common goals and best results.

6.4 Product structure and late customization

SMC's strategy for 2010-2015 underlines the significance of customer service "service is our success!" but is it necessarily the wide range of individual variations and options that serves the customer in best way? Are some of the features offered as options at the moment such that they would exist in the same basic product?

These questions are reasoned and essential as the supply in SMC faces challenges and problems in product variation management. When options and different qualities are offered for the customer, it should be reasoned why there is such a selection of single options, especially when they are deep in product structure. Storing a wide range of varied items raises the lead-time, stock value and other logistical costs. Variations also complicate the operations in purchase, logistics and production management. Subcontractors are highly involved in variation management as there are certain smaller variations in the subassemblies they supply. Most of the parts for these subassemblies are purchased and supplied for the subcontractor by SMC. Figures 35 and 36 below presents simplification of current state of modularity and one example of more idealistic solution from supply chain point of view.

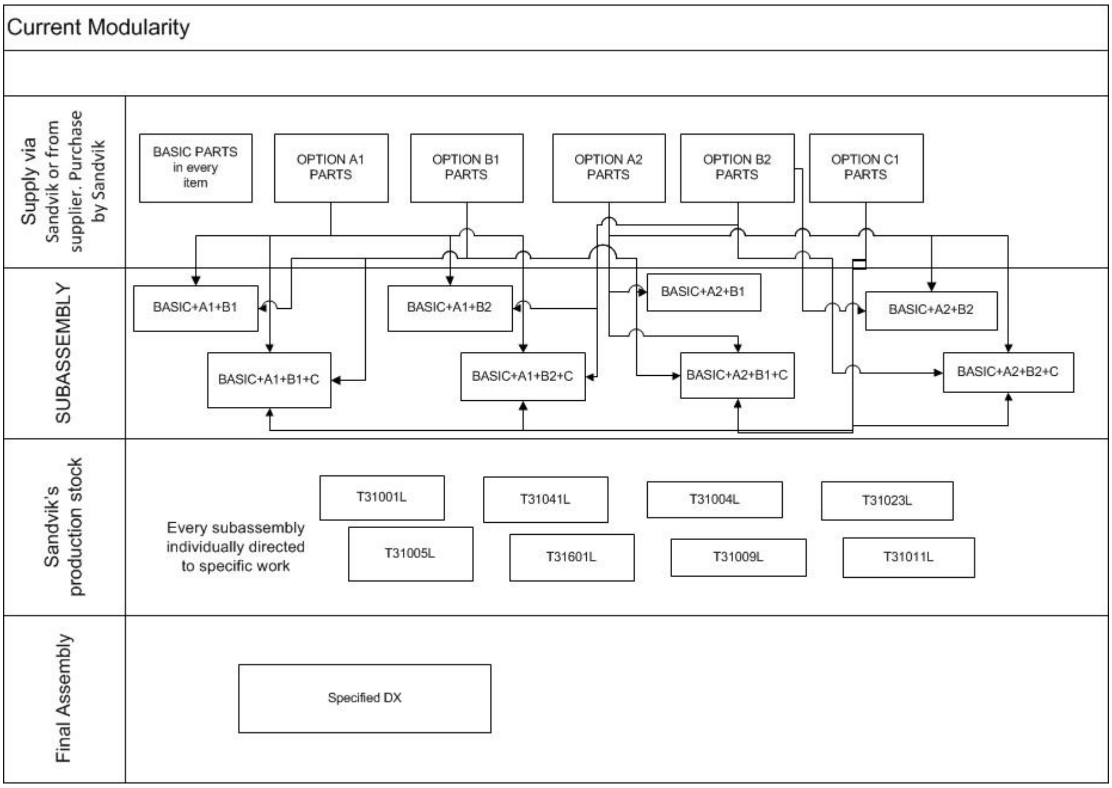


Figure 35: Current general state of modularity related to supply chain.

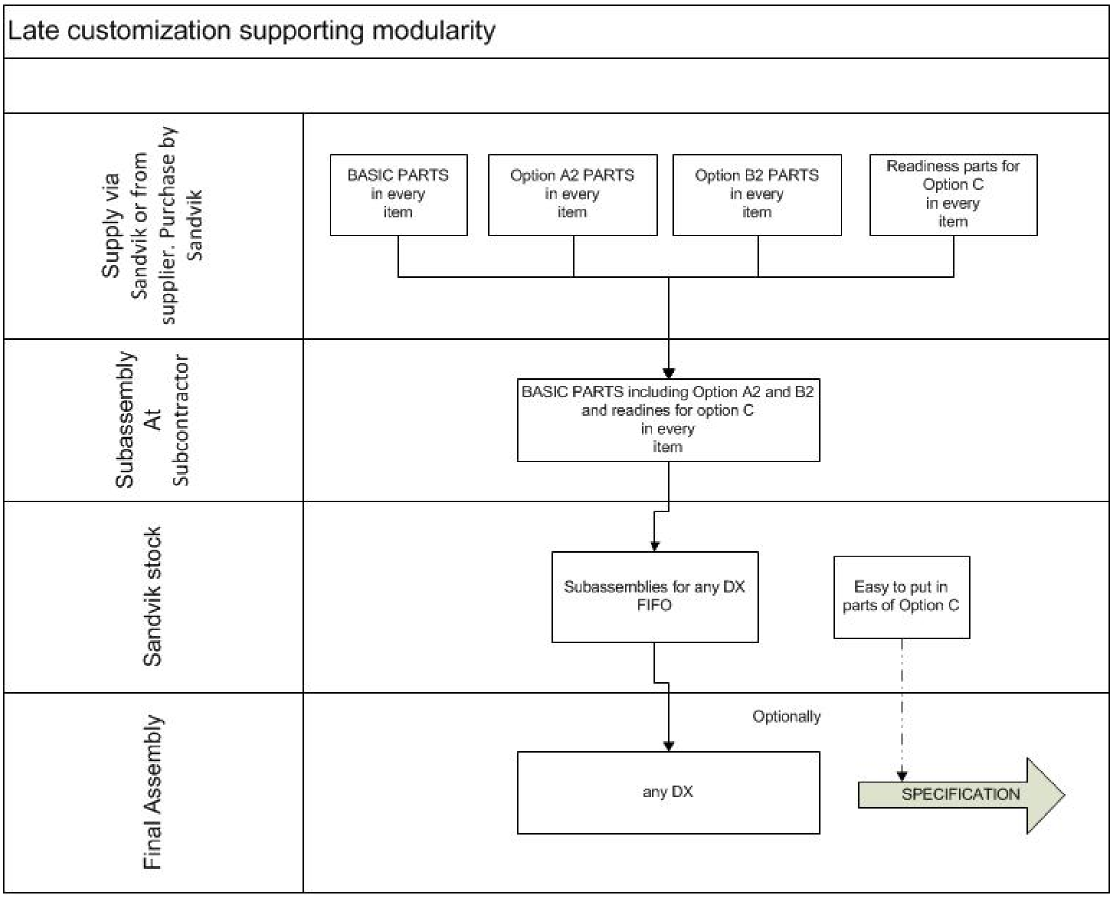


Figure 36: Example of idealistic modularity of the product structure related to supply chain.

Principals of hybrid of lean/agile supply chain can be utilized here. This presented model is a simplification and not necessarily the most ideal model but it presents the possibilities and way of development. The most efficient and reliable modularity management solution for SMC is probably somewhere between these models.

There are two strategic directions to choose that does not necessarily exclude each other but targets of another cannot be achieved with tools and approaches of another alone, with reference to lean and agile supply chain approaches:

- If it is chosen to offer a wide range of options and variations for customer, there must be approaches and tools for flexible and reliable product structure variation and product change management.
- If supply and its operations are tried to be made as cost efficient and "lean" as possible, the product itself should be more standardized.

At the moment operations strategy and supply chain model does not support the offered product range in a best way. Products are desired to vary functionally and regionally but in addition there are numbers of options offered to please customer's special needs. From these premises, the product structure and production should be designed to support late customizing. To maintain wide product range and option offering, the base of product structure and production processes should be more simple and standardized.

When talking about **deviation**, it is good to clarify the difference of concepts "the qualities that final product has" and "the thing that they are deviation from standard". As an idea, the customer wants to have certain qualities but does he mind (is it added value) if the product is capable for something more or if the other products in range are somehow different? Here is an example of a question chain that could be used for estimating when considering the deviation from standard module or standard product structure.

Table 12: Questions for reasoning the deviation.

1. Is this **deviation** adding value for the customer?

- **1.1.** If it is not, is there a compulsory reason (functional compulsion) to make this deviation?
  - **1.1.1.** If there is not, is there good enough reason (sourcing based, production, logistical) to make this deviation compared to added complexity, costs and risks in supply chain?
  - **1.1.2.** If there is, is it possible to take the highest requirements as standards?
- **1.2.** If it is, is it impossible to place this deviation in the more surface level of the product structure to enable late customizing?
  - **1.2.1** If it is not, is there good enough reason (design, sourcing based, production, logistical) to place this deviation deep in structure compared to added complexity, costs and risks in supply chain?
  - **1.2.2.** If it is, is it impossible or too expensive to include the actual device as a standard and leave the enabling part to more surface level?

It is also to be understood that variation in final product qualities is not always the same things as variation in product structure. Today's drill rigs include lots of high-technology and lot of things can be done by adjusting or programming at the end.

6.5 Change management

What are the best tools and approaches to manage different kind of changes and situations where the change is required? Utilization of PLM system and approaches in change management? How different parties in supply chain must be involved and informed in change situation? How the changes in product structure should be transferred in to production; continuously or as a new version?

Change management is not to be concerned only as an application in PLM system. Change management is primarily a controlled function or process where all the information related to changes in product, product structure, production facilities, suppliers or other circumstances is managed centrally and systematically. The key words are controlled and centrally. Change management is not only about informing about changes but also about managing requests for change and causes of change. Changes in product structure and individual purchased items cause challenges and fluctuation for logistics and production when not properly managed.

6.6 Utilization of PLM system and approaches in supply chain management

What competitive advantages utilization of PLM would bring when considering the whole supply chain? Which one, ERP or PLM, is better for managing certain kind of information or operations? What risks there are in integration and simultaneous usage of ERP and PLM system?

SMC already has PDM/PLM system in use but it is not utilized as widely in supply chain as it could be. Whether the tool is ERP or PLM system, but transparency of the product and item information should be considered more carefully. ERP has numerous data fields unused as integration with PLM (currently PDM system) does not provide this information and it is not manually fed. If it is decide to offer some data in both PLM and ERP, then that data must be synchronized with reliable integration. Integration between ERP and PLM

It is possible to get lightweight pictures from PLM system to be attached in corresponding information in ERP without slowing the system operation significantly. Pictures of items, product structures and BOM's would ease visual recognition and understanding in many operations, not least in logistics operations. PLM systems might bring a bridge between production and product development to ease the new product introduction and problem solving on with existing products. Especially as product development managers have presented their desire to get more accurate and useful guidelines for how to consider and involve production system in product designing. The view point of risks and overheads has to be recognized as well.

6.7 Logistics costs and performance measuring

Logistics costs and performance measuring: Measuring of logistics costs and performance is enabled as the quality of logistic information is to be improved by the approaches and tools developed within this thesis. Still, to get reliable and useful measuring information for logistics and supply chain managers as well as for finance department, the reals cost and performance measuring methods and tools must be carefully developed. Current method of measuring supply of the logistics collection does not tell the whole truth about logistics performance. The annual costs of logistics department and transport does not tell the whole truth about logistics costs in supply chain. The impact of logistic operations on profit side of ROI is difficult to measure but should not be underestimated. Activity based methods for measuring logistics costs and performance would bring advantage when offering more transparent and case related information.

7 SUMMARY

The principal for development of logistic operations was to secure supply and increase transparency to operations. Risks in supply are primarily caused by uncertainty and supply chains own structure and processes. Uncertainty is lack of reliable information about current or future issues. Reliable and accurate information about current issues is naturally more possible to reach. Still, that needs effective information management tools, and approaches and tendency to secure information accuracy. When ERP system is used as a main tool and information source for operations, the accuracy and unambiguity of the information is vital. Interaction and operational information sharing should not happen in e-mails and negotiation rooms but centrally in ERP. Reliable and accurate information management is a key component of reliable logistic operations. Reducing complexity in material flows and storages is also one aspect of information management.

Future issues and demands can be forecasted but uncertainty remains especially when forecasts are not relied. It is still possible to be less dependent on future information by reducing logistic lead-time. Logistic lead-time can be reduced by many different approaches that integrate in overall supply chain management. Product and product structure have significant affect to manufacturability and late customizing, and hence possibilities to reduce inventories and logistic lead-time. Product lifecycle management can offer tools to enable effective concurrent working in supply chain based on same centrally stored product information. With change management tools and BOM views it is possible to reduce complexity and uncertainty in different functions and activities in supply chain.

Lean and agile supply chain paradigms have their common and different characteristics. Use of market knowledge, compression of lead-time and collaboration in extended company are highly important for both paradigms. As differences lean is nimble and effective while agile is flexible and serving. With timely separated hybrid solution it is possible to achieve cost effective and yet flexible and market sensitive supply chain. Sourcing and purchasing, depending on division of labour, have significant interaction role towards suppliers. Reliable demand information transparency and reasoned delivery lots make supply chain more agile to adapt in shorter term and inventory risks is reduced. Logistic information management can primarily affect to accuracy and reliability of current state information. If logistic operations are developed separately, not considering overall supply chain and the influence of other functions, the problems will accumulate later. Overall supply chain management integrates all the functions in supply chain to serve common goal without partial optimizing one function’s goals.

Designing, producing and selling the most innovative and best of the range technology products is not profitable in long term, if profit is lost into complexity, high inventories and uncertainty in the supply chain. Markets and business themselves are uncertain and discontinuing, but uncertainty and discontinuity can be managed with overall supply chain management. At least the supply chain should not add uncertainty. Global groups develop their supply chains and product areas with new business strategies that may include relocation decisions. Companies under the group are in different situation than individual companies. Profit itself does not secure continuity, if with relocation or operation integrations the profit or other advantages for the group would be higher. Functions of the company are not necessarily locational integrated anymore. Many groups globally have transformed their production operation separately from product development or marketing. Therefore it is good to understand the meaning of local decisions and actions to company's status in group. Company under the group can secure its continuity by developing its core know-how but also by developing its operations and supply chain to act as a reliable, effective and yet flexible unit. SMC's Tampere site as a part of global Sandvik Group can secure its continuity by developing local interaction cross-functionally and in supplier network. Supply chain and its logistic operations are developed to operate effectively and reliably and they are flexibly adaptable to supply different type of products. This means that logistic approaches or processes do not need significant changes to be able to serve demands of other products produced.

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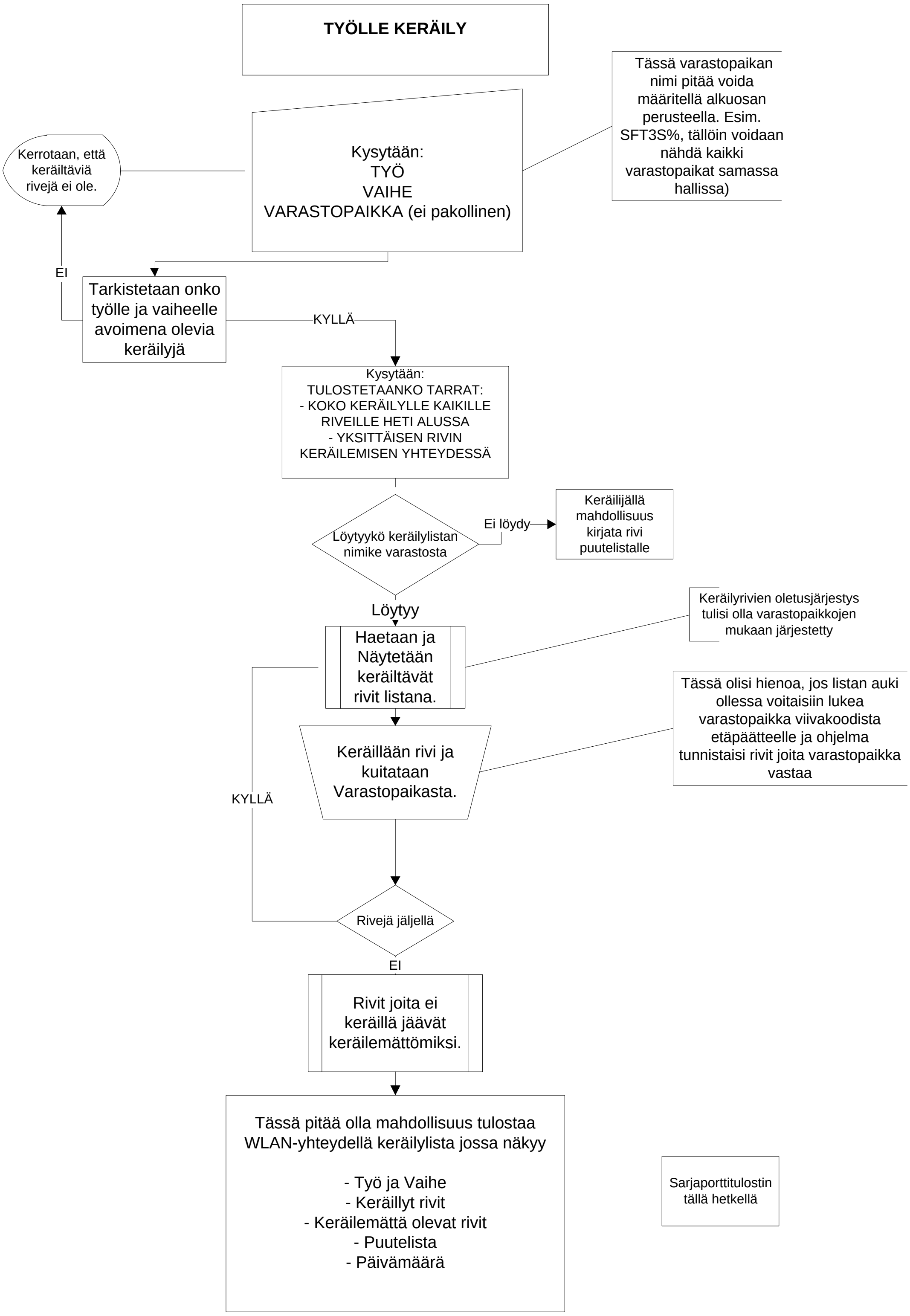
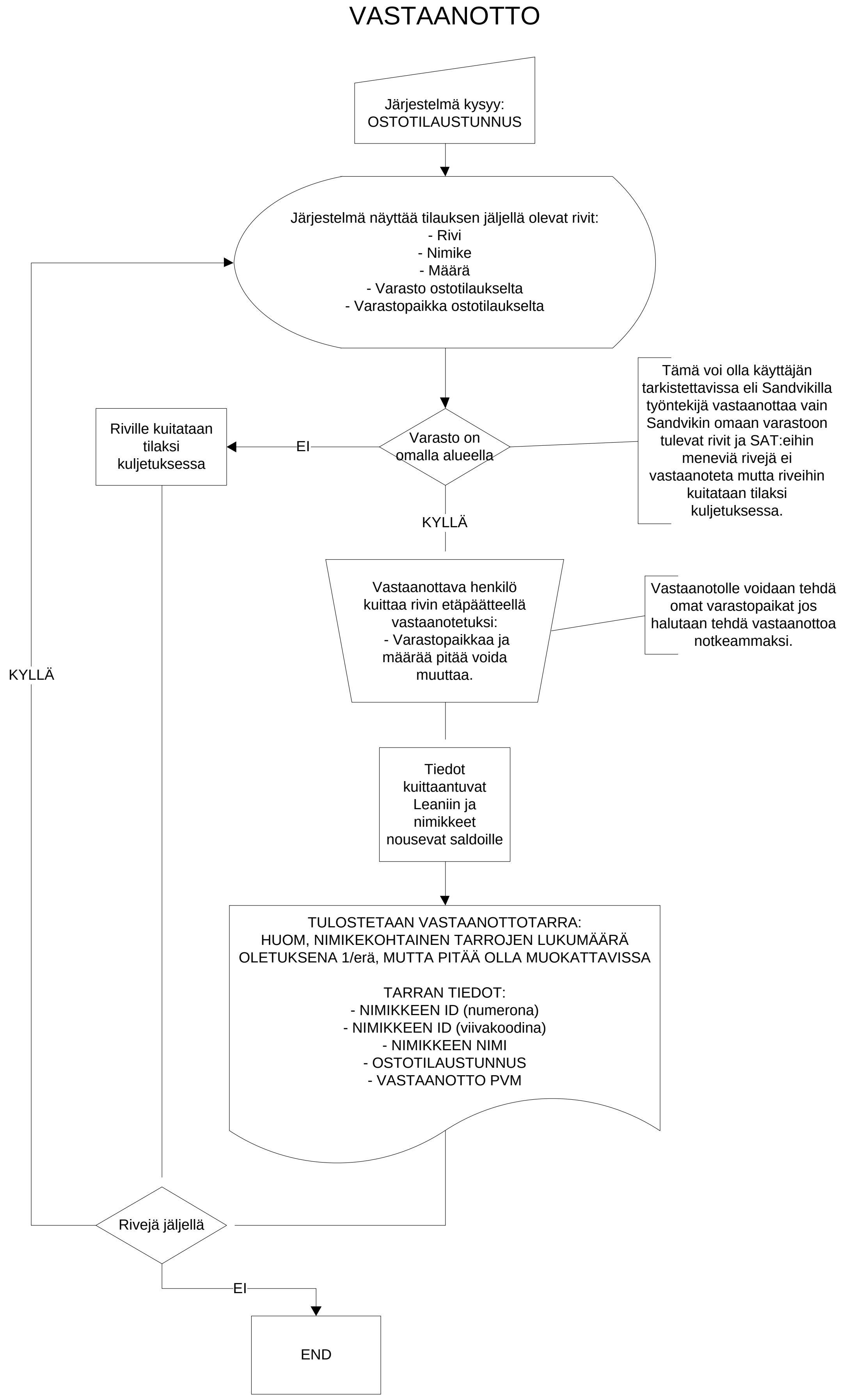
APPENDIX 1: FUNCTIONAL FLOWCHARTS OF MOBILE PORTAL FUNCTIONALITIES

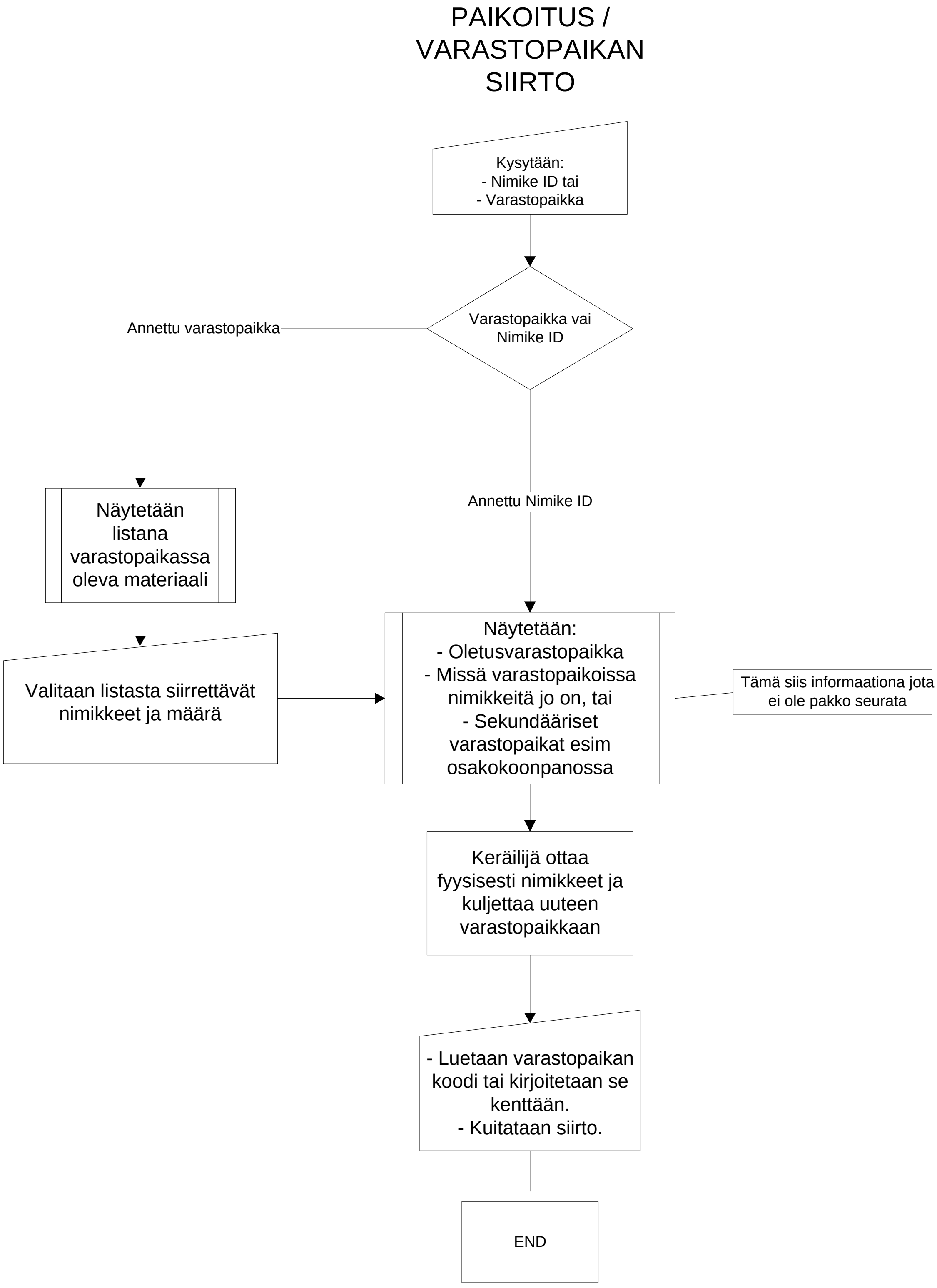
Appendix 1: (1/7) Collecting for work (in Finnish).



Appendix 1: (2/7) Reception (in Finnish).



Appendix 1: (3/7) Placement/storage place transfer (in Finnish).



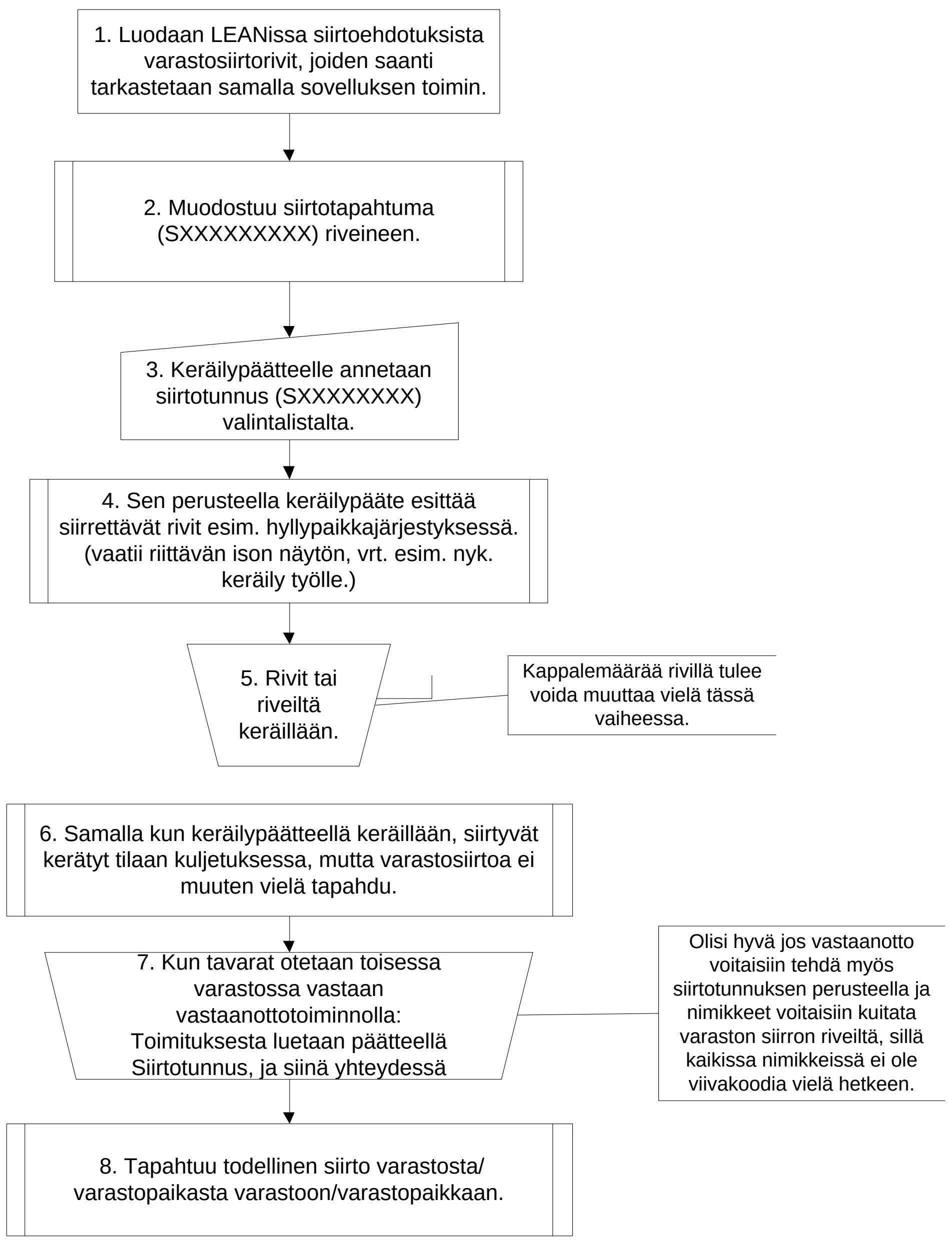
Appendix 1: (4/7) Storage transfer (in Finnish).

VARASTON SIIRTO

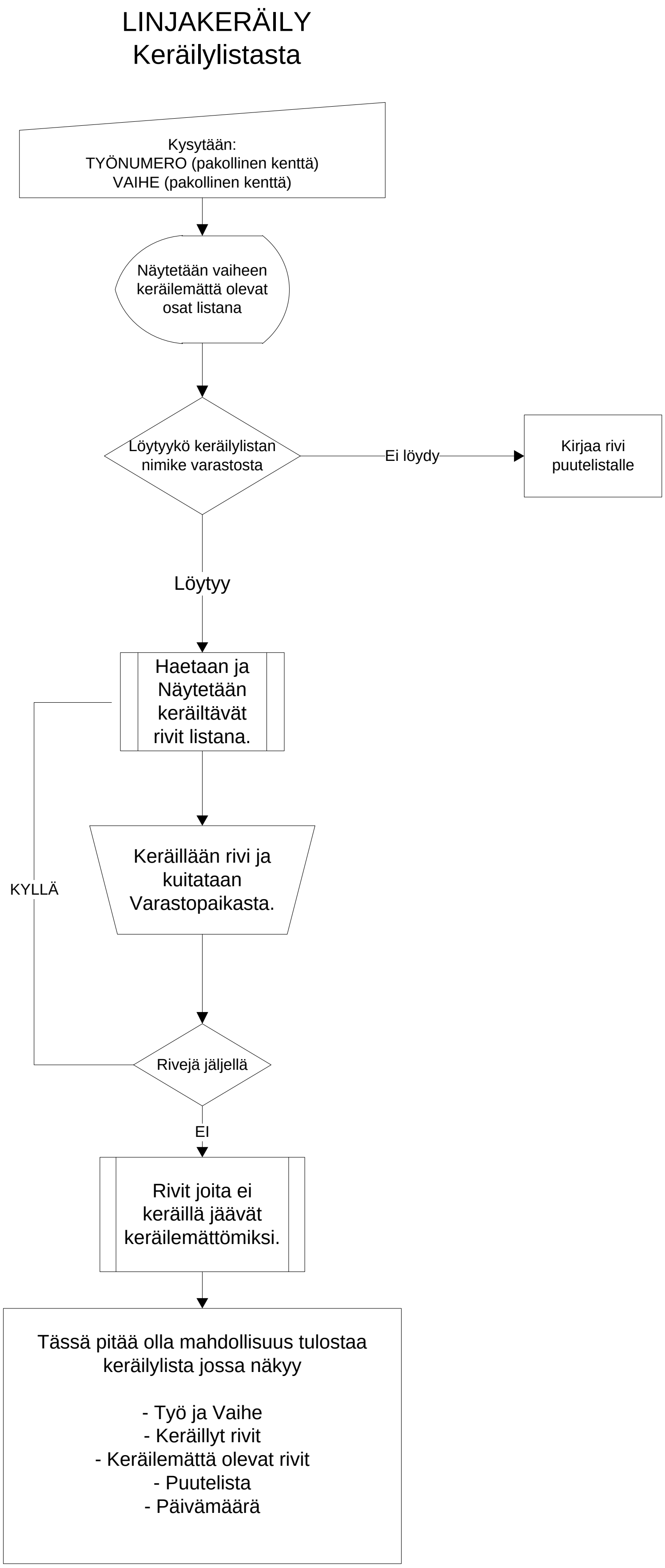
Lähtötilanne:
- LEANiin syntyy varastosiirtoehdotuksia, joiden mukaan saadaan lista, jonka mukaan siirretään tavaraa varastosta toiseen,
- lisäksi tulee sallia tarvittaessa siirto "käsin" ilman siirtoehdotusta.

Toimintaperiaate voisi olla kaksijakoinen:
- Varastosta otto suoritetaan keräilypäätteillä lukemalla siirtolistaa ja keräämällä tavarat.
- Varastoon otto suoritetaan keräilypäätteillä antamalla syötteeksi siirron mukana toimitettu siirtotapahtumanumero (SXXXXXXX).

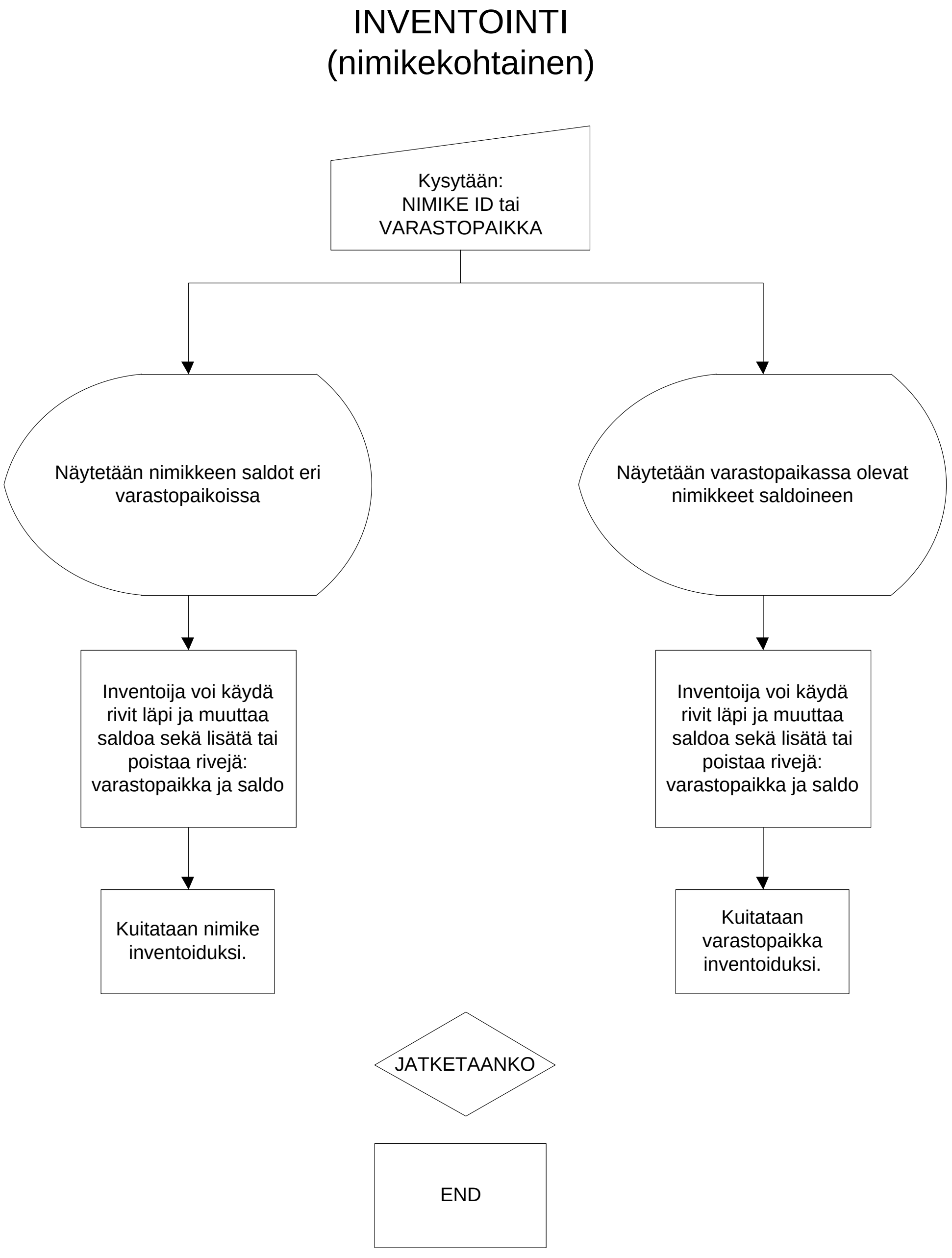
(Huom! Jos/Kun kerätyissä tavaroissa on jo tarrat, ei tässä varastosiirrossa tulostella/liimailla viivakooditarroja.)



Appendix 1: (5/7) Line collecting (in Finnish).



Appendix 1: (6/7) Inventory (in Finnish).



Appendix 1: (7/7) Storage place fill request (in Finnish).