TAMPERE UNIVERSITY OF TECHNOLOGY

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STRATEGIC AGILITY IN PRODUCTION NETWORKS

Master of Science Thesis

Examiner: Professor Reijo Tuokko
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Abstract

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This thesis is written into StrAgile-research project (Strategically Agile Networks), a part of Concept of Operations (Tuotantokonseptit)-program. The research project consists of altogether 12 companies and three research entities, and focuses on customer-specific and demand-driven Finnish machine building industry. The project studies the networks' ability to respond to varying customer requirements, changing demand and competitive situations, and new business opportunities.

The main objective of this thesis is to clarify the term agility and to find characteristics of strategic agility in Finnish machine building networks, as well as, to combine theories on agility to case study observations. In addition, the applicability of other theories – often used in improving companies' performance ability, such as lean – is discussed. The structure of this thesis is divided into three parts: literature review, case study part, and conclusive part.

In literature review, strategic decision making and different network types are discussed. Then, a general picture of research on the field of agility is given, including agility and its characteristic from manufacturing to supply chain level, as well as, strategic agility. Finally, other theories used in case study are introduced. In the case-study part, the results of material and information flow analysis related to tyre set production in the case study supply chain are illustrated and challenges in and goals for the supply chain are presented. In conclusive part, the observations from case study are combined with the theoretical frameworks and discussed in greater detail.

According to one definition, agility is the ability to respond to and even benefit from unexpected change. This ability has become an increasingly important competitive advantage in today's changing business environment. As an outcome of this thesis, the overall picture of agility and its characteristics is clarified. On the grounds of the observations made during the study, applying strategic level agility into Finnish machine building industry is challenging. Achieving high operative level performance – a prerequisite for building agility – requires a significant effort in many companies. Therefore, the goal, especially in small and medium sized companies, is mostly to create processes to more agile direction to enable its characteristic to be built into daily operations. In the case study companies, the three most dominant enablers of agility also improving the performance of the whole supply chain seem to the following: a short lead time both of an individual company and the whole supply chain, which has a direct effect on customer satisfaction; trust among the network partners, which enables faster changes to be made; and efficient use of IT tools, which streamlines the information flow and improves the ability to integrate processes within the supply chain.

Tiivistelmä

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Diplomityö on tehty StrAgile (Strategisesti ketterät tuotantoverkot)-tutkimusprojektiin tiiviisti liittyen. Projekti on Tekes-rahoitteinen ja osa Tuotantokonseptit-ohjelmaa. Projektin pääpainopiste on asiakas- ja tilausohjautuvassa tuotannossa suomalaisessa koneenrakennusteollisuudessa, ja tavoitteena on tutkia kolmen yritysverkon kykyä vastata muuttuviin asiakasvaatimuksiin, muuttuviin kysyntä- ja kilpailutilanteisiin sekä uusiin liiketoimintamahdollisuuksiin. Yhteensä tutkimukseen osallistuu kolme tutkimuslaitosta sekä kaksitoista yritystä.

Diplomityön tavoitteena on tutkia ketteryyteen liittyvää teoriaa, selkeyttää ketteryyttä terminä, sekä selvittää ketteryyden teorioiden hyödynnettävyyttä suomalaisessa koneenrakennusteollisuudessa. Lisäksi tutkimusprojektin kenttätutkimusosuudessa pyritään löytämään ketteryyden kriittisiä ominaisuuksia ja hyödyntämään myös muita teorioita ketteryyden rakentamisessa. Diplomityö muodostuu kolmesta osasta: teoriakartoitus, käytännön osuus, ja soveltava osuus.

Tutkimuksen fokuksesta johtuen teoriaosuuden alussa on määritelty strateginen päätöksenteko erityisesti tuotannon näkökulmasta sekä tarkasteltu lyhyesti erilaisia yritysverkkotyyppejä sekä niiden ominaisuuksia. Ketteryyden teoriaa tarkastellaan strategisella tasolla sekä valmistuksesta aina tuotantoverkkoihin saakka. Teoriakatsauksen viimeinen osuus esittelee muita teorioita, joiden ajatuksia on hyödynnetty tutkimusprojektin kenttätutkimusosuudessa. Käytännön osuudessa on kartoitettu tutkimuksessa mukana olevan yritysverkon osalta materiaali- ja informaatiovirrat koneenrakentajalle toimitettavan rengaspaketin osalta sekä esitelty verkoston haasteita ja tavoitteita projektiin liittyen. Soveltavassa osuudessa yhdistetään käytännön havaintoja teorian tarjoamiin viitekehyksiin sekä pohditaan teorian sovellettavuutta tutkimusprojektin liiketoimintaympäristössä.

Kenttätutkimuksen havaintojen perusteella strategisen tason ketteryyden soveltaminen suomalaiseen koneenrakennusteollisuuteen on haastavaa. Tämä johtuu muun muassa siitä, että operatiivisen toiminnan puitteet eivät ole usein ole riittävän korkealla tasolla mahdollistamaan laajempaa ketteryyden ominaisuuksien rakentamista ja hyödyntämistä yritysverkossa. Täten erityisesti pienissä ja keskisuurissa yrityksissä voidaan strategian roolia pitää ennen kaikkea ketteryyden operatiivisen ominaisuuksien mahdollistajana. Ketteryyttä vahvimmin edistävinä tekijöinä kenttätutkimukseen osallistuvien yritysten toiminnoissa nousivat esille läpimenoajan lyhentäminen, keskinäisen luottamuksen kehittäminen verkossa sekä tietojärjestelmien tehokas hyödyntäminen.

Preface

When I was offered the possibility to work and write my thesis for StrAgile research project, I had very little idea what I was stepping into. The whole project has been an extremely interesting personal growing process for me and I've learned much about how companies operate and what things should be taken into account when implementing a development project in company network. I'm confident that the knowledge I've gained during these months offers a strong foundation for my further working life.

I wish to address my gratitude to Professor Reijo Tuokko for giving me the opportunity to work in the department and for guiding me during the writing process. I'm also thankful to Matti Majuri and Toni Perälä for being patient and for giving me advices and encouragement also during the times when the writing did not seem to progress at all. I would also like to thank other people working at the same room for creating a positive atmosphere to work and to discuss about any given topic. Finally, a great acknowledgement belongs to my family and friends for the support and joy they have given me over the years.

22 March 2010 Tampere

Julius Pesonen

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Terms and abbreviations

AGV(S)	Automated Guided Vehicle (System)
CAD/CAM	Computer Aided Design/Manufacturing
CIRCMI	Center for Research on Information, Customer, and Innovation Management
CMC	Cost Management Center TUT
CSCW	Computer Supported Cooperative Work
Decoupling point	The decoupling point separates the part of organization (supply chain) oriented towards customer order from the part of the organisation (supply chain) based on planning [**1**]
DPE	Department of Production Engineering, TUT
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
FMS	Flexible Manufacturing System
JIT	Just-In-Time
MRP	Material Resource Planning
NC	Numerical Control
OEM	Original Equipment Manufacturer
PDM	Product Data Management
Production network	Production network includes two or more supply chains that share at least one actor (network linkage) [**2**]
StrAgile	Strategically Agile Networks – Research Project
Supply chain	Supply chain is a sequence of productive (i.e. value-adding) activities leading to end use [**2**]
Tekes	Finnish Funding Agency for Technology and Innovation
TOC	Theory of Constraints

1 Introduction

This thesis gives the reader an insight into agility and its characteristics. The change is here to stay, and companies are forced to adapt to new economical and competitive situations faster than ever. Change itself has always been present in industrial and business world, but now it has reached such a speed companies need to find new ways dealing with it. Therefore the concept of agility has been introduced, both to describe the changing environment and its challenges, and to give framework and even tools for companies to utilise in this new situation.

The structure of the thesis is described next. First, a literature review is performed including description of decision making in production strategy, different network types and their dynamics, discussion of agility from factory level to strategic decision making, and a brief overview of other theories used in case study and thought to be useful when building agility. Next, research methods are introduced followed by results from the case study supply chain. Then, the theories introduced in literature review are combined with observations made during the study and conclusions about agile characteristics are drawn. Finally, the significance of agility is discussed.

The following chapter briefly introduces the term agility, as well as StrAgile research project for which this thesis is written. Then, the case study supply chain is introduced. Finally, thesis objectives are presented.

1.1 Research in the field of agility

The competitive and continuously changing business environment of today's global world challenges companies to find alternative operating models to respond to the changes in business environment. During the latest decades the scope of production has shifted from economics of scale to leaner and more adaptive direction and companies are increasingly searching new methods to strive in competition. In order to describe the abilities needed in this business environment, term agility is introduced.

As a term, agility was coined in the early 90s when leading American manufacturers gathered together to define both the environment in which manufacturing industry was operating at that time, and the manufacturing capabilities required in the changing environment in the future. Consequently, agile manufacturing was introduced and the first steps of the research on agility were strongly oriented toward manufacturing. In literature, agility is by many researches considered the latest step of production theories, an evolutionary step proceeding mass production and lean thinking. Evolution can also be seen within the research of agility itself. Upon the turn to 21st century the focus of the research shifted from pure manufacturing point of view to

include other business operations inside the company as well, and to other companies of the supply chain even widening the scope to strategy level.

Agility can be defined as the ability to utilize the core competences of the whole supply net to respond to customer needs rapidly, cost-effectively and with high quality. An agile company or network is able to adapt rapidly to – or even benefit from – unexpected change in business environment.

1.2 StrAgile R&D project

This thesis is a part of StrAgile (Strategically Agile Networks), an R&D project for TEKES program "Concepts of Operations". The project initiated in the autumn 2008 and continues until the summer 2010. Altogether 10 companies from machine building industry and three research entities – Department of Production Engineering (DPE) and Cost Management Center (CMC) from Tampere University of Technology (TUT), and Center for Research on Information, Customer, and Innovation Management (CIRCMI) from University of Tampere (UTA) – are involved. The project consists of three phases: field study, case study, and conclusive part. Since this thesis is performed in the midst of the project, it concentrates on the outcomes of the first two phases. Next, these phases are introduced in more detail.

1.2.1 Phase 1: Field study

In this phase, interviews were performed in 30 companies – not included in the case study – from different business sectors. The goal of the interviews was both to define the current performance level of the company and to find the characteristics of and best practises related to competitive performance in today's business environment. In the first 20 companies, the level of agility was also estimated using the concept of strategic agility and the performance was graded from zero to five in three dimensions: strategic sensitivity, resource fluidity, and collective commitment. The results were then evaluated and the companies for the following ten interviews focused more on covering certain key areas of business operations.

1.2.2 Phase 2: Case study

In the second phase, three supply networks function as a case study environment where a deep study on network development is performed. In addition, the theories and best practices from the first phase have been used as background information. Each research entity is namely responsible for one supply net and coordinates day-to-day operations with it. The development efforts are specified for the network and individual member companies. Though, the research entities cooperate to capitalise on the results of the other supply nets.

The course of the development work in the case network is described next. First, the current state analysis was performed and the constraints restricting the agility were

identified. Next, the goals of the project were mutually defined and agreed with the companies. Finally, measures toward these goals were taken and monitored. During the writing of this thesis these actions are still in progress.

Companies in the case study

This thesis concentrates on one supply chain consisting of three companies: OEM and two sequential supplies – Supplier 1 (tier 1) and Supplier 2 (tier 2). These companies are introduced next.

Supplier 2 produces different kinds of cold steel manufactured components as well as wheels for big working machines. *Supplier 1* manufactures special tyres in various applications and environments including agriculture, material handling and road maintenance. *OEM* is a global machine construction company producing heavy mobile machinery.

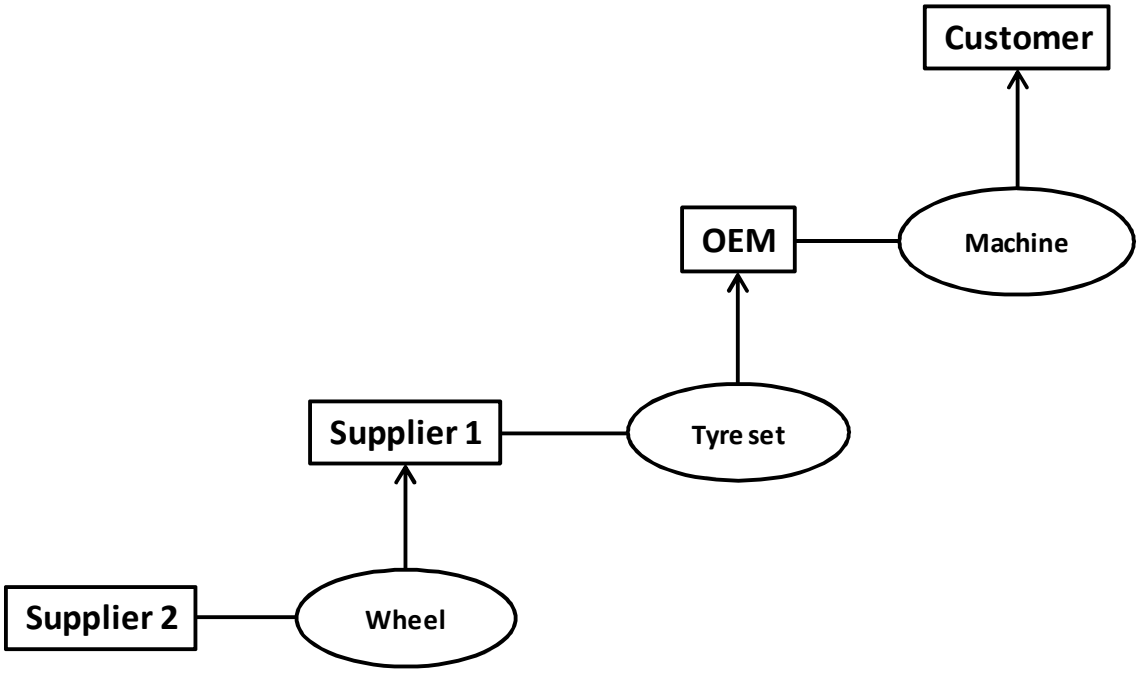

Figure 1-1: The sequence of the case study supply chain

The main sequence of the supply chain is illustrated in Figure 1-1. First, Supplier 2 manufactures a wheel from sheet metal consisting of rim and disc, which are welded together. Next, the wheel is transported to Supplier 1, where outer and inner tyrer, are assembled with the wheel to form a tyre set. Finally, the tyre set is send to the OEM to be mounted to a vehicle.

1.3 Thesis objectives

Although agility is an often discussed topic, it still lacks a good definition and broader understanding among the companies. The objectives of this thesis are presented as follows: to review the literature in the field of agility and to clarify the term strategic

agility; to find characteristics of agility and to adapt them to Finnish machine building industry; and to field-test the applicability of agile characteristics, as well as, other theories and tools related to agility in the case study supply chain.

2 Theoretical Background

This section gives an insight to literature of agility and other theories used in case study. First, strategic decision making is introduced focusing on production strategy. Second, a brief overview to different network types and their dynamics is given. Third, studies and models of agility and its characteristics from factory level to strategic level are presented. Finally, useful theories and tools for supporting the building of agility are introduced.

2.1 Production strategy

In this chapter, the concept of strategy is opened. For this thesis, it is important to define what is strategy and strategic decision making. Due to the focus of the research project, strategy is here considered from productional perspective. First, the term strategy is defined; then, strategic decision making is considered; last, an approach to production strategy is reviewed.

Johnson et al. defines strategy as follows: "Strategy is the *direction* and *scope* of an organisation over the *long-term:* which achieves *advantage* for the organisation through its configuration of *resources* within a challenging *environment*, to meet the needs of *markets* and to fulfil *stakeholder* expectations [**3**]." In other words, strategy should give an answer to the following questions:

- Where is the business trying to get to in the long-term (direction)?
- Which markets should a business compete in and what kinds of activities are involved in such markets? (scope)
- How can the business perform better than the competition in those markets? (advantage)
- What resources (such as skills, assets, finance, relationships, and technical competence) are required in order to be able to compete? (resources)
- What external, environmental factors affect the businesses' ability to compete? (environment)
- What are the values and expectations of those who have power in and around the business? (stakeholders) [**4**].

When strategy is defined for the company or for the supply chain, the above questions should be answered and acted against. Although numerous decisions are made daily in all companies, only few decisions are truly strategic. According to Heikkilä and Ketokivi, the decision is strategic only if it has significance in succeeding in competition and if it is chosen from several options. That is, if decision is not about choosing from certain options, it is not strategic. For instance, aiming to produce economical value added and increasing the welfare of the personnel are not very

purposeful strategic decisions. It is not, that they are unimportant issues, but rather that they do not have any reasonable competitive alternative that could be chosen for the strategy. Actually, a better example for strategic decision is that of choosing the supply chain to concentrate either on flexibility or efficiency. In this decision, there are different alternatives to choose from depending on what characteristics the company is willing to use in competition. Naturally, a combination of these two approaches is also possible [**5**].

In addition to the above, strategic decisions are often complex and required to be made in uncertainty and without full knowledge of all the elements affecting the decision. Consequently, strategic decision making requires an integrated approach within the organisation. Including only one area of expertise or one perspective is usually not enough to form a comprehensive picture of the situation. Managers usually have to cross functional and operational boundaries when dealing with strategic questions, come to an agreement with other managers, and reflect other's objectives to one's own. Strategic decisions also concern other companies and organisations in the network around the company. Therefore, the decisions made within one company should be considered in-line with larger perspective [**3**].

Levels of strategy

Strategies exist at numerous levels in an organisation, from corporate level to even individual strategies of employees. However, the scope of this thesis limits the focus of strategical considerations to productional level. Heikkilä and Ketokivi introduce a model of production strategy (Figure 2-1) consisting of four levels – corporate strategy, business unit strategy, functional strategy, and production strategy. Next, these levels are introduced in more detail.

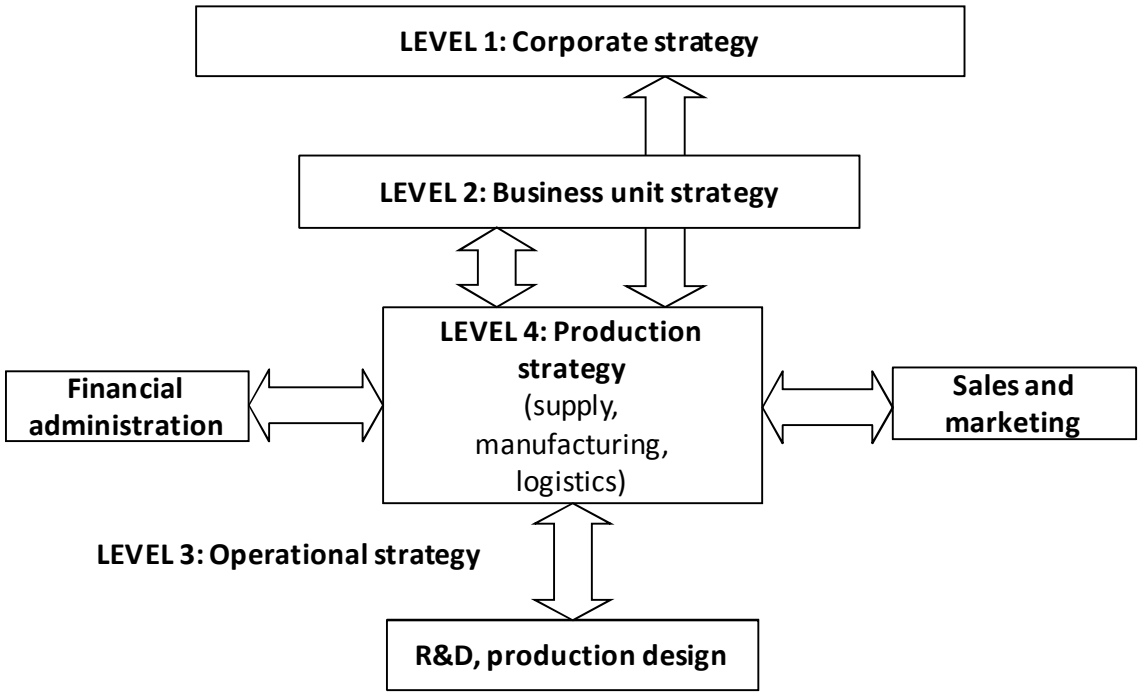

Figure 2-1: Model of manufacturing strategy [**5**]

Corporate strategy specifies two areas of overall interest of the corporation: definition of the businesses in which the company participates, and acquisition of resources and their commitment to each of those businesses. The dominant orientation of the company often defines the businesses in which the corporation will participate, using proper materials, markets, and technologies. The second element – acquisition and deployment of the resources – often results in a strong finance function at the corporate level. In addition, acquiring and deploying human resources, is recognised increasingly important part of corporate level activity [**6**]. From production's viewpoint the strategic questions decided in corporate level are the following: How important production and related topics are in corporate strategy? Does the know-how in production have a significant role when developing business and deciding business areas? [**5**]

Business strategy defines the scope and boundaries of each business unit linking their business strategy to corporate strategy, and specifies the foundation on which the business units will achieve and maintain a competitive advantage. Defining business scope and boundaries include specifying the product/market/service sub-segments for every business unit in order to avoid internal competition and to focus the effort of every business unit. Examples of a competitive advantage would include low cost/high volume, and customer service in selected niches. To be effective, this advantage should fit the business unit resources, recognise competitors' strategies and fit the definition of the product/market segments to be pursued [**6**]. Business strategy considers more concretely the role of the production and its competitiveness as a part of corporate strategy [**5**].

Functional strategy defines how a certain function supports the desired competitive advantage and how it complements the other functions. It concentrates on specifying how production is managed with other functions and operates as an integrator between the functions. The challenges to build efficient information flow and integration between different functional units increase, for example, in case of outsourcing.

Production strategy – or in some literature, manufacturing strategy – commits to organising manufacturing facilities and supply chains in order to execute the business strategy. On production level, goals for manufacturing, supply, and logistics are defined. These goals are then used to determine the day-to-day actions. These actions should also support the upper level strategies, but the focus is mostly on understanding and developing both manufacturing and supply [**5**]. The following chapter opens the decision making and categories of manufacturing strategy.

The categories of decision making in manufacturing strategy

In this chapter, the focus is on manufacturing instead of including also supply and logistics that belong under production. An effective manufacturing operation is not necessarily one that offers the most efficiency, or engineering supremacy, but rather one

that best fits the need of the business. Consequently, translating the business strategy into an appropriate collection of equipment, people, and procedures requires resources, time, and persistent management to ensure that the decisions are understood and mutually supported.

Table 1: Decision categories of manufacturing strategy

1. Capacity – amount, timing, type
2. Facilities – size, location, focus
3. Technology – equipment, automation, connectedness
4. Vertical integration – direction, extent, balance
5. Workforce – skill level, pay, security
6. Quality – defect prevention, monitoring, intervention
7. Production planning/material control – computerisation, centralisation, decision rules
8. Organisation – structure, reporting levels, support groups

According to Wheelwright, the structure and capabilities of the manufacturing strategy in an organisation can be arranged into eight categories as presented in Table 1. These categories can, again, be divided roughly into two different types. According to the author, the first four decision categories – capacity, facilities, technology, and vertical integration – can be viewed as structural and strategic in nature because they have long-term impacts, require high investment, and are difficult to reverse or undo in short notice. The last four categories are viewed more as tactical, since they require a continuous decision making, need to be linked with the current operating aspects of the business, and usually do not need large capital investments at a certain point of time. However, during the time, the small decision making in the last four categories cumulates resulting in situation, which can be difficult to change.

The subcategories under each of these eight points consist of aspects that are connected to each other and should be thought of when making decisions concerning this category. In addition, many of these categories are interrelated; for instance, quality is naturally highly dependent on the workforce and technology used in manufacturing. Due to this interrelatedness of the categories, the decision making should be consistent and collaborative in order to fulfil the business strategy; and if it changes, these smaller decisions are obligated to be reconsidered [**6**].

2.2 Production network types

First, to clarify the difference between supply chain and production network, a definition by Sturgeon is presented as follows: *supply chain* is a sequence of productive (i.e. value-adding) activities leading to end use; *production network* includes two or more supply chains that share at least one actor (network linkage) [**2**]. Although the

literature often uses these terms interchangeably, the scope of this thesis and the case study is on a supply chain rather than a network.

Inter-enterprise cooperation is an essential part of today's business world. As described later in more detail, agility requires not only high performance within the company but also an active cooperation with stakeholders. Therefore, production networks consisting of different organisations are formed in pursuit of better competitiveness in the markets. Depending on the characteristics of the companies and other organisations of the network, dynamics of the network differ from case to case. These dynamics have a great impact on how competitiveness and agility can and should be developed into the network. Next, Kestilä et al. introduce a model including four types of networks presented as follows:

1. Clan type relational networks where coordination is based on social bonds and personal contacts.
2. Bureaucracy type hierarchic networks that rely on the authority of one strong network partner for coordination.
3. Market type contractual networks where coordination is achieved through negotiation and enforcement of contracts.
4. Strategic long term type network where coordination is based on inter-organisational level goal congruence and trust [7].

From these types, the first one is rather theoretical in industrial world where coordination is more or less managed and verified by contracts, and even though social bonds and personal contacts are still important, they are often not a sufficient reason to form business partnerships. However, the last three are commonly found in industry and depending on the situation take different forms.

The supply chains in the case study fall both into category two, where the main supplier is very dominant, and into a combination of categories three and four, where the operations are mainly based on contracts, but there is still a long history collaboration and partnership between the partners. Being aware of the differences in dynamics of the networks can help finding and choosing tools and methods for the development work in that specific group of companies. In the literature concerning agility, the division into different types of networks is often done from the viewpoint of organisation structure rather than network dynamics. The two network types – extended and virtual enterprise – are reviewed next.

Extended enterprise

The extended enterprise extends beyond traditional organizational boundaries including relationships with, for example, customers, suppliers, business partner and former competitors. In addition, the extended enterprise can be regarded as an enterprise represented by all of those organizations, customers, suppliers, and sub-contractors that are engaged collaboratively in the design, development, production and delivery of a

product to the end user. Although the primary challenge in forming and managing extended enterprise is to design and implement appropriate business processes, the efficiency of an organisation is determined mainly by the speed and efficiency by which information can be channelled and managed through the organisation. Therefore, advanced and compatible ICT tools throughout the organisation are a necessity in achieving efficient operations [**8**,**9**].

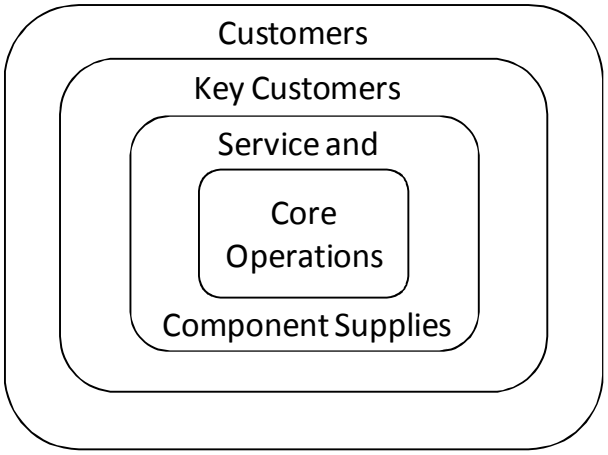

Figure 2-2: The extended enterprise [**9**]

Figure 2-2 describes the structure of the extended enterprise extending from the perspective of a single company and the boundaries to include suppliers, customers and other business partners. The extended enterprise forms a network to bring together the know-how of different units to produce and market products and services. As mentioned above, relationship coordination and communication skills among the partners are the essential characteristics of the extended enterprise. Viewed from this perspective, the characteristics of the extended enterprise can be described as follows:

- The participating enterprises focus on their core businesses and outsource other business activities. Outsourcing improves the competitive ability of the enterprises and increases interdependence.
- The trust and mutual dependency encourages companies to form long-term relationships with the partners.
- Business processes, methods and technologies are available to support activities, which cross the boundaries of traditional companies. The supplier-customer integration is especially important, through which the technical and commercial information is interchanged seamlessly [**8**].

Virtual enterprise

According to Khaje, virtual enterprise is a temporary network of independent companies-suppliers, customers-linked by information technology to share skills, costs, and access to one another's markets. Martinez suggests that virtual enterprise can be formed by multiple organisations to respond to industrial options, which are characterised by multiple strategic objectives: maximising flexibility and adaptability to

environmental changes, developing a collection of competencies and resources, reaching a critical size determined by market constraints, and optimizing global supply chain [**10**].

Browne et al. defines virtual enterprise as a temporary consortium of independent member companies and individuals which gather together to exploit a certain market opportunity. Companies within virtual enterprise assemble themselves based on cost-effectiveness and product uniqueness regardless to organisation size, geographic location, computing environments, technologies deployed, or processes implemented. Virtual enterprises share cost, skills, and core competences which enable them to respond to opportunities that would be out of the reach of individual companies. Browne and Zhang suggests that the following benefits can be achieved through the construction of virtual enterprise: access to wide range of specialised resources, present a large and unified face to large buyers, individual members are able to keep their independence and develop their core competences, change members and reshape the enterprise according to the project or task in hand, and contrary to formal joint ventures resigning is easier. The objective for joining virtual enterprise is often to increase the company's market share and benefits [**8**,**10**].

Comparing extended and virtual enterprises

Although extended and virtual enterprises have some similarities, the differences in organisational focus and structure are noticeable. Whereas extended enterprise is based on trust and mutual dependency between partners, in virtual enterprise the relationships are shorter and created for particular project of creating new products or services. The information sharing is important in both enterprise nets, but virtual enterprise relies even more in fast and accurate information sharing due to the rapid environmental changes caused by continuous creation and dissolving of enterprise groups. The organisation of virtual enterprise is frequently project based and project oriented, whereas the focus of the extended enterprise is longer-sighted, even extending to whole product life cycle.

As a conclusion, both extended and virtual enterprises form organisational partnerships in order to achieve business success in competitive environment. The main difference is in the nature of the enterprise: virtual enterprise is dynamic and temporary and extended enterprise is more stable and long-term. The virtual enterprise is a faster and shorter-in-time gathering of organisations, whereas extended enterprise requires a longer cooperation and organisational stability through the whole value chain [**8**].

2.3 Agility

Literature approaches agility from numerous directions. To give more comprehensive view, this chapter divides agility into three main parts according to the viewpoint as follows: strategic agility, agile manufacturing, and agile supply chain. Strategic agility considers agility from the viewpoint of strategic decision making. Agile manufacturing

and agile supply chain, again, can be seen as an evolutionary step from other production paradigms. The scope of the research on agility has shifted from production oriented scope to include the whole supply chain and even other stakeholders. Before introducing these approaches, term agility is opened next.

2.3.1 Definitions of agility

Merriam-Webster dictionary defines agile person as one "marked by ready ability to move with quick and easy grace", and agile mind as "having a quick resourceful and adaptable character" [**11**]. In business environment, on the other hand, agility is related to the operations performed by and within a certain organisation. The definition of agility has naturally evolved concurrently with the better understanding brought by the research on agility. Some of the definitions are presented next to increase the overall understanding of the term and its characteristics.

Stamatis suggests that "agility is the ability to thrive in a competitive environment of continuous and unanticipated change and to respond quickly to rapidly changing market driven by customer-specified products and services [**12**]." According to Gorason, an agile enterprise is one that responds to – and ideally benefits from – unexpected change. The ability to respond to expected change has traditionally been described as flexibility; however, since future can never be predicted precisely, unexpectedness is the main characteristic of today's business. Therefore, being only flexible will not be adequate to triumph in competition; therefore, term agility is introduced [**13**].

Dove approaches agility from a different perspective and describes it as an objective of operating programs – not a competitor – and a fundamental requirement for all organizations. The author defines agility as "...the ability to manage and apply knowledge effectively." Therefore, it is a combination of response ability – the physical ability to act –, and knowledge management – the intellectual ability to find appropriate things to act on. Earlier, when the change in the environment of organisations was slower, the ability to change rapidly was not a conscious objective; however, nowadays organisations have to be able to assess their agility in order to determine if it is at sufficient level or if it requires improvement [**14**]. According to Kidd, the main characteristic of agility is adaptability of the organisation, which is achieved through reconfiguration capability. In addition, agility is not a tactical but rather a holistic strategic response, which involves building defence against competitive forces through cooperation [**15**].

As a conclusion, agility can be defined in numerous ways. However, the underlying aspect in all definitions is the need of an organisation to be able to respond to changes – either coming from outside or from within. The change can be either continuous or rapid and unexpected. Either way, appropriate actions are to be made in order to cope with the situation.

2.3.2 Strategic agility

The book Fast Strategy by Doz and Kosonen discusses agility from a perspective of strategy and strategic decision making. This perspective is considered here because the following framework functions as a theoretical foundation and a starting point in StrAgile research project. Term *strategic agility* comprises of dimensions that focus on making the strategy and strategic decision making more agile rather than focusing on agility as a performance capability itself. Namely, these three dimensions of strategic agility are strategic sensitivity, resource fluidity, and collective commitment. The authors suggest the following: "*Strategic agility is enterprise's continuous ability to make real time and accurate interpretations of the environment, to reallocate resources fast and in sufficient scale, and to commit collectively to the objectives"* [**16**].

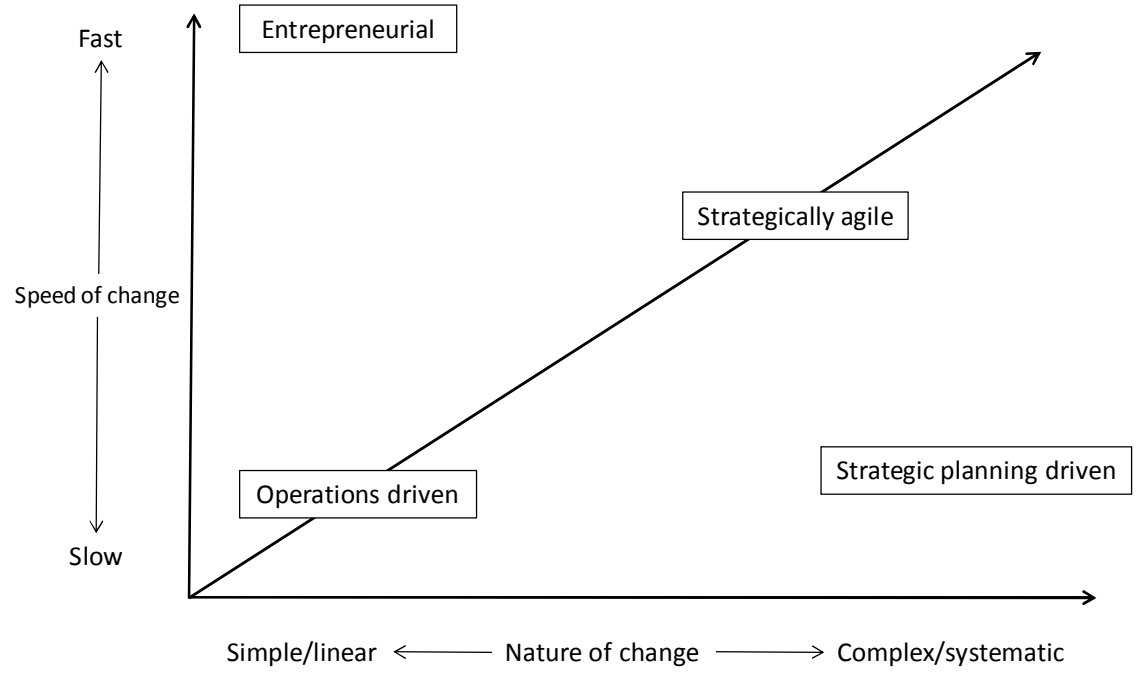

Figure 2-3: Where strategic agility is needed [**17**]

Figure 2-3 illustrates the key are of implementation of the concept of strategic agility. First, operation driven companies are operating in more traditional business areas where the speed of change, especially from the viewpoint of product changes, is low and the focus is on operational excellence. This environment usually embraces efficiency and is not very exposed to fast changes. Second, entrepreneurially driven companies are common in environment where the nature of change is simple, but the speed of it is fast. These companies have to adapt to new challenges with rapid actions. Third, strategic planning driven companies are the common ones, for instance, in machine building industry where the nature of change is complex and systematic. The companies are increasingly networked and the relationships between the companies often are long term. However, the ability to respond to changes coming from outside or

from within takes time. Although the speed of change is not very fast yet, in the future, the speed of change is increasing remarkably. The last type, strategically agile companies, are able to operate in an environment that requires both rapid changes and in which the nature of the change is often complex. As an example, the authors consider IBM as strategically agile companies and recommend strategic planning driven companies to shift toward strategically agile direction. Consequently, the following paragraphs introduce the authors' viewpoint of both the problem of the current company strategies and the dimensions of strategic agility.

Problem with strategy of growing companies

First, successful and growing – often global – company loses its adaptability, when pursuing efficiency in the expense of flexibility. Seeking for profitable growth and benefiting from scale advantage are justified per se, but often lead to focusing on narrow-minded core business, which again easily results in strategic short-sightedness.

Second, resource fluidity decreases in the course of time due to the large scale organisation to business units and product divisions. When operation systems are optimized to current state operations they become accurately defined and inflexible to possible future changes. In addition, tight cooperation with suppliers turns into a bundle of restrictive relations, if not through contracts, at least in company's thinking processes; therefore, finding other solutions and observing objectively becomes more difficult.

Third, collective commitment becomes easily complicated along the company's success. One explanation given by authors is that after a rapid growth the challenges the company is facing are not considered as consistent and challenging as at the early stages of growth. The growth, success, and more defined organisational structures lead to specialisation and people tend to act individually to optimise their own area of responsibility rather than to drive toward a common goal. These three dimensions – strategic sensitivity, resource fluidity, and collective commitment – are discussed in greater detail in the following paragraphs.

Dimensions of strategic agility

Strategic sensitivity is the ability to observe and interpret the changes in the environment constantly and precisely and is divided into three elements: open strategy process, heightened strategic alertness, and high quality internal dialogue (Figure 2-4). Open strategy process improves company's responsiveness toward different viewpoints and ways of thinking. Therefore, it depends upon an active cooperation with company's stakeholders including suppliers, customers, competitors, and research institutes when outlining and shaping the strategy. Heightened strategic alertness enhances the company's ability to form and define strategic questions in a fresh and comprehensive fashion. It requires increasing the diversity of thinking processes within the company by guiding the thinking toward more conceptual direction. High-quality internal dialogue

increases the company's competence to convert individual insights and views into collective and shared direction of strategy. This, again, is build by a systematic reinforcement of knowledge basis and conceptual richness.

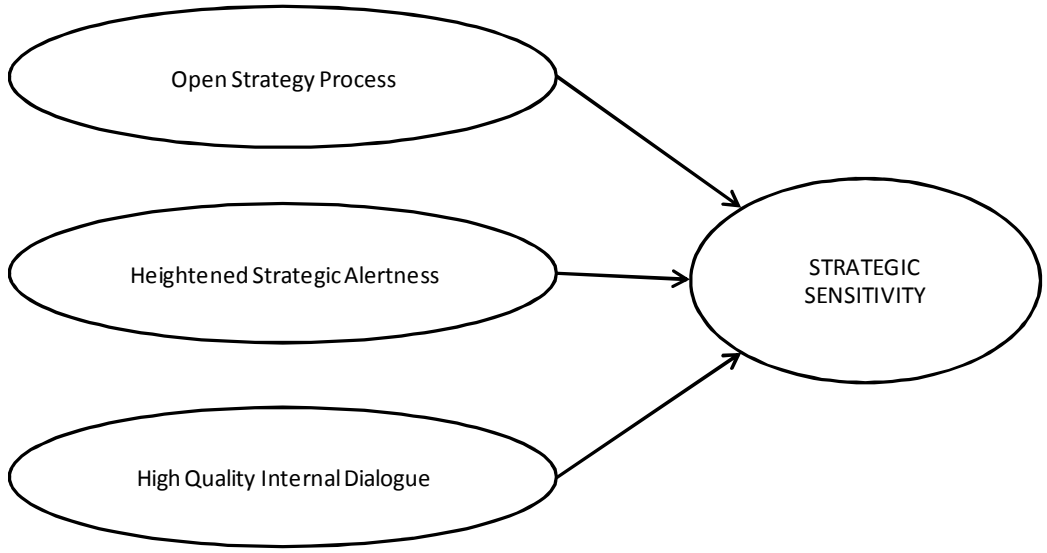

Figure 2-4: Characteristics of strategic sensitivity [**17**]

Resource fluidity is company's ability to reform business models and to reallocate resources rapidly and it is divided into three main clusters of tools – mobilising capital resources, mobilising people and knowledge and create modular structures – presented in Figure 2-5. First, mobilising capital resources means that enhancing the accessibility to resources helps companies to learn and accommodate to changing markets and have an influence on the direction of market development. Second, mobilising people and knowledge contributes the reallocation of scarce resources, prevent resources from getting locked into organisational silos; and therefore, secure company's ability to react rapidly to new business opportunities. Third, the facilitation of resource reallocation through modular reusable systems and processes help companies to reduce risks relating to both initiating new business and, on the other hand, coming off from another one. Therefore, the basic idea of modularity is to prevent organisation from stiffening through time and to preserve the ability to reconfigure rapidly if needed.

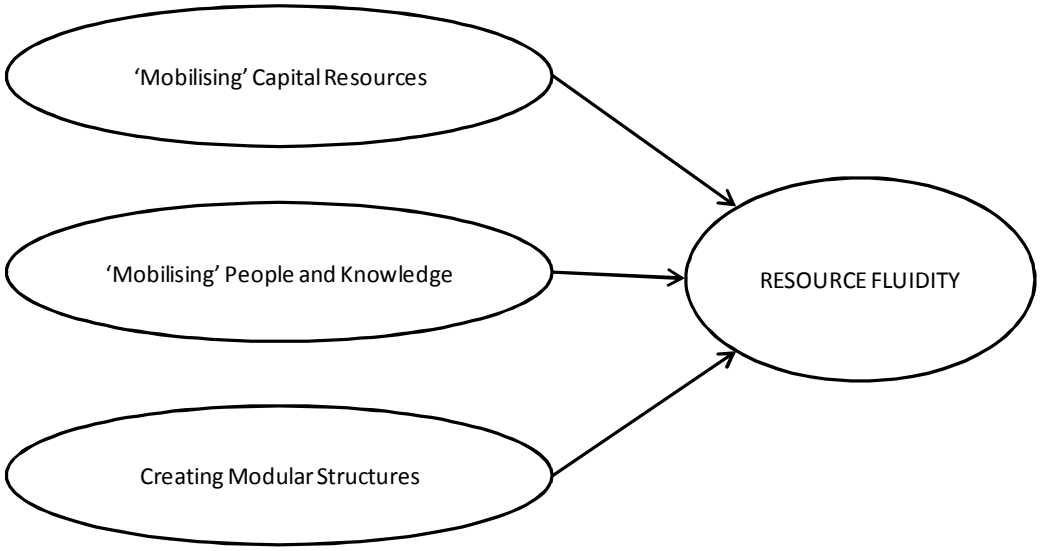

Figure 2-5: Characteristics of resource fluidity [**17**]

Collective commitment – or leadership unity – is defined as the consistency and ability of management teams to make bold and determined decisions without getting stuck with 'zero-sum policy'. These management practices consist of mutual dependency, top team collaboration, and the skills and management style of top executives (Figure 2-6).

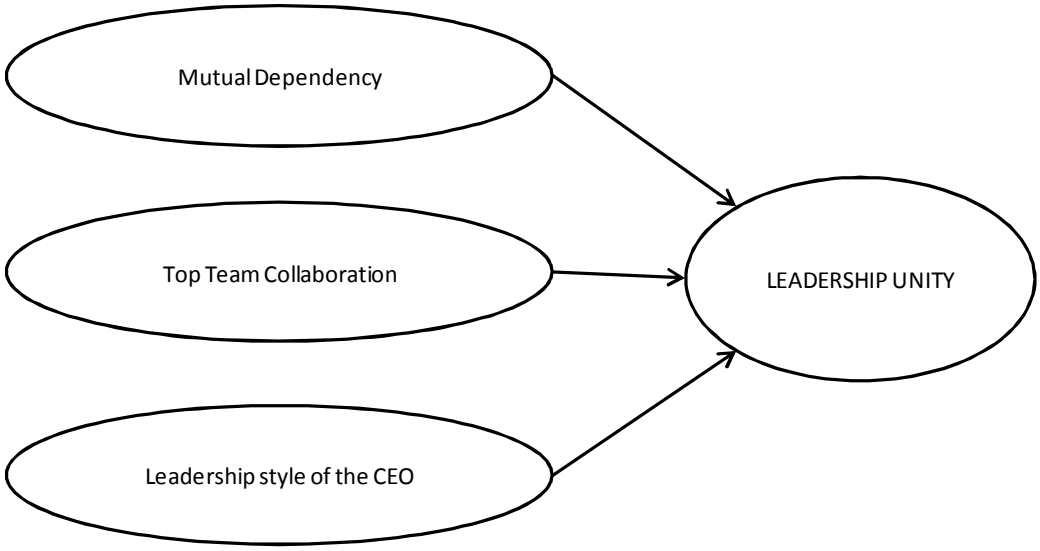

Figure 2-6: Characteristics of leadership unity [**17**]

The mutual dependency within executive management reinforces the willingness to commit collectively and to prevent factionalism. Top team collaboration and working in association with colleagues reinforces management team's performance by developing constructive dialogue. The last, and of the highest importance, is the leadership style of the CEO, that enables company to maximise the results of the diverse but harmonious management team [**16**].

2.3.3 The evolution of agile manufacturing

The agile manufacturing is viewed as either a revolutionary leap or an evolutionary process evolved from the earlier manufacturing philosophies [**18**]. In this paper the viewpoint is evolutionary and incremental one. The evolution of large scale production began in the late 19th century with mass production, which prospered especially in Post-World War II society. The demand superseded the overall supply and the common market winner was the price, which resulted in vigorous cost reductions. In the last decades of the century, succeeding the golden era of mass production, the focus on quality emerged as a basis of the next dominant way of thinking. Gradually, customers began to demand high quality and highly customised products. This resulted in the expansion of efficiency driven, or "lean" thinking, that combines the low unit costs of mass manufacturing with configurable products. This lean thinking is introduced later in greater detail.

The concept of agile manufacturing first appeared in early 90s in *21st Century Manufacturing Enterprise Strategy* report. The report describes the results of a project in which the managers of the most important US companies were brought together to discuss the future of manufacturing in USA. They found that the critical manufacturing issues were continuous change, rapid responding, quality improvements, and social responsibility [**19**].

The concept has evolved during the last decades but still lacks a universally-accepted definition. The principal elements of the definitions of agile manufacturing presented in literature are summarised by Yusuf et al. as follows:

- High quality and highly customised products
- Products and services with high information and value-adding content
- Mobilisation of core competencies
- Responsiveness to social and environmental issues
- Synthesis of diverse technologies
- Response to change and uncertainty
- Intra-enterprise and inter-enterprise integration [**18**].

Compared with traditional manufacturing methods, agile manufacturing is unique in a way of using resources outside of the company differently. According to Civan et al., sharing resources and technology, even with competitors, is essential in agile environment. Thus, cooperation is as important outside the company as it is within. Such cooperation, in general, includes suppliers, competitors and customers [**20**]. The above mentioned elements of agility are considered in greater detail with agile supply chain approach. However, in this section, the focus is on presenting agile manufacturing from a viewpoint that emphasises its transformation and evolutionary development from mass and lean manufacturing. The next paragraphs discuss the characteristics and differences between these three.

Differences between mass, lean and agile manufacturing

Sharp et al. suggests that to be able to meet the need of customers in today's competitive environment and to respond to volatile markets, an evident shift from mass to lean and eventually to agile management and manufacturing philosophy is conducted. Table 2 illustrates that agility is more customer-driven than lean and mass approaches and competitiveness is achieved through diverse and highly customised products. In addition, the processes are highly people oriented and based on their knowledge and competencies.

Table 2: Key differentiation between mass, lean and agile [**21**]

	Mass	Lean	Agile
Drivers	• Economy of scales • Stable markets • Demand led	• Market • Economy of waste • Predictable markets • Make to forecast	• Customer • Economy of diversity • Unpredictable markets • Make to order
Focus	• Equipment and Facilities	• Technology and Systems	• People and Information
Suppliers	• Many • Low level of trust • Adversarial • Relationship	• Fewer • High level of trust • (long-term) • Cooperative	• Selection from many • High level of trust • (short-term) • Shared risk/reward
Organisation	• Division of labour • Hierarchical	• Teaming • Flatter organisation	• Multi skilling • Empowerment
Product	• Few options • Inconsistent quality	• Many options • High quality	• Customised • Fitness for purpose
Process	• Rigid • Hand on labour	• Flexible • Automated	• Adaptive • Knowledge based
Philosophy	• Authoritative	• Administrative	• Leadership

Although lean and agile manufacturing possess some obvious similarities, such as cost-efficiency and customised products, the differences are significant. According to Sharp et al. these are:

- Lean production is regarded by many as an improvement of mass production methods, whereas agility produces much more customized products in any quantity.

- In production line context agility focuses more on economies of scope rather than economies of scale. That is, being able to respond to ever-diminishing niche markets without increased costs.
- Agility utilizes such concepts as rapid formation of multi-company alliances or virtual enterprises to introduce new products to market.
- A lean company can be characterised as very productive and cost-efficient producer.
- An agile company is thought more of a very fast and efficient learning organisation rather than productive and cost-efficient as primary characteristics [**21**].

It could be argued that some characteristics of lean in Table 2 are inaccurate in lean approach. In Toyota, for example, lean thinking is very developed and some differences to the above list could be noted. First, the focus of their operations is rather on safety and quality rather than primarily on technology and systems. Second, although their organisation is based on teaming, people are very multi-skilled which enables effective job rotation and schedule levelling. Third, the processes in purely lean production are very rigid and standardised. However, if needed, these standards can be changed very rapidly and efficiently which may seem outside as if the processes itself are flexible [**22**]. Lean thinking and its main characteristics are reviewed in greater detail later in this paper. The next paragraphs shift the focus from comparison to the tangible structure and characteristics of agile manufacturing.

2.3.4 The model of agile manufacturing

The conceptual model for agile manufacturing is introduced by Sharp et al. and it consists of foundations, enablers as pillars, and outcomes as the roof. Agile manufacturing should be built on a firm foundation of world class or lean manufacturing; therefore, the level of performance is obligated to be already high before being able to build agility into organisation. The next level, competitive foundation, includes continuous change, rapid response, quality improvement, social responsibility, and total customer focus. The roof – the outcome of agile manufacturing –consists of four characteristics of agile manufacturing company: quick response manufacturing, global manufacturing, mass customisation, and improved productivity and quality [**21**].

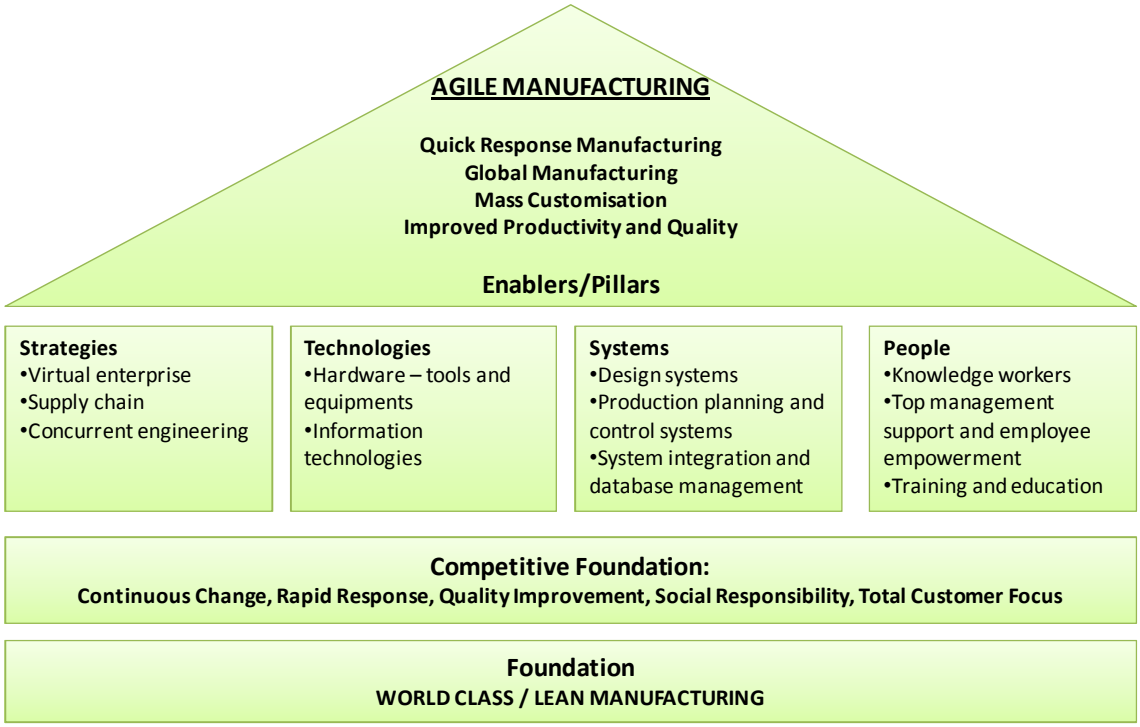

Figure 2-7: Model for agile manufacturing (modified from [**21**])

In Figure 2-3, The original model is modified by the author so that the enablers presented by Sharp et al. are being replaced by other criteria/enablers introduced by Gunasekaran and classified into four groups: strategies, technologies, systems, and people [**23**]. These groups form the middle part of the model enabling the high level characteristics and agility to be built on. Next, some key criteria and elements from the groups are discussed.

Strategies

Strategic approach to improve performance has gained attention in manufacturing. To achieve the goals determined by long-term strategy and interest of the company a number of sub-strategies are introduced including virtual enterprise, rapid-partnership formation, rapid prototyping, and temporary alliances based on core competences. Partnership formation is strategically critical and facilitates agility in manufacturing. Virtual enterprise, as reviewed earlier, is based on core-competencies and temporary alliances in which the selection is based upon three functions that include prequalifying partners, evaluating product design with respect to the capabilities of the potential partner, and selecting optimal group of partners to produce a certain product [**23**].

Supply chain is the global link between raw material producer and end-customer. Producers are seeking solutions to reduce the costs of supply chain; however, in agile manufacturing the focus in relationships to suppliers is primarily in responsiveness and flexibility and secondly in cost-reduction. Therefore, an appropriate management system should be established in order to achieve efficient information flow and to be able to use effective performance measurements. To be truly agile supply

partners must be able to move more quickly and utilise the existing equipment, existing facilities, and existing design increasingly efficiently [**24**].

The speed of designing new products and production methods is essential in pursuit of agile manufacturing. This requires an intelligent engineering design support system which provides rapid evaluation of the designs and design changes enabling all levels of the organisation to work seamlessly together [**23**].

Technologies

Today's global and distributed manufacturing environment information technology plays a great role. It is involved in many other technological enablers of agile manufacturing, such as robotics, AGVSs, NC machine tools, and CAD [**25**]. Agile manufacturing requires a rapid changeover from assembly of one product to assembly of a different one resulting in need for rapid hardware changeover by robots, part feeders, modular assembly hardware, and visual inspection systems. These again require rapid software changeover that is facilitated with, for example, graphical simulations.

Information technologies, such as Internet, CAD/CAM, MRP, and ERP are of great importance when integrating globally distributed companies in agile manufacturing enterprises. Flexible simulation tools will enhance the performance of virtual enterprise when, for instance, software testing can be performed in simulated environment instead of using physical work sells. The selection of technologies – either hardware or information – for achieving agility in manufacturing depends greatly on the strategies that are selected to meet the changing customer and market requirements. FMS may need AGVs and robots, whereas JIT requires EDI [**23**].

Systems

The systems for agile manufacturing include software and decision support systems for planning and control operations including materials requirements planning, design, manufacturing resource planning, scheduling, and production planning and control. Agile manufacturing requires a capability of switching rapidly from old ones to new products. This again requires the company to build design systems to reduce non-value adding activities and thus the time to reach the markets with right products at the right time. As an example of tools, Computer Supported Cooperative Work (CSCW) prototypes have been developed to aid engineering teams in the design of agile manufacturing facility. Prototypes support the functions of design system, such as parallel processing of information, group memory, electronic brainstorming, and consensus building in the design teams. The author also points out the importance of reconfigurability of both hardware and software to achieve agility in manufacturing [**23**].

Tu suggests that production planning and control in an agile manufacturing environments include the following aspects: (1) modelling of evolutionary and concurrent product development and production under a continuous customer's

influence; (2) real-time monitoring and control of the production progress in virtual company; (3) a flexible or dynamic company control structure to cope with uncertainties in the market; (4) adaptive production scheduling structure and algorithms to cope with uncertainties of production state in virtual company; (5) modelling of production states and control system in virtual company; (6) the reference architecture for a virtual company [**26**]. The flexibility can be partly achieved through system control software that is adaptable to new products and components without being unreliable or difficult to maintain. Therefore designing the software in such way that facilitates future changes is essential [**23**].

People

Forsythe summarizes human factors contributions in agile manufacturing environment as follows: (1) development of business practices; (2) design of enabling technologies; and (3) management of the introduction and fielding of new technologies and business practices. In agile manufacturing, integration and networking of information technologies occur in all levels of the enterprise. Hence, system and software compatibility is essential to the seamless flow of product data through the agile enterprise and it cannot be maintained without the coordination and empowerment of administrative and support staff. Often, information does not flow due to human causes and agility is lost; therefore, eliminating human points of failure in infrastructure is essential and should be actively supported [**27**].

Radical changes in the line of reengineering business process caused by the physical distribution of the virtual enterprise demands a total support of top management in terms of technical and financial support together with employee empowerment. Active involvement of top management is also vital in reengineering of the supply chain and logistics in agile environment [**23**].

Agile manufacturing has different requirements of workforce as compared with traditional manufacturing systems and are presented as follows: (1) closer interdependence among activities, (2) different skill requirements, usually higher average skill levels, (3) more immediate and costly consequences of any malfunction, (4) output more sensitive to variations in human skill, knowledge and attitudes, and to mental effort rather than physical effort, (5) continual change and development, and (6) higher capital investment per employee, and favouritism for employees responsible for a particular product, part or process. The focus of training in globally and physically distributed enterprise should be in improving the effectiveness of the multicultural teams and concurrently in gaining understanding of the culture and language of each other [**23**].

2.3.5 Supply chain agility

Jin-Hai et al. present a model that they consider the next evolutionary step from agile manufacturing. Five critical points are emphasized: strategic processing, multiple

winners, integration, core competence, and IT. According to the authors this approach, called real agile manufacturing, is the *strategic process* of responding to the competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets. Real agile manufacturing takes *multiple winners* (manufacturers, suppliers and customers) as an objective, *integration* (of resources, methods, technologies and departments) as the means, with IT as an essential condition and *core competence* as the key. [**18**]"

As reviewed earlier, agile manufacturing is a continuous and strategic process that must be closely incorporated in the organisation's development. However, as Sharp et al. state:

> *"Agility for organisation is a paradox, in that an agile manufacturer has to be lean, flexible and able to respond quickly to changing situations; yet it is recognised that no one company will have all the resources to meet every opportunity This means that companies will have to rely increasingly on partners and suppliers.* [**21**]*"*

In this model the problem is solved through an integration of core competences distributed among organisations that are carefully chosen to be able to focus on speed-to-market, cost reduction, and quality. Temporary alliances based on core competences improve the flexibility and responsiveness of organisations. In addition, as mutual benefit is the pre-condition of building this sort of alliances, they create multiple winners. Improving the performance of these multi-company alliances is complex and relying on the use of cross-organisational teams, information sharing, resource sharing, and risk sharing. The traditional view of an organisation as a separate entity is shifting to more cooperative multi-company perspective. This cooperation requires mutual understanding and trust as a basis of building successive and long term relationships. Integration has gone through several steps beginning from workshop level and spread to include enterprise level and even beyond. Due to the changed environment, modern management methods are concerned with the analysis, design, selection, and activities of entire production system. Thus, to satisfy the requirements many new theories and methods are developed including JIT, MRP, TQM, concurrent engineering, and lean. Finally, information technology is considered as a powerful tool for promoting innovation, the basis of an enterprise's information resources, the bridge between partners, and a platform for knowledge management and the learning oriented organisation. Moreover, functional IT is the essential condition for efficient operations within the organisation [**18**].

Characteristics of supply chain agility

Many required capabilities of agility lay outside of manufacturing and the supply chain wide focus is very relevant when assessing these capabilities [**28**]. Hoek et al. identify four dimensions of agility as follows:

- Customer sensitivity through continuous enrichment as against focusing on waste elimination.
- Virtual integration, with emphasis on instantaneous response in addition to stable production flows.
- Process integration through self-managing teams as against work standardisation and conformance.
- Network integration through "fluid" cluster of associates who venture into temporal opportunities [**28**].

Christopher considers supply chain agility from rather the same perspective; and according to him, the key elements are market sensitivity, virtual supply chain, process integration, and network. *Market sensitivity* means the ability of the supply chain to read and respond to real demand; in other words, being demand-driven rather than forecast-driven. *Virtual supply chain* and virtual integration involve a broad use of information technology between customers and suppliers in order to respond rapidly in to changing requirements. Technologies enable the whole supply chain to respond to the same data, so that distortion of information as well as the response time is remarkably shorter than in conventional supply chain. *Process integration* means collaborative working between buyers and suppliers, shared information, compatible systems, and shared product development. This kind of cooperation is increasingly important since companies are focusing on core competences and outsourcing other activities. *Networking* in supply chain creates a so called extended enterprise in which the boundaries of the companies are blurring and process integration, joint strategy formation, transparency of information, and even open-book accounting are increasingly in use [**29**].

In line with the above models the recent one is presented by Agarwal et al. (Figure 2-8) and it summarises the characteristics of agile supply chain. In contrary to the model presented above, this model adds on centralized and collaborative planning, which emphasises the role of the common goals and planning that takes into account the perspective of every part of the organisation or member of the supply chain [**30**]. Nowadays not individual companies are competing against each other but rather the networks of companies. Therefore the most successful networks are those with better structure, coordination and management of relationships to partners and who are committed to closer, better, and more agile relationships with their final customers [**29**].

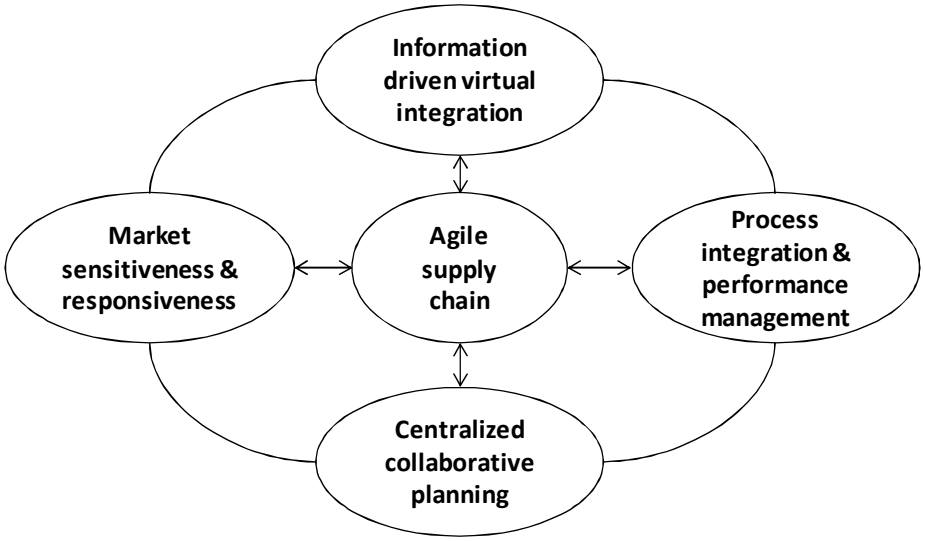

Figure 2-8: Agile supply chain [**30**]

Modelling characteristic of agility in supply chain

Agarwal et al. performed a study identifying variables that have an effect on supply chain agility. The main objective of the study was to derive interdependencies and relationships among these variables, as well as, to classify the variables according to their driving and dependence power. As a result, altogether 15 variables were categorized into three clusters, which were organized into three levels and interdependencies were marked with arrows (Figure 2-9).

The seven top level variables – cost minimisation, customer satisfaction, new product introduction, service level improvement, delivery speed, quality improvement, and lead time reduction - have a direct influence on agility, have a weak driving power, and are strongly dependent on the middle level variables. From these seven variables, cost minimisation and customer satisfaction can be highlighted, since they are the outcome of all the other operations – customer satisfaction is a visible outcome and cost minimisation the inner The two middle level variables – market sensitiveness and data accuracy – have medium driving power and medium dependency on the low level variables. The low level variables - minimizing uncertainty, trust development, minimizing resistance to change, centralized and collaborative planning, process integration, and use of IT tools – have a strong driving power, but low dependency on other variables [**30**].

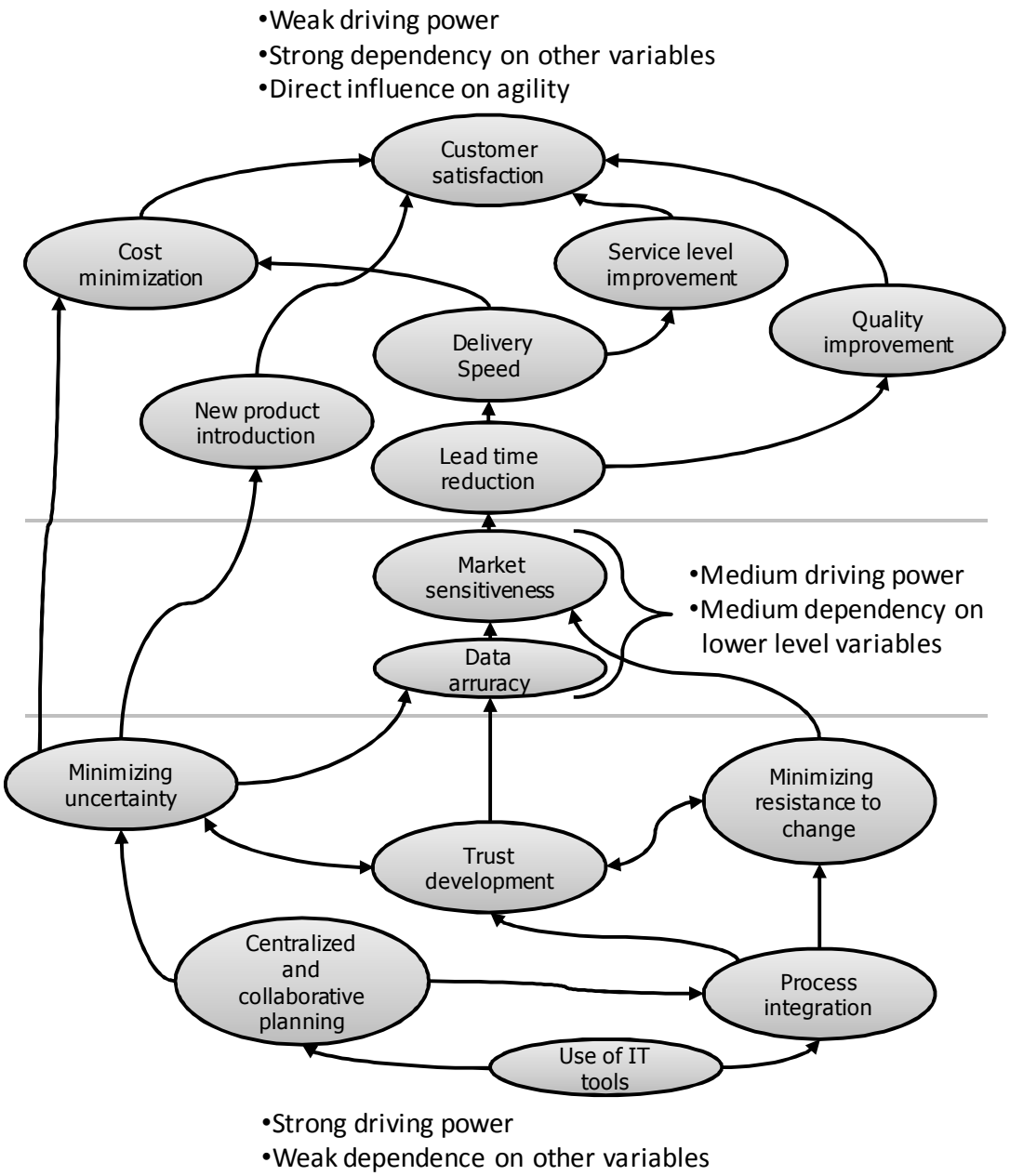

Figure 2-9: Model of the variables for improving supply chain agility (modified from [**30**])

The here introduced model suggests that improvement in higher levels requires a strong lower level performance. First, strong cooperation and trust within the supply chain – a prerequisite of building agility – is achieved through use of IT tools and process integration. These variables are interconnected to minimising resistance to change and minimising uncertainty. Consequently, improvement of these variables enable the next level – data accuracy and market sensitiveness – to enhance the performance ability of the supply chain and affect directly to the top level variables. Finally, the top level is achieved through the following variables:

- new product introduction, which is important to staying actively at the forefront of the development
- lead time reduction in the whole supply chain, which leads to both

- quality improvement through reduced waste and faster interference to problems and
- delivery speed, which again has a direct effect on
- service level improvement

These variables ultimately improve the customer satisfaction and reduce the overall costs of the supply chain increasing the agility of the supply chain. [**30**]. Some of these variables and their significance in supply chain agility are considered in greater detail in the case study part of this thesis.

2.4 Theories supporting the case study

Agility, as defined above, does not consist of any particular set of tools, which would offer an extensive repertoire itself to work with when building processes to agile direction. Therefore, many well known methods and theories that offer a wide variety of ways of improving organisation's performance can be used when improving companies' performance ability. Next, some theoretical approaches – commonly related to agility and process optimisation – are introduced.

2.4.1 Lean

According to Lean Network, lean is "a systematic approach to identifying and eliminating waste through continuous improvement by flowing the product or service at the pull of the customer in pursuit of perfection [**31**]." Womack et al. define lean production as "doing with less and less human effort, less equipment, less time and less space while coming closer and closer to providing customers with exactly what they wanted [**32**]". Lean thinking was first introduced by Toyota and it has had a major impact on different industries during the last decades. The often forgotten fact is that lean is not only a manufacturing paradigm and methodology for improving processes, but rather a holistic view concerning all operations in the organisation. Therefore, the 4P model of Toyota is introduced.

The 4P Model of the Toyota Way

The model consists of four dimensions: problem solving, people, process, and philosophy. As illustrated in Figure 2-10 the philosophy forms a firm foundation of the model on which other elements are build on.

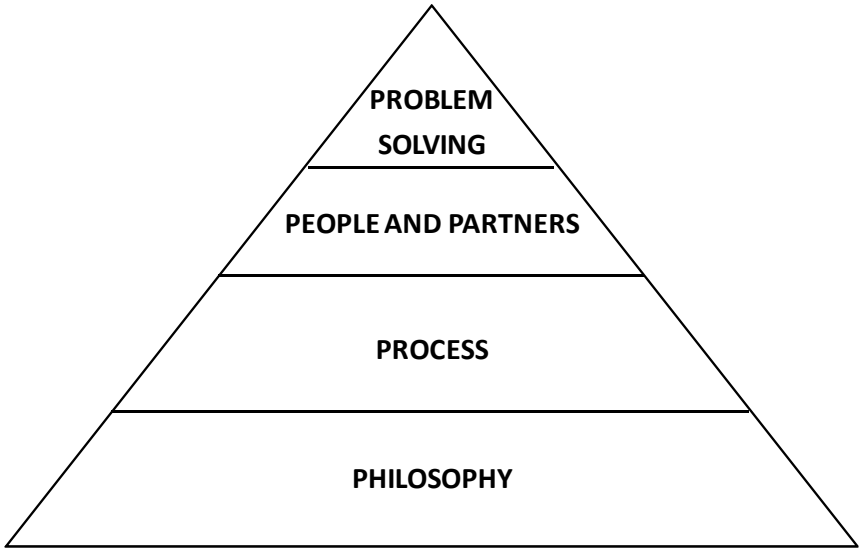

Figure 2-10: The 4P model of Toyota Way

- Problem solving

  Every employee should be considered as a good problem solver and every problem is solved though a root-cause-analysis to embrace continuous improvement and learning.

- People

  Respect, challenge and grow them. People and partners are the greatest capital of the organisation.

- Process

  The right process with elimination of waste will get the right results and all processes should be development continuously toward perfection.

- Philosophy

  Making decisions based on short term views and goals should be supplanted with long term objectives. Company's philosophy is and should be the foundation of all operations of the company and, for example, for Toyota it's satisfying customers and generating value for the customer, society and economy. [**22**]

Within this framework a set of tools for introducing lean thinking and methods into an organisation is presented. Lean has five principals that are considered as a guideline when implementing lean thinking into an organisation [**33**]:

1. Specify value to customer
2. Identify the value streams for each product
3. Make value flow without interruptions
4. Let the customer pull value from the producer
5. Pursue perfection

First, in lean thinking, customer always specifies the value of the product of service. In other words, from customer's point of view producer's only justification for existence is producing value. Therefore, company must identify and specify all the value added activities for which the customer is willing to pay.

Next, the following step is identifying the value stream for each product or service. The key idea is to think holistically and to avoid sub-optimisation, since focusing on improving only one certain area can be harmful for the whole process. Value stream consists of all the activities related to the stream of producing product or service, including both value added and non-value added activities. Value stream activities can be divided into three categories:

- value added activities, that add value to the final product, such as welding or hole drilling
- non-value added activities, that do not add value to the final product, but are necessary auxiliary activity, such as quality assurance and accounting
- unnecessary non-value added activities, that can be removed immediately, such as acceptance inspection following the well performed quality inspection

Third, after value streams are identified and the waste in the processes is eliminated, the flow that adds value is created. The ultimate goal is to build a flow that consists only of activities that add value to the final product. This flow is pursued, for instance in factory level, by reducing the set-up times and arranging the machines close together to avoid transportation and conveyance when possible.

Fourth, the demand of the markets creates a pull that draws products and services toward the end customer. In other words, the processes fill the empty slot created by the proceeding process rather than push the products towards. This enables the company to reduce time-to-market and avoid obsolescence. In addition, pull may solve problems in processes where the flow is difficult to build.

Fifth, the pursuit of perfection combines all the other points to operate together in a continuous iteration loop. Lean is not a development project but a continuum that requires an involvement of the whole organisation over a long time period. In an ideal lean organisation processes are made transparent so that the problematic processes can be seen more easily and new ways of adding value can be created even by people not actively involved in the process [**34**].

"Deadly Wastes"

One characteristic of lean – waste reduction – is reviewed due to its significant role in process improvement through a lean organisation. Liker concludes eight types of wastes adding one to the original model of Toyota Production System as follows:

- Overproduction: manufacturing unneeded parts.
- Waiting: workers are observing automatic machine, waiting for a tool, delivery, component, or otherwise doing nothing due to malfunction of another process.

- Unnecessary transportation or conveyance: delivering unfinished product for long distances, building an inefficient delivery system, or delivering products to and from stock.
- Over processing and incorrect processing: performing unneeded processes in manufacturing, processing inefficiently, or manufacturing higher quality than required.
- Excess inventory: too much raw materials, work in-process, or finished products.
- Unnecessary movement: every unneeded movement an employee has to perform during the work task.
- Defects: manufacturing or repairing defective parts.
- Unused employee creativity: wasting time, ideas, skills, improvements, or learning opportunities, when employees are not engaged or heard.

Overproduction is considered to be the main cause of the other types of wastes and should be avoided in all occasions. Other significant type of waste is excess inventory since it hides problems of other processes, such as uneven production load, late part deliveries from suppliers, and long set-up times [**22**].

2.4.2 Leagility

Leagility refers to combining lean and agile approaches. Recently, many researchers have compared lean and agile approaches and their applicability to enhance supply chain performance in different situations. Christopher suggests that even though there are situations where "pure" agile or lean strategy might be working well for certain cases, often a combination of these two – a hybrid strategy – is more efficient and appropriate in most situations [**29**]. Stratton and Warburton present a model for practical integration of lean and agile supply consisting of four separating elements: separation in space, separation within a whole and its parts; separation in time, and separation upon condition. Next, this approach is reviewed in detail.

Separation in space

Separation in space makes a distinction between functional products with predictable demand and innovative products with unpredictable demand. The innovative products risk loss of sale if demand exceeds supply and risk of obsolescence if supply exceeds demand. Therefore, with agile supply chain the focus is on responsiveness, and with lean supply chain on efficiency. Figure 2-11 illustrates the need to match the focus of supply chain to product types. It suggests that there can be found a match between different type of supply chain – either efficient or responsive – and product type – innovative or functional. Operating outside these match areas is either very difficult and

cost-ineffective (efficient supply chain with innovative products), or unreasonable (responsive supply chain with functional products and stable demand).

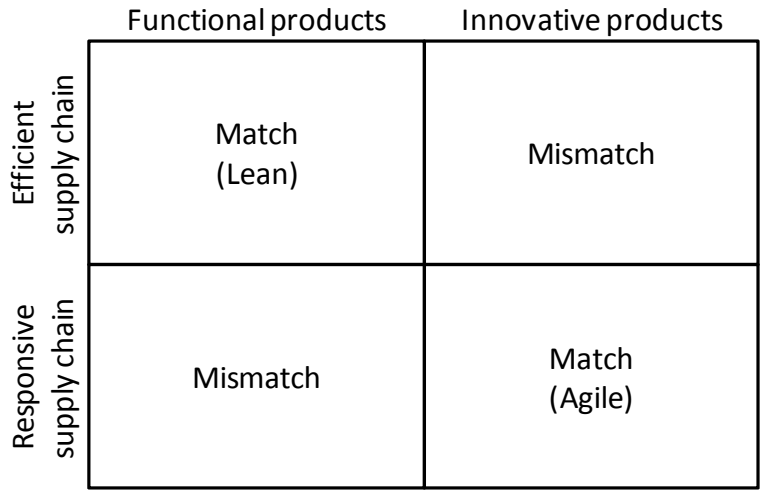

Figure 2-11: Matching supply chain with products [**35**]

Separation within a whole and its parts

Separation within a whole and its parts requires an introduction of decoupling point. Decoupling point – or order penetration point – separates the part of supply chain oriented towards customer orders from the part of the supply chain based on planning (Figure 2-12) [**1**]. In addition, the decoupling point is the point at which a strategic stock is kept as a buffer between the volatile customer orders and/or product variety, and levelled production output [**36**].

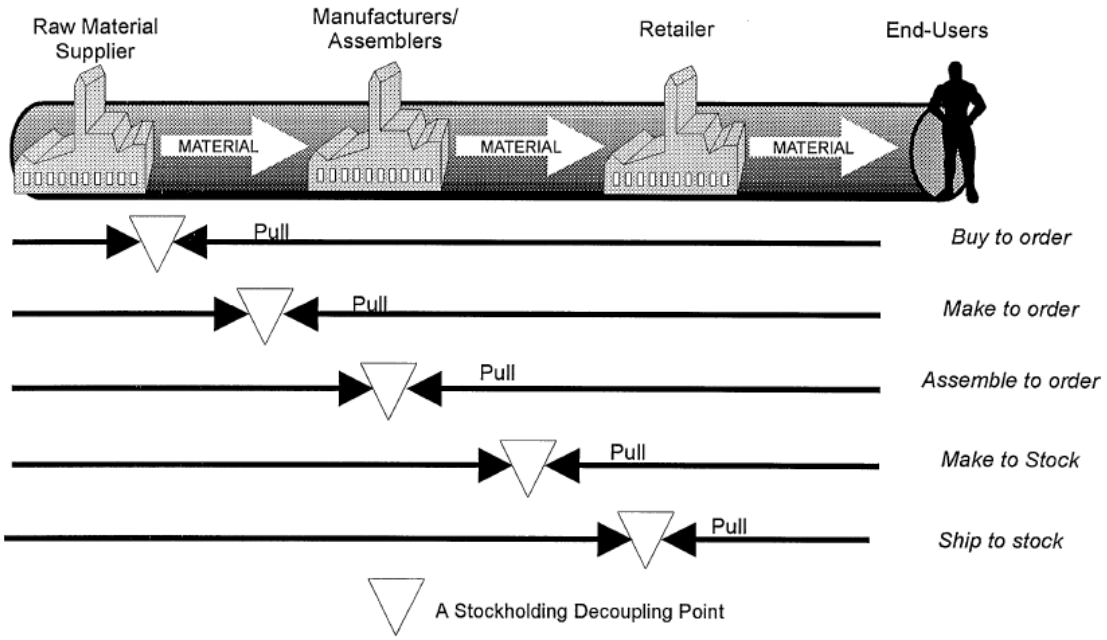

Figure 2-12: Supply chain strategies and decoupling point [**1**]

Different supply chain types can be divided into five categories according to the place of the decoupling point – buy-to-order, make-to-order, assemble-to-order, make-to-stock, and ship-to-stock.

Buy-to-order approach is suitable if products are unique and do not necessarily contain the same raw materials, the end-customer is willing to accept long lead times and the demand of the products is highly variable. If the risk of obsolescence of the products is high, buying to order is a good alternative for the supply chain.

Make-to-order supply chain is able to change from one product to another as long as the used raw materials are the same. The products are usually highly customised – but not unique – and the lead time is still rather long. However, this supply chain is only exposed to risk of holding raw-materials and components in stock.

Assemble-to-order is very common approach in machine building industry. Components and sub-assemblies need to be stocked in order to response to rather short lead times. In this approach, the decoupling point moves to within the manufacturers and assemblers and the customisation is postponed as late as possible. The supply chain is able to provide the customer a range of products, either customised or not. The lead time is greatly reduced and that increases the risk of obsolescence of the components, but not the whole end-product, since the components and parts are versatile.

Make-to-stock supply chain provides standard parts, but is able to respond to location changes in demand as long as the overall demand remains steady. *Ship-to-stock* approach provides standard products in fixed locations and is very inflexible. These kinds of supply chains must be able to forecast the demand very accurately and keep the levels of the stocks on a right level to avoid stock-outs and overstocks [**36**].

The concept of decoupling point uses the opportunity to postpone the design configuration and therefore reduce the impact of variation in the upstream. This concept is widely used to minimize the consequences of market differentiation and the risk of holding inventory in its final differentiated form. Lean approach can be applied to the supply chain upstream of the decoupling point as the demand is smooth and products are standardised. Towards the customer from the decoupling point, the operations are driven by demand and toward the upstream the operations are driven by forecast. Figure 2-13 illustrates the approach of dividing supply chain into two parts: lean, in which the demand is stable and levelled with protective inventory at the de-coupling point; and agile, in which the customisation to different products is done and the demand is fluctuating. The concept decoupling point is used in mass customisation and shifted as far downstream as possible to enable fast response to customer demand and to keep the value of work-in-process as low as possible [**29**,**37**]. A deeper consideration of mass customisation is excluded from this thesis due the nature of the case study supply chain.

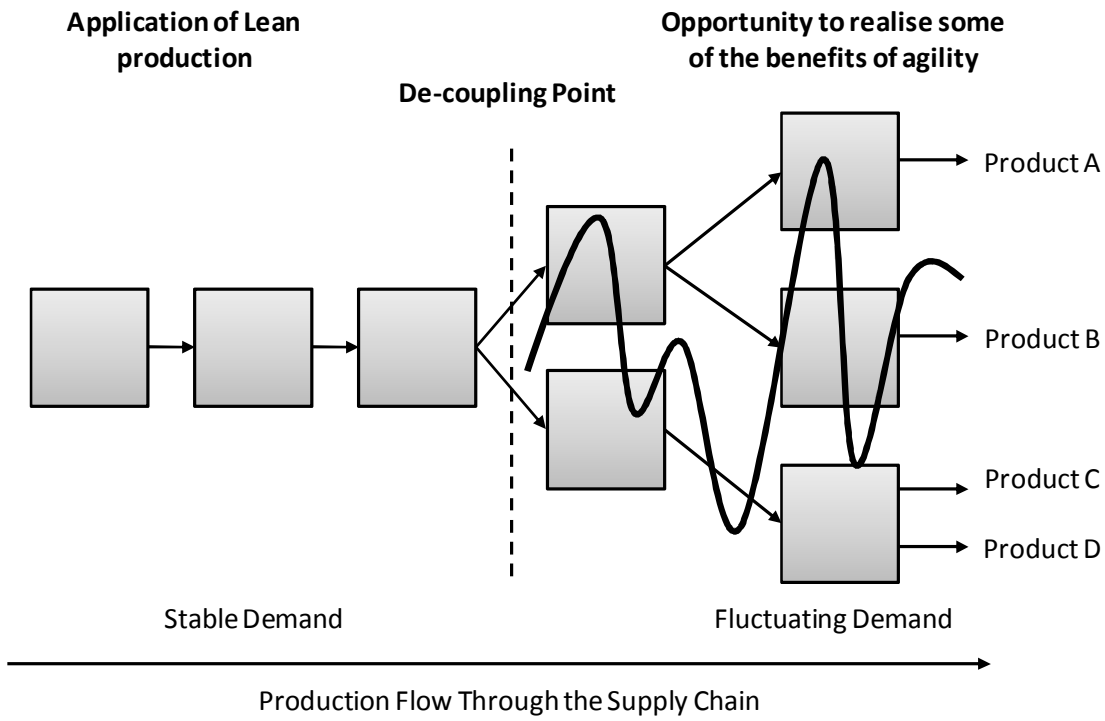

Figure 2-13: Combining lean and agile concepts [**37**]

Decoupling point enables upstream demand to be levelled the same way as lean supply it is decoupled from market demand variation through level scheduling. In contrary, downstream from the decoupling point the number of products flow through one value stream. The demand variation is high and primarily managed through an investment in protective capacity rather than inventory, increasing the agility at the same time [**36**].

In Figure 2-14, the use of decoupling point in combining lean and agile approaches is clarified further. In a pure lean supply (a) the production is levelled and the internal fluctuation is low and capacity loading is high. The inventory is often held at the end of the supply chain to protect against the market fluctuation. Second, a purely agile supply (b) also has low internal inventory levels and it prepares to market fluctuation that penetrates into the supply chain by building protective capacity. Third, the combination of these two (c) offers several advantages. The demand fluctuation penetrates only to the point where protective inventory is held and the upstream of the supply chain can be optimised more easily. The inventory should be held in generic level in order to decrease stock variants and the overall stock volume. In addition, since the components are more generic, the same components can be used in larger variety of finished components. The ability to configure products late and possibly very close to the end customer means higher variety and lower costs enabling strategies of mass customisation to be applied [**29**,**35**].

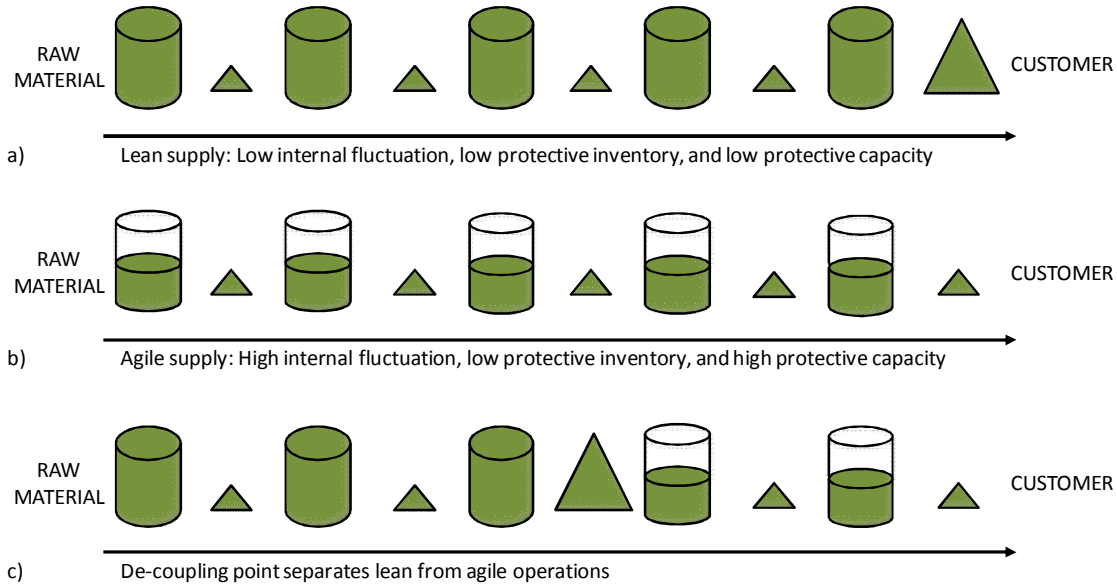

Figure 2-14: How separation point combines lean and agile approaches [**35**]

Separation in time

Separation in time refers to seasonal changes in demand, such as with fashion clothes or other strongly seasonal products. According to one example, a clothing company solved the problem by separating early and late production runs based on the predicted level of uncertainty. The early production runs are efficiency focused and the later top-up orders are delivery speed focused, in response to customer sales data. In the first case, the protective inventory enables the efficient production of the early runs. In contrary, on the second case, the investment of protective capacity enables fast response to uncertain demand [**35**].

Separation upon condition

Separation upon condition is more generic approach including the three other principles, also applying to more abstract parameters, such as order winning criteria and protective capacity. The concept of protective capacity can effectively be used to separate out the operational requirements that often occur. As an example, the conflict whether to centralise or decentralise manufacturing can be resolved by separating the resources that constrain the throughput and using capacity availability as the condition of separation to form a mixed functional and cellular organisation. As a result, the limiting capacity can be remained central as a shared capacity and cellular manufacture replaces protective inventory with protective capacity [**35**].

2.4.3 Theory of Constraints

According to Stratton and Mann Theory of Constraints (TOC) is a management philosophy for improving company's performance by focusing on removing constraints within an organisation. The theory has been developed my Eliyahu Goldratt for more

than 20 years and its principals have been applied to addressing not only physical resource constraints but also policy and paradigm constraints within the organisation. TOC suggests that system throughput is limited by one or few constraint process and improving the other processes does not increase the overall throughput of the system. TOC defines a constraint as "*Anything that prevents the organisation from achieving higher performance versus its goal*". Constraints come in three types presented as follows:

- *Equipment*; the way the equipment are used limits the throughput of the system and the ability to produce more goods or services.
- *People*; the lack of competent and skilled workers limits the system
- *Policy*: a policy of the organisation – both written and unwritten – that limits the throughput of the system [**38**].

In contrary to lean that focuses on improving the performance and minimising waste in all processes, TOC focuses on improving the value adding performance of the organisation by concentrating on one process – a constraint – at a time. In other words, TOC focuses on finding the constraint, or a small number of constraints, that are limiting the throughput of the system. By allocating resources to these constraints and improving their performance, the overall increase in throughput is achieved with minimal increase in cost.

The value added productivity in for-profit organisation is presented as follows:

$$\text{Value added productivity} = \frac{\text{T}}{\text{OE}},$$

where the term Throughput (T) is used to identify the value added component, and Operating Expense (OE) is used to cover all the expenses. TOC centres on increasing Throughput of the system rather than reducing Operating Expenses. That is, although cost cutting is important is should not be carried out without strategic perspective. TOC has many aspect and tools for problem solving and as being the most applicable for the project, "the five focusing steps"-tool is presented next [**39**].

The five focusing steps of TOC

According to Goldratt, TOC follows five steps to eliminate constraints from the system. *First*, identify the constraint. This step is often very easy and straight forward, since the constricting processes in the organisation are usually well known. *Second*, decide how to exploit the constraint. To fully capitalise the output maximisation of this limiting factor, a sufficient case-by-case planning should be carried out. *Third*, subordinate all other processes to above decision. The idea of subordination is to assure that other processes outside the constraint do not limit the use of its capacity. Nor should this capacity be overloaded by other operations, since the chain is still only as strong as its weakest link. *Fourth*, elevate the system's constraint. Often, there is remarkably more untapped capacity than previously thought and by optimising the process the investment for the improvement can be rather low. However, more capacity might have to be

acquired by finding alternatives for the constraint, buying more machines, or hiring more people. *Finally*, if, as a result of these steps, the constraint has moved, return to the first step. After the weakest link has been strengthened, the following task is to find the next weakest link and to continue using this method as an on-going improvement tool [**38**].

2.4.4 Smartsourcing

Smartsourcing is a management tool defined by Thomas Koulopoulos and it offers means of improving the ability of companies and networks to be innovative. According to smartsourcing theory, companies should focus their operations on core competences, get rid of all the other operations, and allocate the released resources to develop the core processes. According to the author, networks using smartsourcing are able to react faster to changing market needs and respond to small market windows. To give a picture of smartsourcing, it can be described easier by what it is not:

Smartsourcing is not about economies of scale;	it is about economics of scope.
Smartsourcing is not just about technology;	it is about competency.
Smartsourcing is not about ownership;	it is about partnership.
Smartsourcing is not just about cost cutting;	it is about innovation.
Smartsourcing is not about cheap labour;	it is about smart, educated workers.
Smartsourcing is not episodic;	it is a continuous process.
Smartsourcing is not just about outsourcing;	outsourcing is only one facet.

First, to apply smartsourcing to company operations, its core competences need to be defined. Second, processes and work tasks need to be specified, so that they are transferable to partner companies. Third, the company must be able to evaluate widely the effect of innovation and development on the business. In Figure 2-15, the smartsourcing framework for assessing performance is presented. The objective in smartsourcing is to concentrate on core processes and to continually optimise them; everything else is offshored, outsourced, or re-engineered. Core competence is never a product; it is a process or a means of performing operations.

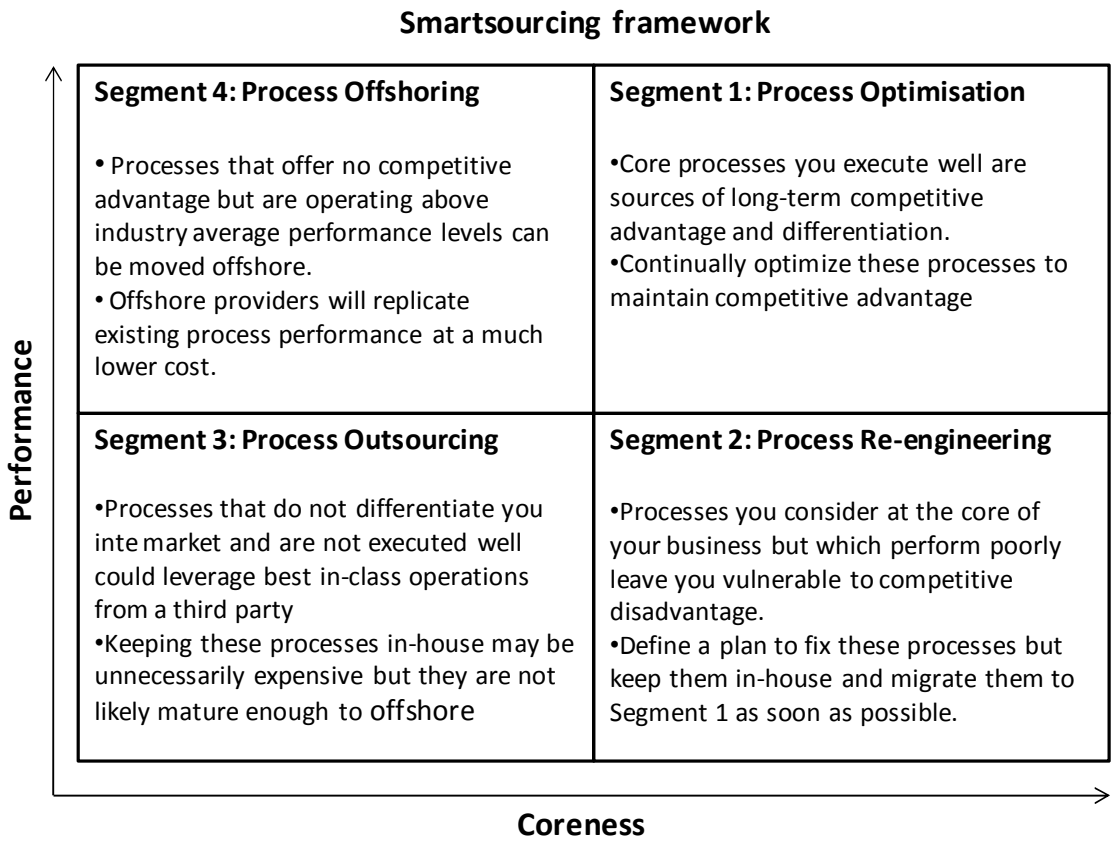

Figure 2-15: Smartsourcing framework [**40**]

Innovation

Innovation is in the core of smartsourcing. Innovation appears in three different types: new product innovation, new service innovation, and new market innovation. Companies' operations cross all of these types, but usually it has core competence only in one type of innovation. To effectively allocate resources to "right" type of innovation to maximise the investment output ratio, the significance of the certain process to business is required to be known. Consequently, if the process is a core process of the company, the investment in it must be remarkable. Other processes should consider being outsourced to partners whose core competence this process belongs and whose resources are allocated to improve this process. Often, core competences are not receiving the required amount of resources and are kept within a small group of workers resulting in situation where the overall amount of investment is low.

Future challenges of organisations

The goal is not to build companies and networks to correspond with a certain future. Since future can never be predicted accurately, the actual challenge is to build such an organisational structure and processes that are able to respond to future challenges. In other words, often the structure of the organisation is not the problem, but its inability to change in compliance with the environment.

This required ability to change causes certain conflicts in organisation. On the first hand, only flexible structures are able to respond to changing environment. On the other hand, workers, suppliers, and customers require defined areas of responsibility and continuity in order to keep the operations clear. This challenge can be approached by the concept of extended enterprise, in which the operations are placed modularly into own or partner organisation. In this approach, the needed solid structures occur in these small modular units, cells, and the flexibility of the organisation comes from fast re-organisation of these them. The cells are very adjustable and agile compared to fixed organisation and can operate simultaneously in hierarchical and horizontal organisation structure.

In this context, two of the essential challenges in extended enterprises are their *ability to preserve the trust among partners* during rapid organisational changes and the *ability to maintain open-systems thinking* in the organisation. The authors suggest both can be facilitated by the development of social networks that cross the organisation, regardless of the current structure. This kind of network requires efficient information flow. Therefore, especially individual workers need to be able to perceive their surrounding social network in order to efficiently know from both where and whom the needed information can be found [**40**].

3 Research methods

As mentioned in the introduction, the project consists of three phases: field study, case study, and conclusive part, from which the first two are reviewed here. In the case study part, ideas and methods from the theories introduced in literature review are considered and applied to development work and operations in case study supply chain.

3.1 Phase 1: Field study

In this phase, interviews were performed in nearly 30 companies – not included in the case study – from different business sectors. The goal of the interviews was both to define the current performance level of the companies and to find the characteristics of and best practises related to the strategic agility to be capitalized in the case study. The interviews were performed face-to-face in the chosen companies and memoranda were written for further study. The results of the first 20 interviews were summarized and presented to the case study companies in the management team meeting in the spring 2009. As a result of the proceeding discussions, the companies for the following 10 interviews were more specifically targeted. These interviews focused on specific areas of interest, such as flexibility in production, and the role of the layout and machinery investment in building agility. The final interviews of the first phase were completed in summer 2009.

3.2 Phase 2: Case study

In the second phase, three supply nets operate as a case study environment in which the best practices from the first phase combined with other theories are tested in practice. Each research entity is namely responsible for one supply net and coordinates the day-to-day operations with it. In addition, the research entities cooperate to gain synergy and to capitalise on the results of one supply network to whole research project. As noted in the introduction, the case study supply chain with which DPE cooperates consists of three companies. Next the course of the case study is presented.

First, a current state analysis was performed and the problems and challenges were identified. Next, the objectives of the research project within the supply chain were mutually set and agreed with the companies. Finally, measures toward these goals were taken continuing together with the writing of this thesis.

3.2.1 Current state analysis

The steps of the case study are defined as follows:

1. The current state analysis
    - Material and information flows both in company and in network level
    - Development needs and requirements
2. Defining the objectives
    - Setting objectives on the network level
    - Dismounting these objectives to company level goals
    - Preferring numerical objectives whenever possible
    - Avoiding sub-optimisation
3. Action plan and implementation
    - The actions are taken in company level in cooperation with other network members and in-line with network level objectives
4. Monitoring
    - Measurement of how the objectives are achieved
    - An on-going process parallel to the implementation
    - If needed, re-assessment and change of the action plan

First, the current state analysis was performed by defining the material flow. After this, the information flow was brought into the description as well. Next, the objectives for this project were discussed and decided on the basis of the outcome of and challenges brought up by the analysis. The main objective was to define goals that would improve the agility of the whole network and, again, form the company level objectives in line with these network objectives. Third, sufficient actions were planned and during the writing of this thesis, also performed. During the whole project, the current state illustration is modified and kept up-to-date during the project to offer companies a tool to use also after this project as a support in their operative work and future development projects.

3.2.1 Other research methods

Ideas and tools of many theories and methods are used during the research project. Lean thinking has been strongly present during the whole case study. For instance, the five-step approach to implement lean into a company was applied when defining the material and information flows of the supply chain and also when making assessment of the development priorities in the companies. According to lean approach, customer specifies the value of the product. Therefore, anything that does not increase the value to the customer should be considered a waste of time and resources. The next step, identifying the value stream for the product, was done in material and information flow analysis. The step three, making value flow without interruptions is an ongoing process

and will continue until the end of the project. It includes improvement both in manufacturing and in information systems.

TOC is also used in the course of the research project. Thinking through constraint seemed to be especially useful when development objectives were considered, since often constraints restricting the throughput are sought only from production. According to TOC, there are three kinds of constraints: equipment, people, and policy. Emphasising the significance of people and policy as constraints opened different approaches when considering the challenges in the network. Smartsourcing offered mostly an approach for thinking, when considering the competitiveness of the companies. It suggests that company should focus only on its core competences and either off-shore, outsource, or re-engineer the processes that do not belong to these. The focus, when implementing this kind of thinking to supply chain, was on increasing the companies' understanding on core competences and their potential in pursuit for better performance.

4 Results

This chapter includes the results and observations from both field study and case study and is divided into three parts. First, the field study part consists of both the problems discussed in interviews with companies and the best practices companies have adopted in their operations. Second, the case study part includes the current state analysis of the case supply chain in which the material and information flows related to tyre set production are illustrated both on the network level and on an individual company level. Finally, the key challenges and collaboratively set development goals for the supply chain are introduced.

4.1 Phase 1: Field study

The remarks and notations that have risen from the interviews of the first phase are concluded here. These perceptions and possible solutions are not arranged according to their frequency of occurrence, but rather considered here as the most significant ones when considering agility. Next, some of the problems that companies and networks are facing are presented as follows:

- Companies don't seek solutions actively when total market goes down. In contrary, they might even stagnate and just wait for the market to recover.
- Supply chain development and cooperation is not practiced actively. Resources and time are invested into cooperation with customers, but the upstream of supply chain often lacks the interest of the company. This area has been seen as an important for development among interviewees in future.
- Processes are not standardised properly resulting in excess expenses when working tasks need to be performed without clear operation models. Undefined processes also cause friction on the interfaces between partner companies.
- Network's relations are not in balance; that is, customer evaluation is experienced as a "taboo" and companies rarely participate in defining the development needs of their customers.
- Flexibility is sought only from production and the potential of other processes is easily ignored.
- Problem solving is too technology centred.
- Single product/small batch production is not considered cost-effective due to inflexibility in production and the challenges it brings to production management.
- Companies and networks are not aware of real cost structure; and therefore, are not able to improve it efficiently.

Best practices for improving agility in companies

The best practices and operational models that seemed to increase the competitiveness of the interviewed companies are concluded as follows:

- Cooperation between design office, component manufacturer, and main supplier in order to develop manufacturability.
- Optimistic attitude toward change that is strongly related to company culture and employee participation in development work.
- Global sourcing that is thoroughly considered from the viewpoint of costs, capacity, market and know-how.
- Opening operations to new market sectors, both geographical and line of business.
- Effective sharing and managing of design information
- Active monitoring and dismounting of strategy to the operational level of the organisation.

Couple of key practices should be brought up from the above list. First, cooperation was seen an important and increasing issue in today's competitive business environment. Not only cooperation with customers, but also an active participation in operations with suppliers was considered essential in order to be aware of the possible problems and upcoming challenges, for example, in case of new product introduction. In addition, some companies operated with "open book"-procedure. In other words, the customer/main supplier knows the cost structure of the supplier and the companies can openly plan the price of, for instance, new product according to this cost structure. Consequently, the profits brought by the increased cost effectiveness and process improvements can then easily be shared among the partners according to the contracts.

Second, optimistic attitude toward change was seen very important to keep company dynamic. In some company workers even requested work circulation and wanted to change their job time to time to maintain their motivation and to improve their working skills. In addition, with well planned job rotation, the company ensures skilled workforce, eases the problems occurring during an absence of a key employee, and even increases flexibility in production.

4.2 Phase 2: Case study

In the beginning of the case study, the view of the supply chain was scattered and unclear both to company representatives and to the researchers. The first meetings helped gain mutual understanding of the processes and of the way of working; still, the true challenges and goals for the project were not clear. One thing to be noted from the supply chain is that the overall performance of it at the beginning of the project was already rather good. Although the delivery reliability of Supplier 2 was not all the time

at a desired level, a protective inventory Supplier 1 helped ensuring to keep the overall delivery reliability to the OEM high. However, to improve the overall agility and competitiveness of the supply chain, the challenges should be charted and analysed. The key idea within our research team was to chart the constraints limiting a better performance, find and analyse the root causes of the emerged challenges and commit the members of the supply chain to the goals that are collaboratively decided.

The current state analysis was performed in cooperation with the companies through a series of interviews, during which constraints and problems within material and especially information flow were discussed. As mentioned earlier, the current state analysis was considered to help building a basis for the research project. It is a powerful and important tool for the companies to use in future development and cooperation projects. In addition, development projects require some kind of a current state analysis, so that the results at the end of the project can be analysed and reflected to the state that of in the beginning of the project.

Illustrating material and information flows has been one of the major tasks in the case study and the results are illustrated next. In Figure 4-1, an overview of the supply chain operations is presented. Upon the daily line-up – the point of time where the machine order is fixed at the OEM and after which any changes to the options are not possible to be made – the information about orders and forecasts is offered to suppliers. Supplier 2 receives the order and schedules both its own tyre production and the tyre set assembly. Then, wheels are ordered, as well as, protective inventory held by Supplier 2. Last, tyre set is delivered to the OEM and assembled to a vehicle. Next, the operations within each company are illustrated in greater detail. In the following figures, the information flow is illustrated with dashed line and material flow with solid line.

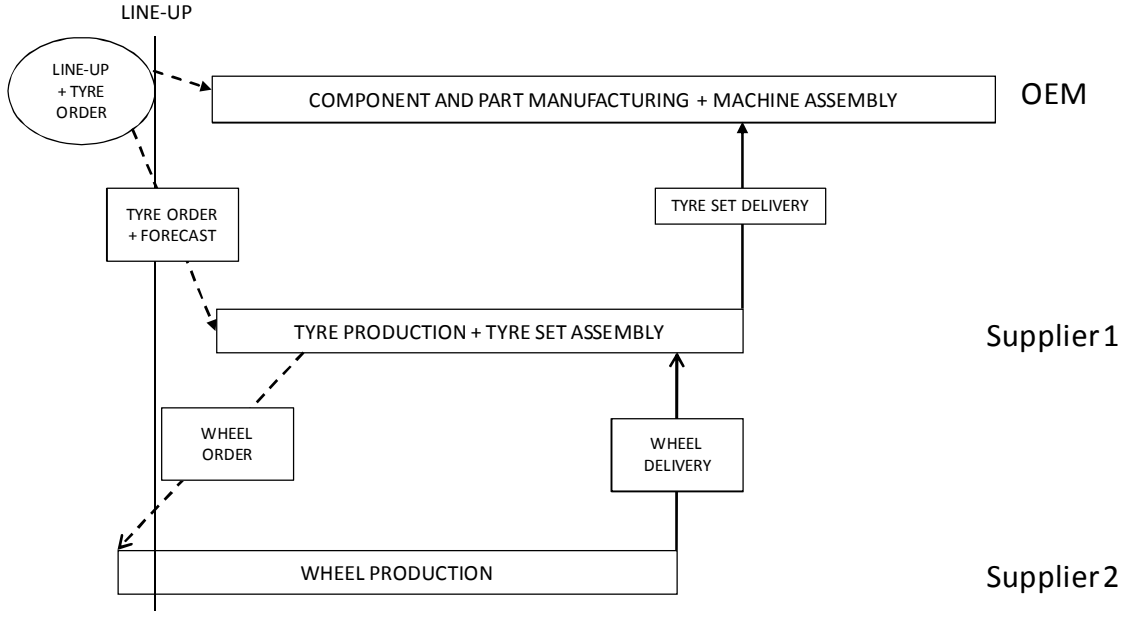

Figure 4-1: Material and information flow of the case study supply chain

OEM operations

As noted earlier, the case study part of this thesis concentrates mainly on operations in Supplier 1 and Supplier 2 and does not go deeply into operations performed in the OEM. However, a general flowchart is illustrated in Figure 4-2. Upon the daily line-up the suppliers are offered the information about the orders and the forecasts. Naturally, this point of time initiates certain operations also within the OEM.

The throughput time of the machine construction is 20 working days. This time period, again, is divided into two sections. First ten day section includes manufacturing and part assembly for own main assembly line. The other ten day section is reserved for the actual machine building. The aforementioned days of sections vary along with the current capacity loading and market situation but should be considered as a good estimate. The tyre set is required on the assembly line on the 13th day from the line-up.

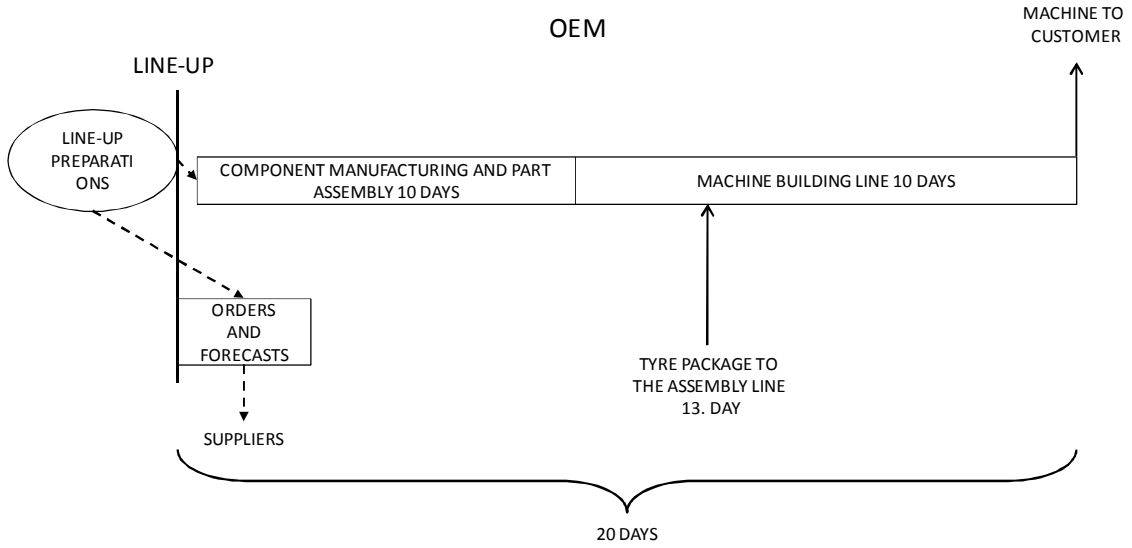

Figure 4-2: Material and information flow of the OEM

Supplier 1 operations

In the Figure 4-3, information and material flows of Supplier 1 on tier 1 are illustrated. First, when information about orders and forecasts is available, it is manually entered to company's own information system and processed into a form that can be used when scheduling production and ordering materials. This takes place every working day. In the order processing, information about wheel and tyre storages are needed. Using this information along with the forecasts, can production scheduling be performed and wheel demand evaluated. According to mutually agreed procedure, wheel orders are sent to supplier once a week and therefore there is zero to five days delay in the information flow. However, upon an exceptional situation or if wheels are needed fast, orders can be placed more often. Company's own production planning is also a continuous process and it is done combining together forecasts, production loading, and the current storage levels. Products have a defined storage level under which the

production planning for this certain product begins. Tyres are therefore manufactured almost exclusively to storage and only small amounts of tyres are made to order.

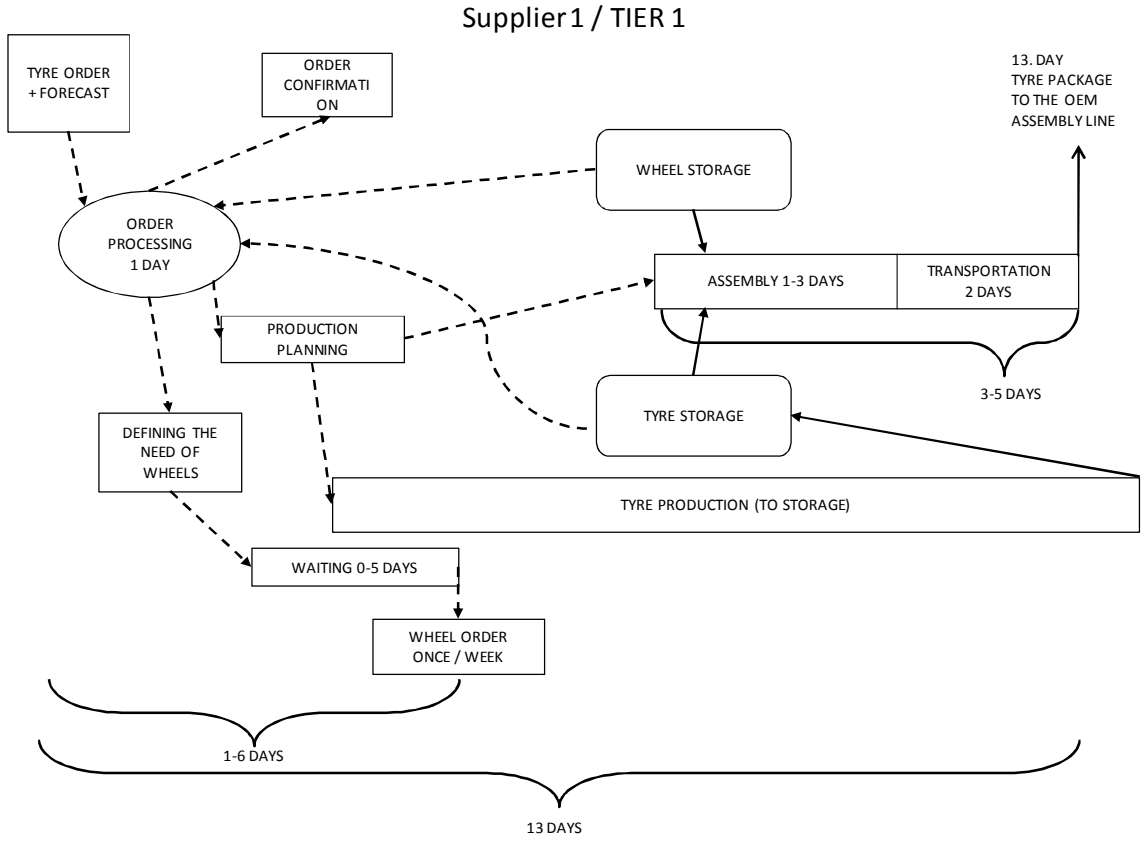

Figure 4-3: Material and information flow of Supplier 1

Supplier 1 has currently 13 days from line up to deliver the tyre set to the OEM and from this time period two days are reserved for transport. Depending on the capacity loading, the assembly is usually scheduled 1-3 days before the transport. Wheels are taken from storage and the assembly for a set of machine tyres lasts for couple of hours depending on the size of the set. Since normally the production of both wheels and tyres lasts longer than the delivery time, and to secure delivery reliability, wheel and tyre buffers are hold before the assembly. Therefore, the ability to deliver is strongly dependent on the size of the buffer and delivery reliability of Supplier 2. Finally, when own production is scheduled and wheel delivery dates are confirmed, an order confirmation is sent to the OEM.

Tier 2 operations

Operations within Supplier 2 are presented in Figure 4-4.The information Supplier 2 uses is purely orders. OEM provides suppliers also with forecast information but due to system incompatibilities and the lack of information about the levels of storage held by Supplier 1, Supplier 2 does not use it. A wheel order is transferred through an extranet in which changes to, for instance, delivery date can be made. Then, order is entered into

company's own ERP. After this, the production planning is performed and order confirmation sent.

First, when order comes, a comparison to rim production queue is made. If the incoming order possesses same rims as already in production, the batch sizes can be increased and job does not need to be placed at the end of the job queue. This procedure decreases the throughput time and increases flexibility. However, if the ordered type of wheel is not in the job queue or the amount of the order is fairly large, it is placed at the end of the queue. The length of the queue is usually up to ten working days depending strongly on the current capacity loading, as well as, on the amount of orders in queue.

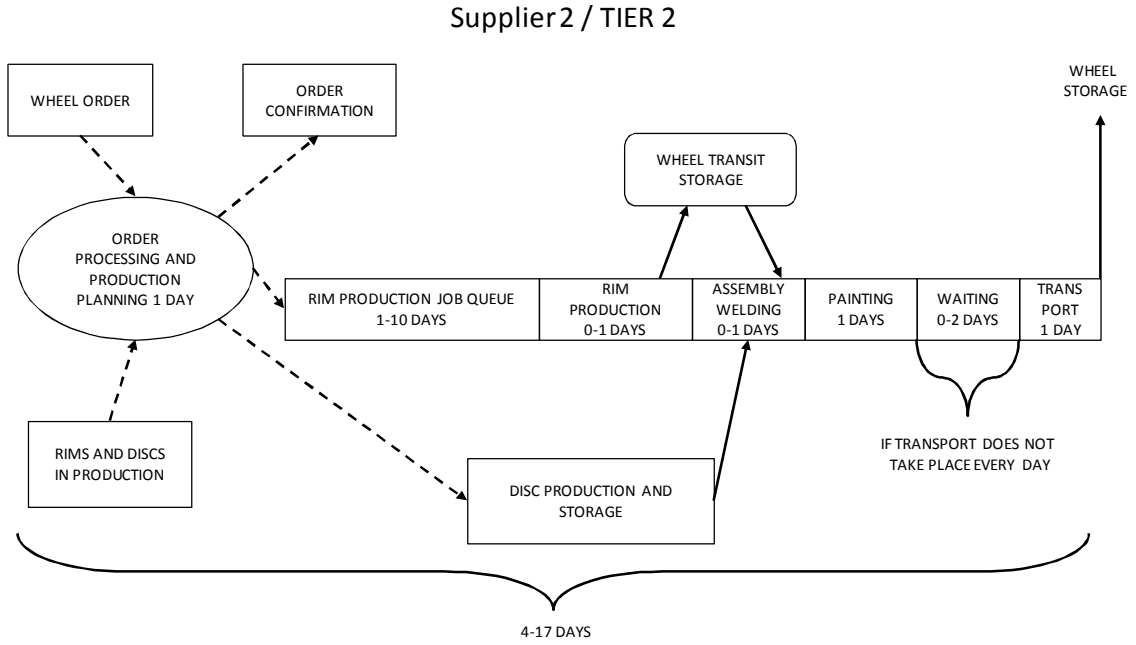

Figure 4-4: Material and information flow of Supplier 2

The reason for the length of the long waiting before the actual manufacturing is mainly the rim production line that is the main bottleneck of the whole production. Not entirely due to its low capacity but rather duo to its inflexibility. Set up times with the old production line were rather long (up to more than 2 hours) and as a result, the batch sizes increased. This, again, was a problem since the welding capacity was not sufficient to respond to very large batches. In addition, intermediate storages were needed to level the workload in the welding. In future, however, this is going to change since a new and robotised production line has just been opened. The line increases the capacity of the rim production, but the main advantage is the flexibility it offers: set up times will decrease significantly. The rim production itself is fairly short operation and when it is completed the rest of the production sequence takes one to two days.

Discs are manufactured separately from the actual orders and buffers are hold before the assembly. After the order is placed, the holes to the discs are made according to the specifications. The following work phase, assembly welding, is partly manual and partly automated. After the welding wheels go to painting that lasts approximately one work shift and after which the wheels are ready to be sent to the customer. If

transportation is not carried out every day to the Supplier 1, wheels wait for up to two days so that there is enough wheels to fill up a truck. This procedure is used nowadays when the capacity loading is fairly low and producing enough wheels to fill up the trucks takes more than one day.

Key challenges in the case study supply chain

The interviews and current state analysis revealed couple of main challenges in the companies' operations and are presented here. As the picture of the supply chain processes – the path from raw materials to a complete product, here the tyre set – begun to build up, the challenges in the production seemed to culminate into couple of key issues:

- The long lead time of the wheels in Supplier 2 results in inventory and manual work on Supplier 1. In addition, this has caused late deliveries and the delivery reliability remained low especially during the times of peak demand. The lead time for the wheel varies from 4 to 17 days.
- The breaks and manual work in information flow causes multiple days' delays that could – with more efficient and faster information flow – be reduced remarkably.

Goals for the case study supply chain

An important phase of the case study was to define the objectives for the supply chain. Lean thinking suggests that the value of the product is defined by the end customer. Therefore, every operation and improvement that does not increase customer value should be avoided. The customer pays only for the following characteristics: quality and characteristics of the product, and ability to deliver, including delivery time and delivery reliability.

According to the above list, the development operations in the network should be considered keeping these characteristics in mind. The future goals for the case network were discussed and defined collaboratively with company representatives and were derived from the key challenges that emerged from the discussions during the current state analysis. The mutually agreed goals for the network are presented as follows:

- To improve information flow – minimising the delays
- To minimise the inventories and lead time for the tyre set without jeopardising the delivery reliability
- To find the full potential of the network – determine if the whole network could deliver to orders

In addition to these goals, the ongoing operations include keeping the current state flow charts up to date and encouraging maintaining an active cooperation and

communication links between the network partners during the project, as well as in the future.

The researchers' focus in the forthcoming development work culminates into couple of points: to determine the future potential of the wheel manufacturing in Supplier 2, and to define the characteristics, possibilities, and constraints of the current information systems in order to determine the future scope of development work. Since the project continues during the writing of this thesis, the results from these actions are not documented here.

5 Conclusions

This section combines both the results and notifications from the case study to theories related to agility. The main focus is on how strategic agility is build into productional networks. First, the characteristics of agility summed from the perspective of Finnish machine building industry are considered in greater detail. Then, topics related to improving agility are discussed and tools from various theories are applied to observations made both during the case study and the whole research project.

5.1 Enablers of agility in production networks

According to Doz and Kosonen (see p13) strategic agility is built into organisation considering three dimensions: strategic sensitivity, resource fluidity, and collective commitment. The theory suggests that these do not improve agility when existing alone, but agility can be increased in the organisation only by bringing all of these three dimensions collectively into the development work and considering them as a whole. We have summed up factors which – according to our perception – belong to under each dimension and enable building agility into organisations. The model of strategic agility is targeted mainly to corporate management level and since our modification of the model is more operative due to the operative nature of agility in smaller companies, word strategic is excluded from titles. The framework itself appears to function well also when applied to operative level. The next illustrated framework (Figure 5-1) introduces these enablers consists rather of characteristics enabling agility rather than of agile characteristics themselves.

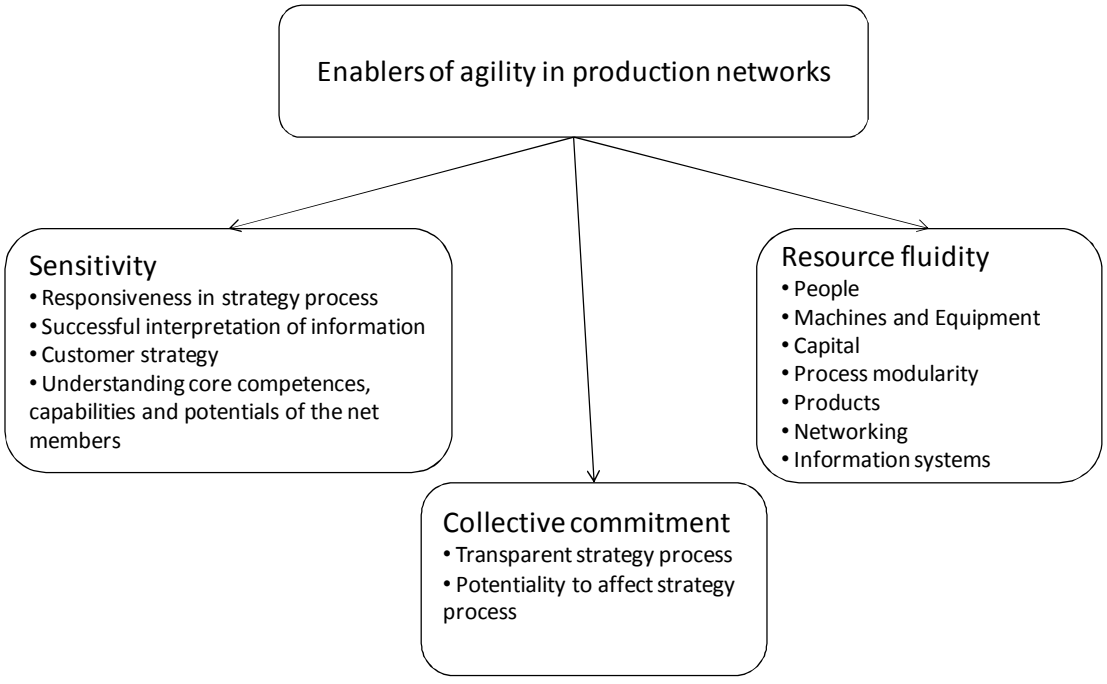

Figure 5-1: Enablers of agility in production networks

5.1.1 Sensitivity

According to our view, sensitivity includes the following aspects: responsiveness in strategy process; successful interpretation of information; customer strategy; and understanding of core competencies, capabilities and potentials of the network members. Next, these characteristics are reviewed in greater detail.

Responsiveness in strategy process means broadmindedness and observation that crosses the company's own line of business. That is, the strategy process should not be considered narrowly to include only current way of operating, but also introduce out of the box thinking and broader solution seeking.

Successful interpretation of information requires understanding the weighting and importance of received signals. Since the amount of information is increasing and it is valid shorter time periods, appropriate filters are essential. Thus, the challenge is to define what information is required for the operations and to adjust the filters in accordance with these requirements in order to make right conclusions.

Customer strategy refers here to independence of especially part and component suppliers from certain geographical region or line of business. Often, when companies operate only with few major customers, volatility and seasonal changes in demand can cause uncertainty and rapid volume changes in production. Therefore, widely distributed customer strategy gives security during changes in economical situation.

Understanding core competences, capabilities and potentials of the net members increases the ability of the companies – especially main suppliers – to react more efficiently to changes in markets. It also facilitates allocating resources to critical points in supply chain when, for example, development needs occur or the direction of strategy is been decided.

5.1.2 Resource fluidity

Resource fluidity is a combination of a number of factors: people, machines and equipment, capital, processes, products, network, and information systems. Next, under these factors, characteristics and enablers increasing agility are discussed.

People are always the most flexible factor that adjust most easily to new situations and should be considered as the most important factor. Fluidity from personnel can be sought by introducing flexible working hours in which employer is able to respond to the volatility of production by using workforce in more flexible manner. However, since employees also gain advantage from this system by being able to manage their working hours, the balance should be negotiated with personnel to ensure that the employer also benefits from the arrangement when needed. As discussed above in the field study chapter, well planned job circulation enables to build multi-skilled workforce and it therefore increases flexibility in the internal operation. Finally, one often used way to increase flexibility is to temporarily use rental workforce to respond to high demand peaks. However, the availability of skilled rental workforce can be rather low especially in specific lines of business.

Machines and equipment form the basis for flexibility in manufacturing. Versatile machinery, such as machining centres and multifunctional lathes, combined with partial or complete unattendedness and use of robotics is a key for increasing productivity and reactivity.

Capital structure and liquid assets strongly affect the company's ability of allocating recourses rapidly. Financial and loan structures are often very dominating aspects and can even limit the use of resources above any other.

Process modularity can be considered a very important aspect of agility. Small and standardised processes (or process modules) are easy to reorganise and duplicate which, again, increases the flexibility of using them.

Products and their design are usually closely related to core competences of the company and modularity is increasing rapidly in both processes and product pallets in order to, for example, gain competitive edge with better response to customer needs or to make assembly more efficient. Nowadays, the knowhow in manufacturing, related closely to personnel, is a factor that often forms the core of the operations and is one of the main strengths when considering competitiveness of the company.

Networking forms the foundation of agility both strategic and on operational level. Since companies are not able to respond to all market opportunities individually, partnerships with other organisations are significant. Cooperation with other companies should not be limited to building only tighter relationships with suppliers and customers, but horizontal integration should also be considered. With horizontal networking a group of companies on the same business line could more efficiently respond to demand by utilizing their core competences and knowhow. More precisely, the order coming into the horizontal network could be routed to a company of the most appropriate competence and capacity to respond to the order most efficiently and cost-effectively. One factor that can be included both to sensitivity and to resource fluidity is the cooperation with research institutes. Projects funded by Tekes or other funding agencies offer companies an opportunity to participate in development projects with rather low financial investment. This cooperation enables the company to gain access to the most current research information and methods that can be used in company's operations and development projects. In addition, involving students and researches are potential and competent workforce for the company in the future.

Information systems do not create value itself but are either enablers or hinderers of other operations. Therefore, the design of information systems should be done hand in hand with other development projects. For example, an improper design and implementation of an information system can even result in situation where the advantages and planned changes to improve agility are lost due to the limits of an information system. In addition, as noticed in the case study, the incompatibility between different information systems is often a very limiting factor and system integrators are needed. Ideally, all parts of the whole network use the same information system. However, since suppliers have often times many customers and vice versa, implementing a unified system is very challenging.

5.1.3 Collective commitment

Collective commitment is the last dimension of strategic agility and arguably the most important. Efficient agile strategy requires the commitment of the whole network and clarity of the mutual goal. We suggest that two important factors of collective commitment are transparent strategy process and potentiality of network members to affect it.

Transparent strategy process promotes understanding within the enterprise and among the network partners. The clarity about the role of each company in the network and the understanding of mutual goals furthers partners' commitment. Transparency also makes the evaluation of the strategy process easier.

Potentiality to affect strategy process again increases companies' willingness to commitment. However, this aspect is strongly depended on the structure of the supply chain network and if the network is strongly dominated by the main supplier the companies might have only a minor ability to influence the decisions concerning the network. However, if network dynamics are more balanced in the network, the optimisation of the strategy on the network level covers more ground among the members. In other words, when the strategy is optimised holistically, the members have more possibilities to affect when deciding the goals. Thus, the decisions are mutually understood and members are committed to them.

5.2 Improving agility

Building agile network is not using a box of agile tools, since such a box does not exist. Rather, an agile organisation is able to gather suitable theories and methods to support its way of becoming better in responding to changes – coming from within or from the environment – and thriving in competition. Many ideas from commonly known theories can be applied to support making the company or network more agile, but since situations and business environments differ significantly in each case, the current need has to be analysed and an appropriate theory or elements from a certain theory should be applied.

In this research project, ideas and elements from other theories are used for supporting thinking processes by introducing theoretical background for development work, and by linking elements of these theories to building agility. This chapter presents some of the business operations and fields to which a certain idea could be applied in order to improve the overall agility.

5.2.1 Combining efficiency and agility

Improving both efficiency and flexibility are often seen as contradictive goals. However, as presented in Figure 5-2, this is valid assumption only if the operations are already at the efficiency borderline. At the case of Company A, increasing both flexibility and cost-efficiency is possible without compromising either one until the

level of operations reaches the efficiency borderline at some point. At the case of Company B, the operations are already at the efficiency borderline. Therefore, increasing both characteristics is not possible without pushing the borderline further by innovating and investing on new technology.

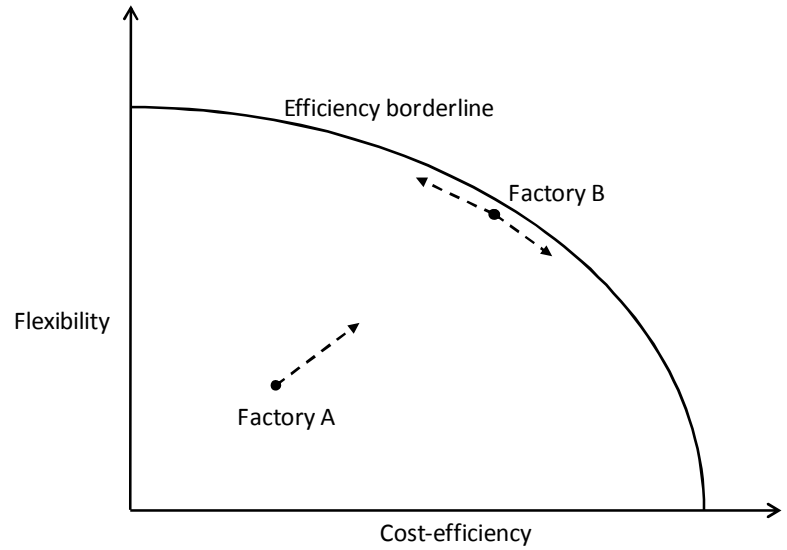

Figure 5-2: The concept of borderline efficiency [**5**]

Comparing to the previous approach and using the same analogy, building agility and keeping the costs low are somewhat contradictive goals, but only if "agility/low costs borderline" has been reached. At that case, in order to increase agility, the cost effectiveness will worsen. Many companies are operating significantly inside the borderline, and improving both characteristics is naturally possible and highly recommended [**5**].

The following example illustrates a situation where the borderline has already been reached. In Toyota, the processes are very efficient and standardised, so that, for example, new product development is significantly faster that of its competitors' and thus they have a significant competitive edge compared to other car manufacturers. On the other hand, in order to fully optimise and to level their manufacturing they require rather constant internal demand. Volatility of volume in demand is difficult to handle using lean methods in short notice, and it commonly results in finished good stock, which – in addition to storage costs – may cause other problems, such as obsolescence.

An approach to increasing efficiency still keeping the flexibility is to apply postponement and late differentiation into production and decouple the first and part of the production from the latter where differentiation is done. This offers a possibility to level the production of the first part to produce greatly standardised parts with lean approaches and to protect this part of production against fluctuation with inventory. The customisation is done in the latter part of production – from the decoupling point towards the customer – in which the number of product variants increases remarkably. As examined in literature review, the decoupling point and postponement enables the

organisation to operate very efficiently on one part and apply more agile approach to the part facing customer.

Often, the decoupling point after which the postponement is done, is placed as close to the customer as possible in order to lengthen the part of leanness in production. This allows the company to customise the products as late as possible keeping the inventory very generic until the customisation. According to Christopher there are two decoupling points: the material decoupling point should lie as far downstream in the supply chain as possible and near the customer; the information decoupling point should lie as much upstream as possible in supply chain as it is the furthest point to which information of the real demand penetrates [**29**]. However, offering information very far upstream is often seen unnecessary, and the decoupling points are for instance in the case study supply chain at the same place. Inspired by the observation during the study, another approach to combining agility and lean methods is introduced next.

As the information of the real demand should penetrate as much upstream as possible, could the material decoupling point be shifted towards the upstream at the same time? For example in the case of machine building industry, the construction of some components would allow this. For example, since one of the benefits of postponement is keeping the inventory in as generic for as possible, the solution could be shifting the inventory toward raw materials.

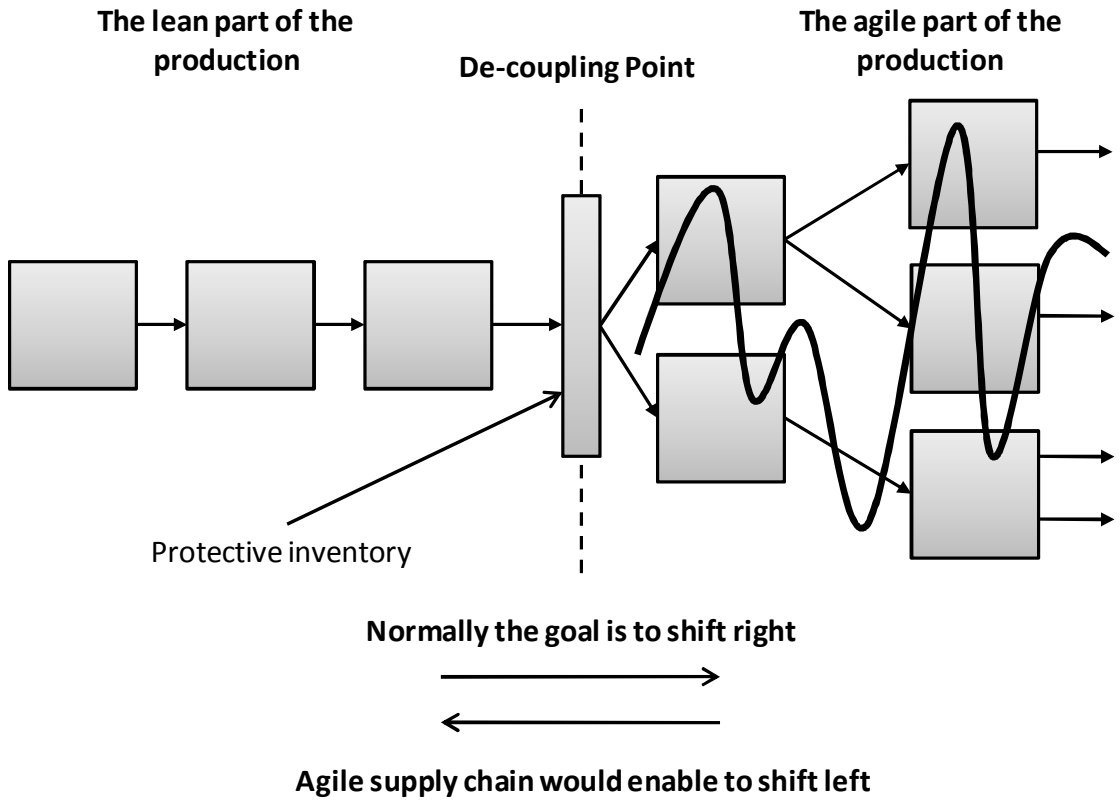

Figure 5-3: Shifting the decoupling point

Figure 5-3 illustrates the material decoupling point in which the protective inventory is placed. Undoubtedly, the flow of information about real demand should

extend as far upstream as possible, but if the agility of the supply chain could be increased, the decoupling point would not have to be shifted right, but even left. The rapid information flow through the supply chain combined with short throughput time in supply chain itself decreases the need for postponement. However, the applicability of this model is highly dependent on the resources of the supply chain and should be considered individually in every case. Even within one company, different products should be considered separately to find the best way of exploiting this approach. The more agile the supply chain is, the further the decoupling point can be shifted without decreasing the delivery reliability.

Decoupling point in the case study network

In the case study network, the above approach can also be applied. Both material and information decoupling points of the network are currently in Supplier 1 and even though the order information is available to Supplier 2, it is not in exploitable form since the amount of inventory at Supplier 1 is not accessible to Supplier 2. However, during this project, the development work is focused on both extending the information flow of the demand and orders further upstream in the supply chain to be exploited by Supplier 2, and also to find the potential of the new rim profiling line. The new automated rim profiling line increases the flexibility of the wheel production. It both decreases the throughput time of the rims and enables the rims to be produced in smaller batches. This, again, has a positive effect on the amount of rim inventory that both functions as a buffer for the assembly welding, and the gives new opportunities for the production control of the wheel manufacturing. It could be argued that the future development of the wheel manufacturing in the case study supply chain culminates into two things: how to organise the production control with new more flexible machinery, and what opportunities and challenges the change brings to production flow and throughput time. These considerations will have an impact on where the decoupling point is placed in future.

When considering the applicability of shifting the decoupling point the structure of the supply chain and the product should be analysed accurately. Shifting the decoupling point requires trust among partners and high delivery reliability, since if large buffers are held after the decoupling point to secure the delivery reliability the benefits can be scarce. It should also be noticed that the decoupling point cannot be transferred endlessly toward the raw material production. The decision concerning the point in which the protective inventory is held is a strategic that should be considered in line with the objectives of the supply chain.

5.2.1 Forecasting and responsiveness

Forecasting and responsiveness are two terms often at the opposite sides of the scale. If the changes in demand and in business environment can be forecasted a long time before they happen, the company have no need to be responsive. This was the case

decades ago, when production was planned for years ahead and no surprising changes emerged. However, now the business environment is very different. Making predictions about the future becomes more and more difficult and companies must be more agile to be able respond to unpredictable changes. Improving the forecasting processes is naturally very important, but it should not be done without increasing the organisation's ability to respond more rapidly. Next, both forecasting and responsiveness are discussed more closely.

Responding to long term forecasts

Forecasting is one of the most current topics in discussion of performance ability nowadays. A lot of effort has been applied to increase the accuracy of the forecasts. The long term demand of the products often follows global trends and economical situations. There are lots of metrics and indicators that can be used in predicting the economical situations in future and the difficulty is usually not the lack of information. However, since observing myriad of different indicators is virtually impossible, the main challenge is to find those giving the most accurate information. Whether it is the price of the houses in the USA or the price of timber, it is essential to know how the indicator reacts to and is affected by the changes in economical situation. Even if the long term predictions would be correct, making the changes in ways of operating to adapt to this new situation is never easy.

Many company representatives that were interviewed during this project saw that the depression was coming in the summer 2008. However, when operating as a part of a bigger company network it is difficult to act against these observations. If your customer still orders products and the demand remains high, starting to ramp down the production to prepare for the recession is virtually impossible. During the last meltdown, this resulted in situation where the whole chain was driven to the wall with full speed. At worst, suppliers were required to increase their production one week and the next week the order book was empty. Any kinds of changes often affect most the companies far upstream in the supply chain and the bullwhip effect is as real during the depression as it is during the next upturn.

To illustrate the bullwhip effect, the order quantity for a typical supply chain is presented in Figure 5-4. The volatility of orders increases towards the upstream of the supply chain. This is a result both of inaccuracy in forecasting and of protective inventory that is often held at all levels of supply chain to prevent out-of-stock situations. This volatility has an effect on the operations during "normal times" but it culminates especially during an economic up- and downswing.

Figure 5-4: Increasing variability of orders up the supply chain [**41**]

In machine building industry, the ongoing recession initiated a chain reaction. When customer orders begun to decrease, retailers started to run down their storages and were followed by the OEM, which could still continue selling the end-product without replenishing their inventory and ordering from their supply chain. However, this resulted in a total collapse of order books in the supply chain and, as mentioned above, even though some suppliers were able to predict the change, their leverage to respond to it was minimal. Even if companies were able to predict the downswing, responding to a change of this scale is extremely difficult. In discussion with companies, this was seen as a challenge that does not have an answer yet.

Responding to short term forecasts

In this chapter, the focus is on short term forecasting; in other words, how to predict what products and with which options customers are willing to buy during the upcoming weeks and months. This is the information both OEM and suppliers are very interest to gather from the customers. In addition, it is the information on which the daily operations in the companies are mainly built.

In the beginning of the case study research one of the main topics of the discussion was forecasting. However, the rate of success of forecasting was not measured, so improving the accuracy would not be reasonable with the current ways of operating. First, to assess the forecasting, the forecasting process should be accurately defined, even standardised, so that it would be done every time the same way. Then, the success rate should be measured by collecting enough data. Finally, the development work of the forecasting process itself could be initiated. Due to the lack of assessment of

the forecasting accuracy in the case study network and because it was not a priority one in development objectives, forecasting has been put aside since far in our case study network. However, in future, forecasting is taken into the scope of research and it is especially important when the information flow in the network is optimised. When improving the information flow and building compatibility into information systems, the way of transferring both order information and forecasts should be seamless and if information systems are not compatible a middleware is needed.

When considering the needed characteristics in the supply chain, the customer should be allowed to be inflexible. Consequently, the network supplying the product requires flexibility and responsiveness. Actually, as OEM often desires to be the most inflexible in its operations, the supply chain should be increasingly flexible toward its upstream. However, in the case study supply chain the flexibility ceases to raw material deliveries and Supplier 2 needs to protect against this inflexibility with raw material inventory. In other words, due to long delivery times of steel raw material, that part of the supply chain is also decoupled from the rest of the supply chain with protective inventory. Therefore, the supply chain actually consists of two independent decoupling points, of which only the place of the one that is directly related to daily wheel orders can be affect.

5.2.2 Trust and networking in pursuit of competitiveness

During the whole project the main goal of the research team was to keep in mind that although development efforts are performed within individual enterprises, agility is build collectively into the whole supply network. Therefore, process improvements and development work should be considered keeping the mutual objectives that increase the competitiveness of the supply chain in mind.

Agarwal et al. noted that building agility into supply chain network requires a strong basis. This basis consists of networking and building trust between network partners. According to the author, the basis for agility consists of process integration, centralised and collaborative planning, using the IT tools to develop trust and to minimise uncertainty and resistance to change [**30**]. Cooperating with case study companies has demonstrated that trust and willingness to cooperate with each other has a tremendous effect on development work. Consequently, one of the significant constraints in building agility often seems to be the lack of mutual goals and trust among the partner companies. However, the level of trust is highly dependent on the network type. As discussed in literature review, according to Kestilä et al. there are four types of production networks: clan type relational network, bureaucracy type hierarchic network, market type contractual network, and strategic long term network [**7**]. One example of the role of the network type is presented next. If supply chain is strongly OEM-driven and hierarchic type building mutual trust can be difficult. In this type of network decisions are easily made only by the main supplier and the leverage of the rest of the supply chain to affect the decisions concerning the supply chain goals is often

insignificant resulting in one party dominance and lack of trust among other partners. Shortage of trust and collaborative planning may have some drawbacks. For example, if the main supplier is very dominant and there is no mutual understanding in the supply chain, parallel suppliers may begin to compete against each other. In this case, cooperating for mutual benefit could create multiple winners. If solutions were sought and goals were set collaboratively, the results could be more beneficial to the whole supply chain. In order the network to be changed, for example, toward a type that includes more long-term and deeper cooperation with suppliers, a reason for change should be offered. An evidence of a clear interdependence between supply chain agility and collaboration and cooperation with other members of the network could offer that reason. Even though forming deeper relationships within the supply chain appears to have positive effects on the performance level, it is still not widely recognised.

One issue should be highlighted from the field study: partnerships were sought in relationships to customers, but not in relationships to suppliers. This behaviour might be considered from wrong point of view: only customer is seen important since it is the one from which the income comes. However, deepening the relationships toward suppliers could improve the overall performance of the supply chain and, thus, help gaining competitive edge of the whole network. Since 70-80% of the manufacturing costs in typical machine building company come from purchases, the relationships toward suppliers and the management of the supply chain should be very carefully considered. Therefore, the focus and knowhow of many companies should be targeted toward cooperating with suppliers rather than toward customers.

5.2.3 Core competences

Core competences are a topic of much interest nowadays and also widely discussed. Many management books and theories suggest that companies should define and concentrate their core competences and get rid of or re-engineer operations which do not belong under companies' core processes. By doing this, companies are able to release resources to be allocated in developing operations that are more of greater importance to company [**40**]. Using make-or-buy analysis, the company is able to assess their operations and decide is they should either be outsourced, off-shored, or re-engineered, since these operations are most likely to be done with greater efficiency somewhere else. In these cases, own resources could be allocated to operations which are more important to the company. This process assessment to different sectors is very strategic and should be considered along with the other strategic objectives the company has.

Core competences and agility

According to many definitions, agility exists only in company networks, since an individual company is not able to respond efficiently to changes coming either from customers or surrounding environment. Therefore, efficient networking is essential and

if supply chain is formed by including only companies that are operating within their core competences, the potential for improving the networks agility is inarguably better than if companies have to include processes that are not managed well or that are not their core competences. Naturally, having high performance level and focusing on core competences does not automatically improve agility, but it offers a very strong foundation to build on.

5.2.4 Constraints in building agility

Thinking through constraints has been an effective way of approaching development objectives in the case study supply chain. The different constraints – people, equipment, and policy – are all restricting the throughput and the ability of the companies to change their operations to adapt to new situations [**38**]. As noticed in the research project, the dominant constraint is often the manufacturing. If rim production line in Supplier 2 is not capable of producing more throughput due to capacity restrictions, and smaller batches due to long set up times, improving the surrounding operations does not have very significant effect on the whole throughput of the system. However, even though the manufacturing itself does have the needed flexibility and responsiveness, people and policies have a tremendous effect on the overall throughput of the supply chain and their significance is introduced next.

People are one of the major constraints in especially in smaller and medium sized companies. Especially, workers who have been in the company for a long time doing the same tasks may constrain the operations. They can be either unable to think broadly and get easily stuck with the ways the things were performed during the years, or they can even act against development work if it challenges their way of working. Therefore, the people aspect should be carefully considered if agility is build into the organisation. The resistance to change is often build – not consciously – into the company culture and can be decreased with proper attitude change. One example of a change on company culture comes from an interview during the project: after introducing job rotation in factory level, the culture of the company had changed and workers are even asking for continuous change in their job descriptions. This increases the amount of multi skilled workers, increases flexibility in manufacturing, and decreases the overall resistance to change.

Another constraint from the very other end of the scale is the policy of a company. A remark made during the case study was that the rigidness of a large corporation was often a constraint. For example, even if suggestions that were made for improving operations and processes were seen positive by the OEM, they could not necessarily be changed due to their corporation policy. Or if they could be changed, the change would require a lot of paper work and a long time. Therefore, the corporate strategy and its role as an enabler should be considered when building agility into the operations.

Related to company policy, constraints that may not be that visible in day-to-day operation are the ways of operating that have long historical roots, but that do not meet the needs of today's requirements. Once in a while a clause heard when suggesting new ways of operating is that 'things have always been done here this way". Often these ways of working do not have any reasoning as a support, but still no one has challenged them. A new pair of eyes could sometimes be a solution for highlighting these flaws and getting rid of them, and in the case study supply chain, pointing out these matters has been one of the main tasks of the researchers.

5.2.5 Characteristics of agility in the case study supply chain

This chapter consists of observations concerning agility and its appearance in the case study supply chain. These observations are linked into model and characteristics of agility introduced by Agarwal et al. (Figure 6-3). Next, three characteristics – use of IT tools, trust development and delivery speed – from different levels of the model are discussed in greater detail.

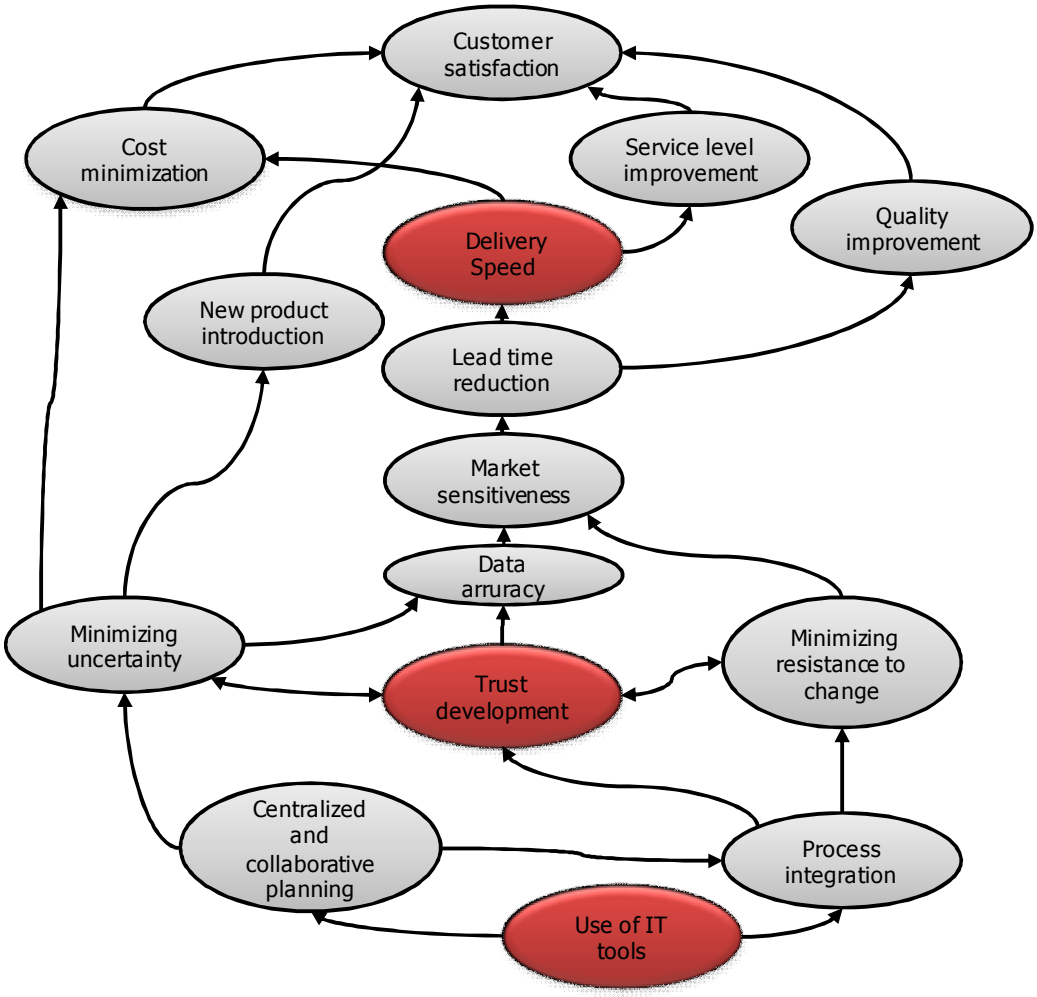

Figure 5-5: Characteristics of agility in the case study supply chain (modified from [**30**])

IT tools have been built into the supply chain for longer time to integrate the information systems of the companies. However, the newly introduced link – a web-

based system integrator between Supplier 1 and Supplier 2 – has been a significant step of improvement in integrating the operations between the companies. It streamlines the information flow by decreasing the amount of needed manual work at both companies, by enabling easy changes to order specifications, such as price and delivery date, and by offering an extra tool for monitoring both orders and deliveries. A system integrator for creating a link between the companies of the case study has been planned, and analyses to clarify its required characteristic have been initiated. This system providing the suppliers with information, including both orders and forecasts, would remarkably decrease the time needed for information delivery at the same time decreasing the overall lead time of the supply chain as well.

Trust and trust development among the supply chain companies during this research project has eased the cooperation between the case study companies. The current state analysis increased the companies' awareness of the operations within their own company and of how operations are run within other companies. Longer term planning and decision making is easier when ways of operating are transparent to everyone and people are talking a common language. In addition, the companies are willing to commit themselves to collectively set objectives, which is arguably beneficial to reaching the goals. Common language also seems to promote integration within the supply chain, since performing joint development projects is considerably easier when the other company's way of operating is well-known.

Short lead time is one of the major enablers of agility, and operations – also in this supply chain – culminate into the ability to manufacture fast. The implementation of new automated rim profiling line in Supplier 2 gives more flexibility and throughput for the company itself and for the whole supply chain, since it wheel manufacturing has been a constraint since far. How much the new line eventually gives flexibility and decreases the inventories in the supply chain is a question without an answer yet. However, in combination with streamlined information flow it will inarguably offer a higher performance level compared to the earlier manufacturing line. The improvement in rim production naturally challenges other operations and production control and the following constraints are likely to appear in supporting processes.

5.2.6 The significance of short lead time when improving agility

The advantages of short throughput time and short lead time are obvious in any line of business. Customers have to be satisfied faster than before without exploding the costs within the company and supply chain. Consequently, the pressure to decrease the lead time is increasing all the time. Lead time is the amount of time from customer order to delivery. Throughput time, again, is the amount of time required for manufacturing. Throughput time is often a lot shorter than the lead time that is seen by the customer. The interviews with companies brought up some thoughts about the significance of short lead time when pursuing agility and are considered next in greater detail.

A shortened lead time has many direct benefits. First, it enables the company to respond to customer orders – rather than to forecasts – in greater amount than with longer lead time decreasing the need for long term forecasts. This is a great advantage since forecasting accuracy diminishes remarkably the longer the time span. Second, when aiming to shorten the lead time, it automatically requires an improvement in supporting processes, such as supply and design. Waste in these processes should be minimised as they only support the core part of the company, the production, in which the actual value adding work is performed. Third, short lead time often decreases the amount of inventory – both the end product and work-in-process, and if inventories need to be held, they can be transferred further upstream into less processed form. In addition, the waste is also reduced from the factory floor operations when throughput time is shortened and production streamlined. Fourth, the reduction of throughput time has a beneficial effect on quality, since defects emerge earlier when material flow is faster. Investing in new machinery and possibly to automation to achieve shorter throughput goals can also offer quality improvement by reducing the human factor in processes. Finally, short throughput time can offer flexibility to manufacturing. If there is a significant difference between needed lead time and throughput time, this difference can be used in increasing the flexibility of manufacturing by placing the orders to production schedule more freely.

5.2.7 Improving agility in SME's

Small and medium sized companies are common in machine building industry and building agility into them requires some considerations compared to bigger companies. One of the constraints in smaller companies is the lack of leverage when negotiating for instance about terms of contract with suppliers and customers. For example, if a large customer does not see it beneficial to form deeper relationships to suppliers and the cooperation is mostly contract based, building agility can be difficult.

Therefore, an important issue is the evaluation of customers. However, making an evaluation of customers is, according to my perception, done very seldom in smaller companies. For instance, assessing how making business with this particular customer effects company's longer term operations is hardly ever done. The fact is that some orders are more profitable than others; therefore, an active monitoring of the received orders and comparison to company's own core competences and field of operations can be useful. If some particular order is – for instance due to its large quantity or challenging characteristics – outside the core competences or operational range of the company, refusing to receive it can be more beneficial in longer time perspective. Naturally, implementing this kind of approach can be challenging, especially if the amount of customers is small. This again leads to another way of operating that reduces risks: customer strategy. It is important not only to select the incoming orders, but to actively broaden the pool of customers at the same time spreading the risk of being dependent on only few ones on one line of business.

Another reason for not being able to implement agile thinking into SMEs can be the lack of strategic competence in management. In many SMEs, the growth has been organic and the company has slowly increased its operating environment. Strategic objective can even be “controllable growth”, which actually does not fulfil the requirements of strategic decision making at all. When considering the capabilities of these companies to apply agile thinking into their operations, it should be noted that the lack of strategic competence in management of SME’s is often a limiting factor when adopting new theories and frameworks.

6 Summary

The term agility is used actively in discussions concerning companies' ability to adapt to changing business environment. However, the questions what agility is and what agile characteristics are have not been answered clearly. The objective of this thesis was threefold: to perform a literature review and define the term strategic agility, to find characteristics of agility and to adapt them to Finnish machine building industry, and to field-test the applicability of these characteristics combined with other commonly known theories and tools in improving agility of the case study supply chain.

During the project, we have defined agility as performance ability. According to that definition, a*gile network of enterprises responds to customer needs rapidly, cost-effectively, and with high quality (quantitative and qualitative response ability)*. Here, it should be noted that our definition includes the assumption that agility is not a method or way operating, but rather a characteristic of a network. Operating momentarily in an agile or flexible manner does not make the organisation agile. Next example given by a research colleague of mine illustrates the difference of these two ways of operating. If a company that only seemingly operates in agile manner receives an order that should be delivered in short notice, it mixes up the whole manufacturing process, makes people to work overtime, sky-rockets the costs, and finally delivers the product by plane with huge transformation costs. In contrary, when a company that is truly agile receives the same order, it can follow its standard procedures and manufacture the product without doing anything abnormal, delivering the product in time via normal transportation. From customers point of view the result is the same, but only in the second case it is done in such way that is sustainable in a longer run.

The following chapters summarise the observations and theoretical background. First, the nature of the needed agility in Finnish machine building industry is discussed. Then, competitiveness and agility are compared. Finally, the role of agility in the future is considered.

6.1 Operative agility as a strategic objective

The framework of strategic agility defined by Doz and Kosonen operates as a theoretical foundation of StrAgile research project. This framework focuses strongly on the agility of the strategy itself, the ability to make real time and accurate interpretations of the environment, to reallocate resources fast, and to commit collectively to the objectives in managerial level. During the writing of this thesis it has emerged that applying this framework directly to case study companies is challenging. Strategic agility can be considered as a good goal to aim to, but the gap between the current operations and the level and characteristics of agility described in the framework is too wide. The companies participating in the research project fall better into the zone of

strategic planning driven companies (Figure 6-1). In this zone, the speed of change is not necessarily very fast and the nature of change varies. That is, product life-cycles are longer and changes in market environment are slower compared to, for example, electronics industry. In addition, the relationships to other companies in supply chain often require more cooperation and collaborative design due to the complexity of the products. Therefore, it could be argued that some other approach to describe the required characteristics and the nature and of agility in current business environment could be more appropriate.

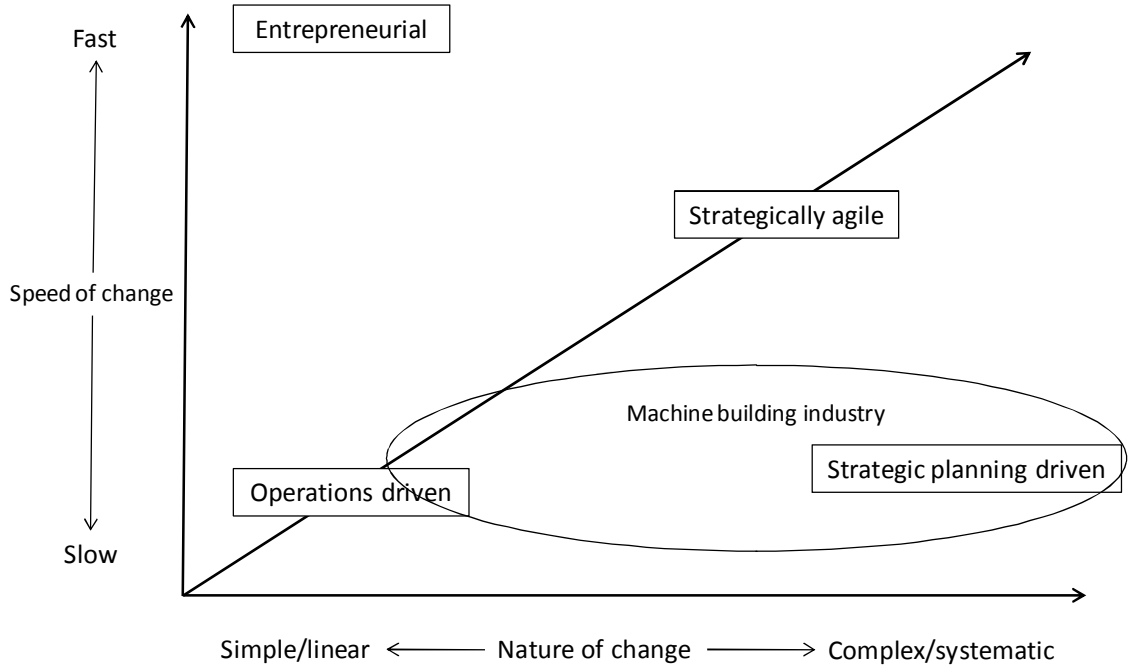

Figure 6-1: Placing machine building industry into framework of strategic agility (modified from [**17**])

Overall, in machine building industry, in which many companies are small and medium sized, building agility even on operational level still requires a lot of work. In order to build agility into organisation, the basic level of performance should already be rather high. However, in many companies, the processes are far from their optimal state; also, when considering strategic level decisions, the competence on strategy is, especially in smaller companies, rather low. Since strategy is often decided for many years ahead and future can never be predicted accurately, a strategy should mainly enable and support operational agility. In other words, when strategy is formed and strategic decisions are made, they should not stiffen organisation's operations, but rather enable the characteristics of agility to be built into organisation. Many of the characteristics enabling agility – introduced in Figure 6-2 – require strategic level decision making, but all of them are not necessarily strategic level characteristics. From these enablers, possibly closest to "traditional" approach is resource fluidity, under which the enablers are the closest to production strategy. Other two dimensions – sensitivity and collective commitment – are not that easily placed under any specific area of operations but are rather integrated into the whole organisation. However, in

order to commit the whole company or network to drive collectively toward the same goal, especially collective commitment is extremely important topic to be discussed.

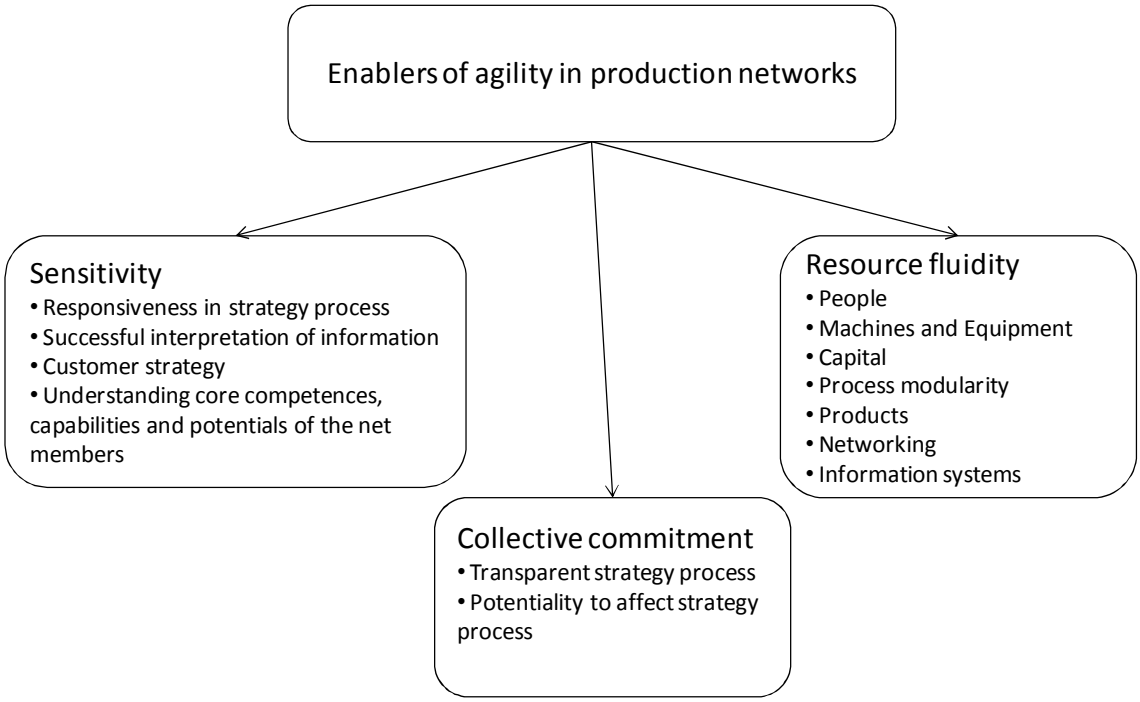

Figure 6-2: Enablers of agility in production networks

When deciding the strategy for the company, the above three dimensions should be considered along with traditional strategy building process. According to Wheelwright, strategic decisions concerning production strategy are made in eight categories: capacity, facilities, technology, vertical integration, workforce, quality, production planning/material control, and organisation. The author considers the first four as structural and strategic, whereas the last four are more tactical level characteristic. In contrary to this approach, for example in Toyota, the long-term strategic decisions are made concerning workforce and quality and cannot be compromised in short term. However, for instance technology, such as equipment and machinery, can be changed very rapidly if needed.

Traditional strategy building process is strongly related to operations within one company and since agility itself often requires participation of the whole network or supply chain, the scope should be broadened to network level. In other words, the decisions within one company should, ideally, benefit the whole network rather than only that particular company.

The enablers of agility broaden the way of approaching strategy building process especially if strategy is normally built focusing mainly on production. In addition, considering these enablers from wider perspective may offer a way of thinking that is many companies are not familiar with. What should be considered thoroughly is how these enablers should be used in order to increase the operative agility of a particular company in particular operational environment is. However, whatever is decided, the

strategy should not tie the operations too much in order to enable certain manoeuvrability and flexibility in the operative work. As Doz & Kosonen suggests, one of the main problems of companies' operations is that they tend to stiffen over the time. Processes and operations are easily formed to respond to certain predicted future, and if changes need to be made, problems occur. Therefore, considering agile characteristics upon strategic decision making and keeping the organisation's operational structure changeable can increase the ability to respond to unpredicted changes.

6.2 Competitiveness or agility

As literature review indicated, theory on agility does not contain any toolbox that gives an answer to how to build business operations nor a theory that even fits every situation. Agile characteristics and enablers enhance organisation's performance level and ability to respond to change, but they vary according to situation and are always measured in comparison with other companies in the same line of business. In the case study supply chain the dominant enablers of agility that increase the ability to operate in the business environment seem to be the short lead time, effective use of IT-tools and mutual trust among partner companies. Short lead times form the core of operations: it enables responding increasingly to order information instead of forecasts, it gives flexibility and operational freedom, and it is one of the characteristics which have a direct effect on customer satisfaction. However, in order to achieve reductions in lead time, all processes within companies need to be carefully considered and streamlined to support the production. IT-tools should be used efficiently both to integrate processes within one company and between the partners, and to enable seamless bidirectional information flow through the whole supply chain. Again, process integration and awareness of how other members are operating in the network promotes trust development, which is one of the major enablers of agility.

The question, what is the difference between agility and competitiveness, has come up during the project. The characteristics described above do increase agility, but are also characteristics which increase the competitiveness even if fast responsiveness to change is not needed. It could be argued that agile organisation is by definition competitive since agility itself requires operational performance level to be high and that the characteristics which are important to agility also increase the overall competitiveness. However, that is true only if that organisation operates in business environment in which agility is needed. Therefore, for instance in lines of business where volumes are large and products are mostly standardised, effectiveness and low costs may be everything that is needed in competition and building the ability to respond to changes – expected or unexpected – can be a waste of resources. However, in most business environments agile characteristics are beneficial.

Since agility is not the only characteristic increasing competitiveness, for instance in machine building industry, other actions to improve the performance ability of the organisation often increases its capabilities of striving in competition. Therefore,

other approaches used in improving the performance, such as lean and TOC, can help increasing the overall performance level of the network and thus if even its agility. It could be argued that finding ways and tools for improving the performance level and agility should be considered case by case. Consequently, the need for agility in the current and in the future business environment should be considered both from the viewpoint of strategic decision making and operative work. When aiming to more agile direction, the tools which are used should be selected considering both the characteristics that are needed to succeed in the particular business environment, and the level of own performance and competencies compared to competitors' ones.

6.3 Future challenges

A report considering European manufacturing summarises the expected future challenges from number of studies as follows:

- Increasingly competitive global economic climate
- Anticipation of new market and societal needs
- Rapid advances in science and technology
- Increased supply chain efficiency
- Environmental challenges and sustainability requirements
- Integrate new knowledge and improve workforce skills
- Societal values and public acceptance of technology [**42**]

Agility is an especially interesting topic when considering the future, since agile organisations are characterised by their ability to respond to unpredictable change, and ideally even benefit from it [**13**]. As mentioned above, the world's economical situation and business environment are changing constantly at an increasing speed challenging companies in every line of business. Environmental consciousness, sustainable thinking, scarce natural resources, and fierce competition require actions in many companies. The role of agility increases remarkably because only organisations which are able to adapt to new situations thrive in a long run. Also, since the competition occurs between company networks rather than between individual companies preparing only within one's own company to changing environment is not sufficient. Industry will be distributed into smaller and more specialised units; therefore, in order to respond efficiently to ever more challenging demand the ability to create efficient networks is essential. This requires more efficient exploitation of core competences, as well as, skilled and competent workforce to enable adaptation to new situations.

As a conclusion, the ability to react and respond to change will be one of the most significant capabilities in future. A significant competitive advantage can be gained by deploying agile approaches and building agility into all levels of organisation. Therefore, in future studies, agile characteristics and enablers should be specified in order to enable efficient application in practice.

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