# The Role of Production Topology in Information Based Structuring of Organizations

The design of craft-based and industrialized construction firms

Robert Gerth
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KTH Royal Institute of Technology
School of Industrial Engineering and Management
Department of Production Engineering

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Production Systems
Department of Production Engineering
KTH Royal Institute of Technology
S-100 44 Stockholm

Tryck: Universitetstryckeriet US AB

# Abstract

Industrialization of construction is a business strategy to significantly improve competitiveness. However, the organization structure of the construction firms needs to support the new production system. The knowledge on why and how this business development can be accomplished is scarce, both within academia and in business practice. This research seeks to fill this knowledge gap.

The purpose of organization structure and the production system have is to coordinate the firm's processes and control the work performing resources. Information is one of the most fundamental dimensions for steering and controlling the work. The different information types are determined by the firm's product customization strategy and the production system flexibility. Further, diverse information types are managed in different extent by the organizational steering mechanisms. Consequently, firms with dissimilar customization strategy or production flexibility should organizationally be designed differently in order to be efficient.

The developed model identifies four generic production topologies: *"engineer-to-order"* (ETO), *"manufacture-to-order"* (MTO), *"assembly-to-order"* (ATO), and *"make-standard-products"* (MSP). The differences between the topologies can be related to the location of the *"customer-order-decoupling-point"* (CODP) in the product realization process; and to what extent the upstream and downstream processes continuously use stored information or process information to accomplish the work of each product order. The model predicts which organization structure mechanisms that should be used for which processes for each production topology. It is the specific configuration of the mechanisms that gives each production topology their organizational capability. The model has been validated by case studies in four organizations, each representing one of the four generic production topologies. Three cases considered housing and one studied truck manufacturing.

It has been shown that the conventional housing firms have an ETO-production topology, while industrialized housing firms belonging to one of the others, i.e. MTO, ATO or MSP. The reason is that ETO-firms rely on crafts-based production to manage the work, while the other topologies base their steering mechanisms on industrial principles. These two types of production are fundamentally different, which also explain the need for different organization structures. The research complements previous knowledge and significantly increases the ability to predict, analyze and explain an organization's design and behavior. The model can be used in practice to guide business development work and performance improvement programs.

***Keywords:*** Organization structure, organization development, production system, production topology, engineer-to-order, manufacture-to-order, assembly-to-order, make-to-stock, customer-order-the-coupling-point, information processing, information storage, industrial construction, housing, cybernetic, management

# Sammanfattning

Industrialisering är en affärsstrategi för byggföretag att radikalt förbättra sin konkurrenskraft. Det kräver dock att organisationsstrukturen utvecklas på sådant sätt att den stödjer det nya sättet att producera. Kunskapen om varför och hur denna organisationsutveckling bör genomföras är bristande, både inom akademi och i industrin. Det försöker denna forskning råda bot på.

Organisationsstrukturen och produktionssystemet har till uppgift att koordinera företagets alla processer och styra resurserna som utför arbetet så effektivt som möjligt. Samtidigt är det information som är den mest grundläggande dimensionen för att styra och kontrollera arbetet. Typen av information beror på i vilken omfattning företagets produkter kan kundanpassas och hur flexibelt produktionssystemet är. De olika informationstyperna hanteras i varierande grad av de olika organisatoriska styrmekanismerna. Av den anledningen bör företag med olika kundanpassningsstrategier eller produktionsflexibilitet strukturera sig på olika sätt föra att styra arbetet på ett effektivt sätt.

Den utvecklade modellen identifierar fyra grundläggande produktionstopologier: ”*engineer-to-order”* (ETO), *“manufacture-to-order”* (MTO), ”*assembly-to-order”* (ATO) och ”*make-standard-products”* (MSP). Produktionstopologiernas olikheter kan härledas till kundorderpunktens placering [*customer-order-decoupling-point* (CODP)] i produkt-realisationsprocessen, och i vilken omfattning processerna uppströms och nedströms till CODP kontinuerligt använder sig av lagrad information eller bearbetar ny information för varje produktorder. Modellen förutsäger vilka organisationsstrukturella mekanismer som bör användas för vilka processer i respektive produktionsstoplogi, vilket även ger varje topologi dess typiska karakteristik. Vidare har modellen validerats genom fallstudier av fyra företag, en för respektive produktionstopologi, tre inom byggsektorn och ett inom fordonsindustrin.

Konventionella byggföretag har en ETO-topologi, som är fundamentalt annorlunda de andra. Det innebär samtidigt att industriella byggföretag, som är någon av topologierna MTO, ATO eller MSP, organisatoriskt och produktionssystemsmässigt är radikalt olika traditionella byggare. Anledningen är att traditionella byggföretag använder sig av hantverksbaserad produktion, medan de andra topologierna har byggt upp sina produktionssystem utifrån industriella principer. Dessa två produktionstyper hanterar information på olika sätt, vilket också förklarar varför företagsstrukturerna är olika. Den genomförda forskningen kompletterar tidigare teorier och ökar förmågan att förutse, analysera och förklara organisationers design, verksamhet och beteende. I praktiken kan modellen användas för att vägleda effektiviserings- och organisationsutvecklingsarbete.

# Acknowledgement

It has been a privilege to conduct this research and writing the thesis, especially when the research problem has been so intertwined with my personal interests and business experiences. As an industrial PhD-student, my ten years of business experiences, from conventional construction and industrialized housing, provided me with a pre-understanding of the research topic. Similarly, the research work has challenged and developed my knowledge and perception on how to solve practical business problems. The goal has been to contribute to a deeper understanding on the structuring of conventional and industrialized construction scientifically as well as in practice – the time will tell if I succeeded.

However, a PhD work process cannot be accomplished without support of numerous of people – some of them should be emphasized little more than others. Scientifically, I would like to thank my supervisor, Professor Bengt Lindberg, for your discussions and providing me with different research approaches and perspectives on industrial differences. Professor Mats Engwall, my co-supervisor, for the guidance of the scientific process considering case studies and the discussions on project based organizations. My gratitude is also extended to PhD. Marcus Bjelkemyr and Associate Professor Daniel Tesfamariam Semere, for reading the thesis and giving constructive comments. All colleagues at KTH IIP are of course acknowledged, but especially the PhD-students at seminars-course for the encouraging and inspiring discussions we have had during the years; Associate Professor Peter Gröndahl, Mats Bagge, Tord Johansson, and Magnus Lundgren in front of the others. Patrik Jensen (Tyrens) and Albert Boqvist (NCC) are acknowledged, for the stimulating conversations about construction versus industry. I also thank Professor Per-Erik Josephson (Chalmers) and associate professor Dan Engström (LTU/NCC) for your commitment, time and improvement suggestions. Linda Otton is also acknowledged for spending time to correct the thesis' language the last minute.

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The most grateful of acknowledgments is given to my family, Sofia and Thea, whose understanding and support during this difficult process of writing the thesis has kept me going.

*Robert Gerth*
Stockholm, September 2013

# Abbreviations

| | |
|---|---|
| APS | Action Planning System |
| ATO | Assembly To Order (production topology) |
| CODP | Customer Order Decoupling Point |
| CTO | Configure To Order (product configuration strategy) |
| CPM | Critical Path Method (planning method, e.g. gant-schemes) |
| DLL | The product concept ”Det ljuva livet” within NCC |
| ETO | Engineer To Order (production topology and product configuration strategy) |
| ICT | Information and Communication System |
| IPS | Integral Product Structure |
| IT | Information Technology |
| LOU | Public procurement act (in Swedish “Lagen om offentlig upphandling”) |
| MC | Mass Customization |
| MSP | Make Standard Products (production topology) see also MTS |
| MTO | Modify To Order (product configuration strategy) |
| MTO | Manufacturing To Order (production topology) |
| MTS | Make To Stock (production topology) |
| NPD | New Product Development |
| OPP | Order Penetration Point |
| PBO | Project Based Organizations |
| PCS | Performance Control System |
| PMPS | Parametrical Modular Product Structure |
| PTO-model | “Production Topology Organization”-model |
| SABO | Swedish Association of Public Housing Companies |
| SHD | The Small House Department within the industrial division at NCC |
| SMPS | Standard Modular Product Structure |
| SPS | Scania Production System (the firm’s name on the endeavor of systematic work with lean) |
| SPV | Select Product Variant (product configuration strategy) |

# Keywords

| | |
|---|---|
| Generic | The characteristic of a whole group or class (Merriam Webster, 2013). |
| Information | Here defined as the necessary knowledge or data to steer and execute work tasks to realize a business objective. |
| Information processing | The gathering, interpreting, synthesis, and structuring of information (Tushman and Nadler, 1978). In the thesis it is used to denote the process of developing new information or the configuration of stored information to create useful data so specific work tasks can be executed. |
| Information storage | The ability to retain and recall information of things past (Walsh and Ungeson, 1991). Her it mean explicit, formalized information of different type, stored within the organization for reuse in order to facilitate management, steering and execution of work tasks. |
| Knowledge | Implicit skills, data and information possessed by a human being used to solve problems and work tasks. |
| Organizational configuration | A specific design of the generic organizational mechanisms that is appropriate for the market situation and the production topology (Mintzberg, 1979). |
| Product/production configuration | The process when pre-determined constituents of a generic product structure or a production system are specified and combined to realize a product with new attributes (cf. Piller, 2004). |
| Production topology | The major infrastructural and generic characteristics of production systems related to the product realization process, e.g. production flow, process type, production layout, technology, and placement of the CODP or OPP. |

# CONTENT

# 1 INTRODUCTION

*This chapter introduces the research background and motivates the research questions. It is suggested that conventional housing and industrialized housing requires diverse production topologies and organization configurations, due to different information needs.*

## 1.1 Industrialization - a strategy for improvements

Industrialization is a business strategy for construction firms to significantly improve their competitiveness. However, in order to realize its potential both the production system as well as the organization design must be developed in an appropriate way. This thesis describes why the changes must be accomplished and how these should be designed.

The inspiration for the industrialization of construction has for decades been the automotive industry (e.g. Zhang and Skitmore, 2012; Nahmens and Bindroo, 2011; Gann, 1996; Stinchombe, 1959). The manufacturing industry has a remarkable productivity progress; statistics from Konjunkturinstitutet (2013) shows that the industry's productivity improvement was 278 % between the years 1980 and 2012 (see figure 1:1). During the same period the improvement was 26 % in the construction sector. Interesting to note is that even the service sector has a better track record than construction with an improvement on 47 %.

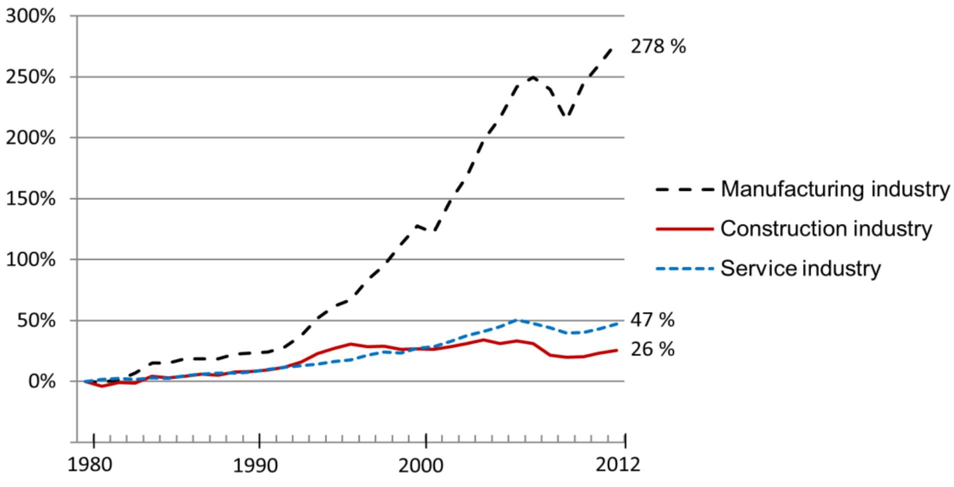


Figure 1:1 The productivity improvements for construction sector, manufacturing industry and the services branches between the years 1980 and 2012. Statics from Konjunkturinstitutet (2013).

Research has also noted these differences, as Richard (2005, p. 442) for example asserts;

> *"If a car was produced the way building is delivered, very few people would be able to own one; if a computer was produced the way a building is delivered, it would cost a fortune".*

Similarly, Jongeling et al. (2007, p. 1) declare;

> "*If the construction industry produced cars the same way as they are building houses the price of cars would be ten times higher. The most prestigious SUV model produced by VOLVO would have cost 550 000 € compared to the market price of 55 000 € and still they would have a much lower profit margin compared to the automotive industry".*

Even if the last citation is a rough estimation based on comparing statistics of the productivity improvement in the construction and automotive sector – it still points out the significant difference of the capability for improvement between the sectors. However, the comparison of productivity measurements between industry sectors had been subject for discussion whether the comparison is relevant or not (e.g. Lind and Song, 2012; Statskontoret, 2009; Winch, 2003).

### 1.1.1 The foundation of industrial production improvement

The reason for the significant improvement of productivity, cost, delivery time and quality in manufacturing firms is that they build their progress on continuous improvement of the production systems (e.g. Tangen, 2005; Hayes and Pinsano, 1994; Taylor, 1967). Industrial manufacturing systems support explicit knowledge or information storage, control, feedback and regulation of the production processes (cf. Fairbank et al., 2006; Asby, 1956). This means that when improvements are made new knowledge are formalized and stored within the system for repeatable use when producing all future product orders.

Nevertheless, implementation of major developments or new strategies have often required re-organization of the entire firm to achieve the full potential, e.g. when a manufacturer goes from being a mass producers to be a mass customizer (Trentin and Forza, 2010; Chen and Hao, 2010; McCarthy and Tsinopouls, 2003; Duray, 2002). Figure 1:2 exemplifies the evolution of the automotive sector from craft-based production, through mass production to the current paradigm of mass customization. Note that the firms' organization structure had evolved significantly from one paradigm to the next. In construction similar organizational changes can be assumed to be necessary if the industrialization strategy is going to be successful and contribute to firms' competitiveness.

## 1.2 Obstacles for industrialization of construction

Despite years of industrialization efforts in the construction sector similar progress as the manufacturing industry possess have not been achieved (Statskontoret, 2009; Borgbrant, 2003). The obstacles can be explained by the fact that industrial developments are based on organizational principles for repetitive production, which many construction companies have been reluctant to apply (Mossman, 2009; Höök and Stehn, 2008a; Unger, 2006). Therefore, these authors assert that the industrial way of managing and producing buildings require a different kind of organization design than what is appropriate for conventional construction. On the contrary, Lind (2011), Adler (2005) and Lundström (2003) claim that many of the used manufacturing inspired methods are inefficient because they are not developed and adjusted to the special conditions of construction.

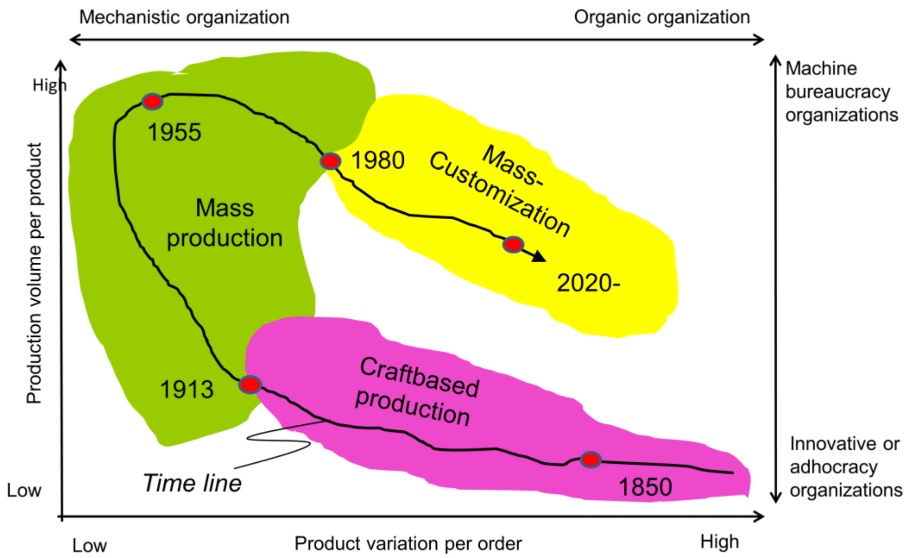


Figure 1:2 The evolution of the automotive sector from craft, to mass production and mass customization. Note that each production paradigm corresponds to a specific organization mode. Based on Jovane et al. (2003), Mintzberg (1979) and Burns and Stalker (1961).

The discussion about industrialization is further limited because there is no agreed definition of industrialized construction (Zhang and Skitmore, 2012; Kamar et al., 2011). For example, common denotations are prefabrication or off-site production of building parts, which is about removing portions of the craftsmen’s work on-site to factory environments. In practice the use of this kind of industrialized construction is determined on project level (e.g. Taylor, 2010; Unger, 2006; Hastak, 1998). Therefore, the industrialization endeavor is often assumed to be equally successfully whether it is applied in a single project or within a whole company (cf. Lessing, 2006). The major problem when interpreting the accomplishment of a single project as industrialized construction, when the rest of a company is accomplish project through conventional construction processes, is that the long term potential advantages will not appear. For example, in Sweden the major construction firms accomplish 1000-3000 of projects per year (cf. Josephson and Saukkoriipi, 2009): thus, if only few projects are executed in an "industrial mode" it can hardly be said to contribute to the firm's strategic competitiveness.

In summary, industrialization of construction, through e.g. product standardization, automation or robot driven development, require expansion of the traditional single-project scope to include the entire construction firm in order to pay off (Maas and van Gassel, 2005; Richard, 2005). Each single project cannot start from scratch every time without considering earlier experiences (Gerth et al., 2013). The use of industrialization technology requires a long term commitment and that many processes, both of central management, project and on-site type need to be re-engineered (Gerth, 2008). Nevertheless, how to accomplish this is an area of scarce knowledge (e.g. Zhang and Skitmore, 2012; Pan and Goodier, 2012).

## 1.3 Industrialized housing require a new organization design

In this thesis industrialized housing is perceived as a business strategy that is fundamentally different from conventional housing and therefore requires a different organization and production system (cf. Rudberg and Jonsson, 2012; Winch, 2003; Gann, 1996). Höök and Stehn (2008b, p. 1092) have developed the following definition of industrial housing that capture this company wide approach:

> *"Production in a closed factory environment where only assembly is performed at the construction site, with one evident process owner and a clear product goal of repetition in housing design and production"*.

However, it is not enough to put craftsmen into the factory to make the construction process more efficient. The organization and management of craftsmen and manual work in industrial factories is fundamentally different (Rudberg and Jonsson, 2012; Frohm, 2008; Taylor, 1967). The definition should be complemented with the assumption that craftsmen must be replaced by industrial labor. The transition from craft-based to industrial production implies fundamentally new requirements on the organization structure as a coordinating and steering mechanism (see appendix A). Gerth (2008) even claimed that an industrialized construction firm has more in common with an industrial producer than a conventional constructor: however, the causes of the differences were not explicitly explained (see appendix B). This motivates deepened investigations of the organizational requirements in order to realize high performance industrial construction. On the other hand, why cannot the theories from other fields being directly used and applied in construction?

## 1.4 The lack of understanding of flexible producing organizations

In the beginning of the 20th century the research of production engineering, organization and management focused on how companies could make the transition from craft-based to mass production (e.g. Bayraktar et al., 2007; Shafritz and Ott, 1996; Taylor, 1967). Today, much of the current dominating research is founded on the mass production paradigm trying to make the organizations as well as the production systems more flexible (e.g. Ott et al., 2011; Wadwa et al., 2009; Stavrulaki and Davis, 2010; Nambiar, 2009). Thus, the research approaches the flexibility from the opposite direction than construction research. The industrialization of construction should, therefore, have more in common with the first paradigm shift (see figure 1:2, p. 3).

Further, the current dominating organization theories are often principle, focus on few organizational elements and are often based on a limited understanding of the production processes (e.g. Kates and Galbraith, 2007; Collis et al., 2007; Miller et al., 2006). The knowledge on production technology is also not up to date and used in a different way than in engineering (cf. Frohm, 2008; Sanidas, 2004). On the contrary, organization knowledge is scarce in the production engineering as well as in the construction area. Despite that numerous reports (e.g. Hvam et al., 2008; Unger, 2006; Blecker and Abdelkafi, 2006a; Pine et al., 1993) have pointed out that a change of the production topology imply a radical revision of the firm’s organization as well as overall business model. Unfortunately, the interaction between organizational structure and production system is not well understood and has not gained enough interest, especially when the production flexibility is changed (Hasan et al., 2012; Trentin et al., 2011; Stefanovic et al., 2011; Ruffini et al., 2000).

### 1.4.1 Information processing - a key dimension in organizations

According to Jensen et al. (2009), Burke (2003) and Galbraith (1974) can the variations of companies organization design, be explained by the firms’ ability to process information. Information processing means gathering, development and transformation of data into information that can be communicated and used to accomplish the business processes (Scott, 2004; Egelhoff, 1982). Repeatedly manage and reuse the same information or to process new information to accomplish the work requires different organizational devices (cf. Galbraith, 1974). The same devices will not be able to handle the different information situations effectively, which explains the various designs of organizations (Fairbank et al., 2006; Daft and Lengel, 1986)

Nevertheless, the information processing theory has evolved during the mass production paradigm, when a competitive advantage could be accomplished by increasing the product customization degree and the production flexibility. In order to realize these advantages the mass production firms should develop the organization to support information processing

(Trentin and Forza, 2010). The focus has therefore been on the information processing and not its correlation to the dimension of information storage. Still, this focus is the dominating (e.g. Engström, 2012; Trentin et al., 2011; Jensen, 2009; Brun et al., 2009), and only few studies acknowledge the importance of information storage (e.g. Dosi et al., 2008; Fairbank et al., 2006; Egelhoff, 1982). Thereby, the information processing approach should be complemented with an information storage dimension in order explain why the organization design is affected by reduction of flexibility.

## 1.5 New production topology – new organization design

The reasons for the change of the organization and the production system when a firm industrialized its processes also becomes apparent when considering the four common production topologies: (1) *engineer-to-order* (ETO), (2) *manufacture-to-order* (MTO), (3) *assembly-to-order* (ATO), and (4) *make-standard-products* (MSP) (see figure 1:3). The ETO-topology allows firms to produce one-of-a-kind products. Each product order is engineered from scratch which also requires development of a new production organization and process for realizing the specific product. In the MSP-topology the entire organization and the production system is designed in advance for producing one or few standardized products in high volumes. In the topologies ATO and MTO are the organization and production system prepared for producing customizable products; meaning the product structure as well as the production process are developed in advanced, but reconfigurable for each order (e.g. Stavrulaki and Davis, 2010; Wikner and Ruberg, 2004; Slack et al.,2005).

According to Swierczek (2010) emerge the different topology characteristics based on where the order penetrates the product realization process. Further, Olhager (2010) and Wikner and Wong (2007) assert that processes located upstream or downstream the *order-penetration-point* (OPP) require different management approaches (see figure 1:3).

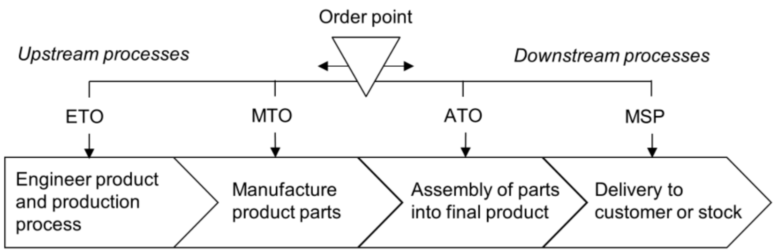


Figure 1:3 A visualization of the four production topologies separated based on which process the order point hits the product realization process. Processes upstream and downstream the OPP require different management approaches and organization structures. See also chapter 4.5 on p. 40.

The explanation is that processes pre-OPP can be perceived as mass production and post-OPP as agile or flexible processes. The organization structure aspects or the different needs of information to support the managerial approach were, however, not considered. These aspects have been covered by Trentin et al. (2011) and Trautmann et al. (2009), but their focuses were on how the information processing differed between pre- and post-OPP processes for understanding how to increase the flexibility. Further, how to use already stored information and how this impacts the information processing per order were not considered.

When reconnecting to industrialization of construction the problem is how to redesign the organization in such a way that it supports a more standardized production topology (Haug et al., 2009; Gerth, 2008). In conclusion, the organization must be developed to store more information in advance and reduce the information processing amount per project. It is obvious that the organization design must change when a housing firm changes the production topology and become industrialized – the question is how?

## 1.6 The objective and research questions of the thesis

The objective with the thesis is to explain why and how an industrialization of housing firms requires a change of the production topology and develop the organization structure. Two research questions have been articulated to capture the essence of the objectives.

- *What are the generic causes that explain the organization structure differences between firms with diverse production topologies?*
- *How does the change of a firm's production topology impact the design of the organization structure and the production system?*

### 1.6.1 Delimitations

The research result presented here considers large business firms that produce physical products and own the major parts of the production value chain. Further, industrialization is perceived as a business strategy for the entire company. So, when a conventional construction firm has implemented an industrial construction strategy it impacts the realization of every product order or project.

Culture and sociological aspects are acknowledged as important for the understanding of business organizations. However, according to Ahrne and Brunsson (2004) these dimensions expand the concept of organization structure and production system to be more than the *"management infrastructure of the transformation processes"*. Therefore, the research focuses on "infrastructure" issues, the impact of corporate culture, sociological patterns, and norms, are not targeted.

### 1.6.2 The accomplishment of the objective or the outline of the thesis

In order to answer the research objective and questions this thesis is structured as illustrated in figure 1:4. The present chapter 1 has introduced and motivated the objective and the research questions. It is followed by chapter 2 which describes how the work process has been scientifically accomplished. It is placed at the center because it indicates how the other chapters have been used to answer the research questions. Chapter 3 to 5 is the frame of reference, there chapter 3 presents the theories of control and information processing, which frames the interpretation of the chapters 4-5. Chapter 4 addresses important aspects of flexible production system, and briefly theories of product structures and product configurations because of their relevance for customization. Chapter 5 considers organization design theories with focus on structure, including descriptions on common organization configurations relevant for the thesis' objective. In chapter 6 the *"Production-Topology-Organization-model*" (PTO-model) is presented, which is a conceptualization of the theories presented in chapter 3-5. The PTO-model can explain and predict the specific organization design configurations for each production topology. These predictions are put up for empirical validation in the chapters 7-8. Chapter 7 presents the four case study organizations and chapter 8 analyze how well each case matches the predictions. The final chapter, chapter 9, includes highlights of the most important findings and suggests future work and research questions.

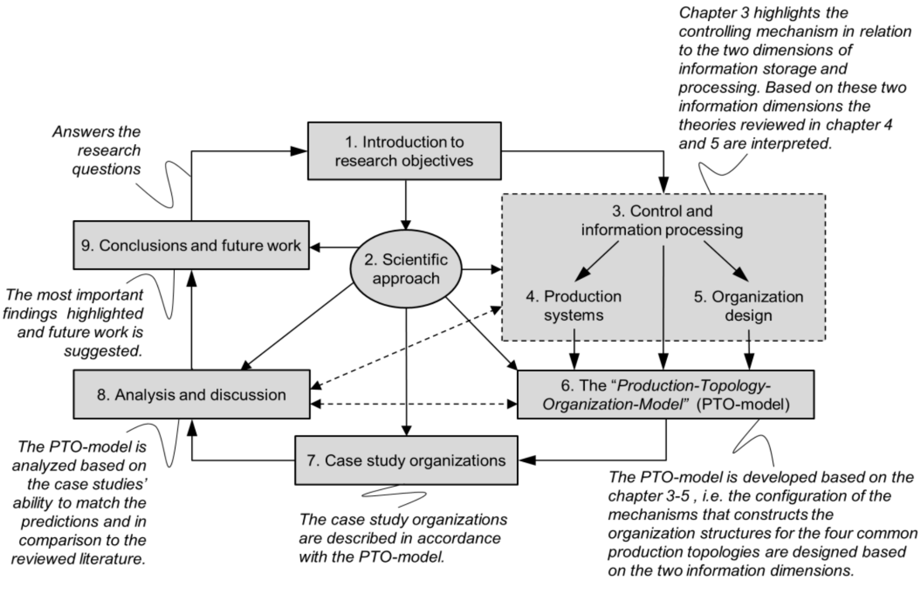


Figure 1:4. The outline of the thesis' chapters and their relation to each other.

# 2 SCIENTIFIC APPROACH

*This chapter presents the scientific approach chosen during the research project. These are important for external judgment and validation of the research results.*

## 2.1 Research Perspective and Strategy

The aim of the present study has been to scientifically explain the interaction between different production topologies and their appropriate organizational structure from an information approach. The research was conducted based on the authors pre-understanding about this phenomenon, which has evolved from academic studies in engineering as well as work within the industry for over ten years with both conventional and industrial housing.

Both the academic field of production engineering and the business practice are social contexts that are based on the epistemology of rationality, positivism and system thinking (cf. Hjørland, 2005). These epistemology directions are also motivated by theoretical definitions of organizations and production systems (see chapter 4 and 5), which consider these phenomenon as social constructed systems to achieve a goal (e.g. Ott et al., 2011; Senge, 1995). The organization design theory emphasizes the integration or interaction of all different elements that constructs the firm in order to meet its strategic objective. In production system theory it is the resources and transformation process that is emphasized to realize the products. Both approaches relies on the assumption that the world exists and is observable outside ourselves (Carter and Little, 2007; Åsberg, 2001). Naturally these arenas have formed the perception of how the science has been conducted.

### 2.1.1 Research strategy

In order to answer the research questions a deductive research approach was chosen, i.e. based on current theories a model was conceptualized and tested in an empirical context (e.g. Chalmers, 1999). The PTO-model consists of theoretical identified parts and relations between these; it is these constructs that had been exposed for empirical tests. Thereby, it corresponds to what Hartman (1998) assert to be major parts of a scientific model and process: existential, relational hypotheses and empirical validation. Further, the model has been developed based on system thinking in contrast to reductionism. According to Tesfamariam (2005) there are the two major approaches used when analyzing systems in practice. Reductionism assumes that a system consists of separated parts, and the system behavior is generated by just adding the contribution of each part together (cf. Sterman. 2002; Patton and Appelbaum, 2003). Therefore, a reductionist decomposes the systems into isolated parts for individual analysis, which result in systems descriptions based on its constituent elements. The focus in systems thinking is on the relationship among the system parts (Bjelkemyr et al., 2007). The underlying assumption is that the overall behavior is not the equal to the contribution of each individually constituent. Instead their relations can increase or decrease the system overall performance (Sterman, 2002).

### 2.1.2 Case studies

The nature of the PTO-model is normative, i.e. it stipulates why and how different production organizations should be designed from a theoretical approach. However, it is not necessarily that the real-world-business-firms are organized in such a way. According to Badersten (2006) is normative research about investigate and explain why a specific phenomenon should have certain design and how it can be achieved. This puts additional requirements on the empirical validation procedures. Even if a specific hypothesis could not be explicitly identified, the empirical investigation should be able to provide enough data on which arguments whether the hypothesis is possible or not can be based. In order to empirical test the PTO-model, deep qualitative empirical data was assumed to be required. The empirical data had to be deep and detailed enough to provide possibilities to derive the reasons for particular design solutions of the organization and the production system. According to Eisenhardt and Graebner (2007) case studies it is a particular appropriate method for studies focusing on “how” and “why” questions and for studying the phenomenon under investigation in its natural context. Therefore, case studies were considered as an appropriate research strategy.

The PTO-model differentiates between four generic production topologies (see chapter 4), which creates different organization structures. Yin (2007) asserts that the cause-and-consequent explanation become more evident when several cases are compared. Thereby, four cases, one for respectively topology, were chosen for investigation.

## 2.2 Choices of the four case study companies

The choices of the four cases were made based on their pre-assumed inherency of the production topology and organization configuration (see chapter 5). The unit of observation was both the formal and informal management mechanisms of the operative work. This includes the main and overall structures and the systems necessary to manage the product realization process, even if the focus has been on the production related work.

By including cases from the four common production topologies the analysis could be nuanced and the empirical validation be strengthen. The possibility to generalize the findings was also assumed to be improved if the investigated companies belonged to different industry sectors. Together, the four cases created a more evident relation between the unit of observation and the analysis (cf. Yin, 2007). A more practical reason for the choices of the respectively case was the necessity of openness and willingness provide essential information and material. Several companies were asked but declined or could not meet these requirements.

### 2.2.1 The cases from the construction sector

In the construction sector conventional housing firms are typically *project-based-organizations* (PBO) and produce with the production topology of *engineer-to-order* (ETO) (cf. Bresnen et al., 2005; Winch, 2003). It is also rather common for housing companies to try and to increase their competitiveness through industrialization of the building process, i.e. going from an ETO to a *manufacture-to-order* (MTO), *assembly-to-order* (ATO) or even a variant of the topology *make-standard-products* (MSP). In theory the topology differences have major impacts on the organization design, which should also be identifiable in practice. If not, some performance and organizational problems should be observable.

Three construction related cases were chosen: (1) Peab as a representative of the ETO-topology with a typical PBO-structure and a craft-based production, (2) NCC Komponent with a MTO-topology and a bureaucratic organizational form, and (3) the case of *Det-ljuva-livet* (DLL) representing the MTS-topology with an organization of mechanistic type. The NCC Komponent-case was under development during the time of investigation. This hampered the data collection because all the information has to be correlated to the time of collection and the development progress. However, the development of the company started from technological approach, but soon it was obvious to the firm that in order to make the firm function in accordance with the strategy the organization also has to change. Therefore, during the time of the empirical investigation the firm stressed the relation between business strategy, organization design and production technology – thus, the development state was actually an access.

The DLL-case was different than first assumed; after the case analysis it was obvious that it did not represent the typical MTS-topology and the bureaucratic organization. The product was standardized and produced within a factory staffed with craftsmen. The projects were managed by a network organization consisting of different parties within the traditional construction supply chain (see chapter 7). Based on this, one could argue that this case should be removed from the study due to its ill fit to the research objective. However, the derivation of the many irregularities from the predictions of the PTO-model actually provided insights and explained the correlation between the two information dimensions and the organization structure mechanisms.

### 2.2.2 The case of the truck manufacturer

Most theories and practice of business organization and production systems rest on the mass production paradigm, therefore they recognize flexibility and customization as the future setting (e.g. Ott et al, 2011; Bayraktar et al., 2007; Santos et al., 2002a). The automotive industry is often perceived as the manifestation of this paradigm, and often inspires other sectors by their endeavors in e.g. lean production, automation and modularity. A case that represents this industry is therefore appropriate for the research project, especially if the case consists of a flexible production system. So, when exploring housing firms' transition from craft-based production to industrial production, a case from the manufacturing sector can act as reference point. Further, if the PTO-model can predict the result of construction firms' design as well as an automotive manufacture's, it should be valid for more sectors than only construction.

The choice of the case study was Scania, because the firm had a product customization strategy and an ATO-production topology with appropriate organizational configuration. This corporation is also well known for its systematic way of managing their business (see chapter 7), and it is a very well analyzed and reported firm. Consequently, there is a lot of secondary information, e.g. research studies, books, public reports and papers to compare the case study findings with. Further, considering the product customization strategy and production topology the Scania-case was placed between the NCC Komponent and the DLL-case, which facilitated the cross-case analysis.

## 2.3 Empirical data collecting

When conducting research based on quality empirical data there are no exact recommendations of sample sizes. Instead, theorists are discussing the empirical saturation, i.e. the point when additional data does not provide new insights (e.g. Guest et al., 2006; Morse, 2000). The chosen data collecting methods: semi-structured interviews, archives and document analyses, and observations were guided by the definitions of the constructs of the PTO-model. Observe that the various types of data sources provide different insights. Together these can provide a holistic and balanced picture of the investigated phenomenon, which motivates the use of triangulation (Jick, 1979).

A common problem occurring when collecting qualitative data is the gathering of too much data. When using multiple data sources for triangulation this problem usually increases. Therefore, the thesis had followed the suggestions of number interviews, which according to Francis et al. (2010) and Guest et al. (2006) is between 10-15 in order to achieve empirical saturation and consistence. Further, because the research project was of deductive art it was possible to use pattern matching (Yin, 2007) or directed content analysis (Hsieh and

Shannon, 2005). In other words, the conceptualized PTO-model directed the empirical investigation and reduced the risk for capturing of unintended data (cf. Åsberg, 2001).

The empirical data collection was, however, performed as a complete participant of the three construction cases, which significantly increase the amount of assessable information. In the Scania-case, the data collection was accomplished as an external observer which limits the accessible information. Scania was therefore an appropriate choice due to its openness and the many public reports about the firm. Therefore, the numbers of interviews, documents, secondary information and observations have varied between the cases. Table 2:1 summaries the data collecting methods and sample sizes for each case.

Table 2:1 Summarizing table over the empirical data sources for each case study.

| Method | Peab | NCC Komponent. | DLL-network | Scania |
|---|---|---|---|---|
| Interviews | 35 | 36 | 14 and<br>2 group meetings | 18 |
| Archives and documents | Numerous | Numerous | Numerous | Numerous |
| Observations | Observer<br>~1 day/week<br>(2010-2013) | Observer<br>~1 day/week<br>(2006-2008) | Observer<br>~1 day/week<br>(2006-2007) | 12 visits (2007-2011) |
| Secondary Research Reports | 0 | 1 paper | 1 PhD. Thesis<br>1 Lic. Thesis | 1 PhD. Thesis<br>1 Lic. Thesis |
| Other notation | Employment<br>2009-2013 | Employment<br>2003-2008 | Employment<br>2005-2008 | - |

### 2.3.1 Semi-structured interviews

The interviews were semi-structured and based on different interview guides for the Peab-case (see appendix C) and for the other cases (see appendix D). The main reason for this was the different organization configuration types and that interviews were conducted during different time periods. In the DLL-case the interviews and the group discussions were based on the interview guide 2, but many irrelevant questions were removed, e.g. those that considered the customization. Instead focus was on the network organization management, production and the project delivery. The interview informants were chosen based on their position (see appendix E). Most of the interviews were recorded and transcribed for analysis, as recommended by e.g. Lantz (2007). Further, about half of the interviews were conducted by master thesis students within the research topic.

### 2.3.2 Archives and documents analyses

The written sources for the archives and documents analyses were chosen based on their topic, e.g. business descriptions, business strategies (when accessible), annual reports, organizational charts, functions and role descriptions, processes and procedures, production methods, presentations, revision reports, internal reports, newspaper articles etc. Secondary research reports, e.g. journal or conference papers and PhD. and licentiate thesis were also used both for giving input to the case illustration and for validation of interpretations.

### 2.3.3 Observations

Conducting observations are about capturing social events in the natural context (Silverman, 2010), which is almost impossible with other empirical methods (Yin, 2007). Observations can be accomplished in different ways; the extremes are when the investigator is a complete participant with the observed event, or a complete outside observer (Vinten, 1994). Because of the researcher's employment in the three housing cases, the observations in these cases have been both of the participating and of the outside type. Summary notes for most observation occasions were taken for analysis. The following categories of events had been observed: management meetings, product and production systems development meetings, staff meetings, factory production processes, on-site processes etc. In the truck-case the observations was of complete outside observation type. In this case the following events had been observed: presentation of production process developments, plant management offices, production line meetings, factory processes (component and module manufacturing), and final assembly plant.

## 2.4 Validation of the research study

Qualitative and case-based research is often criticized for its inability to provide scientific result of precision, objectivity and consistency from a quantitative approach (Patton and Appelbaum, 2003). The possibilities with case studies for deep and holistic investigations of real-world phenomenon emerge on the expense of generalization, which is a major requirement of scientific valid results. Therefore, the entire research process must be much more explicit and evident for qualitative than for quantitative research (Carter and Little, 2007). Especially the steps of operationalizing, internal and external validation and reliability are different and important to consider (e.g. Yin, 2007; Scandura and Williams, 2000) – how these steps have been conducted is presented here.

### 2.4.1 Operationalizing and empirical data analyze

The collected qualitative data was analyzed based on the recommendations by Hsieh and Shannon (2005) for directed content analysis. It is appropriate when there are prior theories, which are conceptualized to a model for empirical verification. The PTO-model is operationalized by defining the logic between "*the generic causes that explain the organization structure differences for different production topologies*", and how these impact "*the necessary design of the organization structure for each production topology*" (cf. chapter 1.6, p. 7). The mechanisms, that constructs the organization design, should be tangible and observable within the cases, so the empirical information can determine whether predictions can be verified or not (Elo and Kyngäs, 2007). The following steps were conducted in order to analyze and empirically verify the PTO-model:

(1) operationalization of the model into tangible concepts,
(2) the relationships between the concept and the generic hypotheses was coded,
(3) the empirical data was collected directed by the concepts,
(4) the collected data was read and key parts/words marked,
(5) marked data was categorized, and finally
(6) the constructed concepts were analyzed whether the empirical data corresponded to the predictions and if there were confirmations for confirmation of the generic hypotheses or not.

This process made it very clear that different data sources provided data for the different concepts in different degrees. The final case descriptions would not have been possible to produce if not all the sources had been used.

### 2.4.2 Internal validity

Internal validity concerns the internal case causality between the different factors under investigation (Scandura and Williams, 2000). Meaning, in the context of this thesis, that the observable organization behavior and performances are caused by identifiable organization structures and devices. In order to increase the internal validity this study has followed the recommendation by Yin (2007):

- multiple data sources (see section 2.3)
- directed content analysis or pattern matching (see chapter 2.4.1 and 6-8)
- considerations of rivaling explanations (see chapter 3-6 and 8)
- logic explanations (see chapter 3-6 and 8)

### 2.4.3 External validity

External validity considers the generality of the research findings across times, contexts, organization settings and individuals. According to Scandura and Williams (2000) this is the most important factor in making an honest representation of the case relation to other situations and contexts. In order to reduce the risk of limited generalization Badersten (2006) assert that a study should rely on general theories developed by research authorities. Yin (2007) emphasizes the use of multiple cases and performing replication studies of similar cases in order to increase the external validity. The research process has followed these recommendations. In fact, the PTO-model rely heavily on previous theories combined into new ways (compare the frame of reference and the PTO-model). The validation has been conducted within four cases as noted earlier. The table 2:2 shows that each case possesses some similarities and differences to the other, which implies that the study included some replication and generalization possibilities (see also section 2.2).

Table 2:2 Illustrations of important similarities and differences among the cases.

| Case | Industry sector | Production type | Product configuration | Organization/ management |
|---|---|---|---|---|
| Case A: Peab | Construction/ housing | Craft-based | Unique projects | PBO/organic |
| Case B: NCC Komponent | Construction/ housing | Industrial | Customized products | Bureaucratic/ flexible |
| Case C: DLL network | Construction/ housing | Industrial/ craft-based | Standardized products | Bureaucratic/ organic |
| Case D: Scania | Automotive/truck | Industrial | Customization products | Bureaucratic/ flexible |

### 2.4.4 Reliability

In qualitative case studies, reliability means that other researchers would come to the same result and draw the same conclusion based on the documented of the research project (Yin, 2007). The reason is that the real-world cases and data sources change continuously in contrast to what happens in an experiment in a laboratory. Thus, it is more or less impossible to repeat a specific case study, i.e. collect identical empirical data again from the same data sources. A more appropriate method is therefore to validate the conducted research based on the presented report. The external validator should come to the same result in order to say that the conclusions are scientifically reliable.

However, the reliability correlates to the major critic of quality research (Patton and Appelbaum, 2003), because the validator must trust the conducting researchers accounted process, interpretations, descriptions and findings. There is no way to control if these are correct, therefore, the researcher’s background and pre-understanding of the studied phenomenon become important to present, as well as the relation to the case study companies (e.g. Riege, 2003). The solution of this problem for the thesis has been to provide some personal background descriptions in the preface, and descriptions of the situation when collecting the empirical data (see section 2.3). The implication of the employment can be a risk for bias; however, due to that the employments have been within the three construction cases it was assumed that the risk was reduced. Instead it made the empirical data and pre-understanding for the construction cases more complete than for the truck manufacture case. Therefore, it was more important in the Scania-case with openness and many secondary reports about the firm.

# 3 CONTROL AND INFORMATION PROCESSING

*This chapter starts with an introduction to concepts of coordination and control because these are the steering mechanisms of production systems as well as organizations. It is also clarified how these concepts use information to steer the work. The information processing theory is complemented with thoughts on information storage, in order to further explain the necessary organizational differences between companies with dissimilar production topologies.*

## 3.1 Coordination and control the purpose of organization

Organization structure and production system have the common purpose of managing, coordinating and controlling the work so that the firm's strategic objectives can be met (see chapter 4 and 5). These concepts deals with the steering issue in similar ways (Potocan and Mulej, 2009; Koontz, 1980) and are about maximizing the advantage and utilization of the performing resources (Kumar and Suresh, 2008).

Management is about planning, organizing, directing, controlling, adjusting and staffing the work (Service, 2010; Kumar and Suresh, 2008). Coordination is, according to Arshinder et al. (2008, p. 318), *"the act of managing interdependencies between entities and the joint effort of entities working together towards mutually defined goals"*. Similarly, Trautman et al. (2009) assert that coordination is the same as integration, meaning that coordinated activities are dependent and supports the overall goal. Malone and Crowston (1990) identified the following components of coordination: goals, activities, actors, and interdependencies. The interdependence is the most important constituent, without it nothing can be coordinated. Similarly, Green and Welsh (1988) defines the concept of control as the exercise of restraining or directing influence over activities to achieve a predefined task, i.e. regulation of the work process. Control is accomplished through structures, systems, rules, norms and soft skills that managers use to influence organizational members' behavior (Dahlgren and Söderlund, 2010). Simons (1995) claims that the management control systems consists of four parameters: corporate beliefs (culture), boundary systems (formal rules), diagnostic control (measurement systems), and interactive control systems (IT-system for information transfer vertically in the corporation). Therefore, Egelhoff (1982) asserts that information is the intervening dimension of management, coordination and control.

All of these concepts rely on the principles of cybernetics, because it is the generic theory of steering any kind of system, e.g. organizations or production systems (e.g. Potocan and Mulej, 2009, Shafritz and Ott, 1996; Ashby, 1956).

### 3.1.1 Cybernetic control

Cybernetics is the study of systems that are open for energy and disturbances, but closed for information of control (Ashby, 1956). In brief cybernetic is about controlling the output of the system processes by comparing it with the pre-determined objectives. The performance status of the process is fed back to the regulating unit, which adjusts the working process if there is a difference, see figure 3:1.

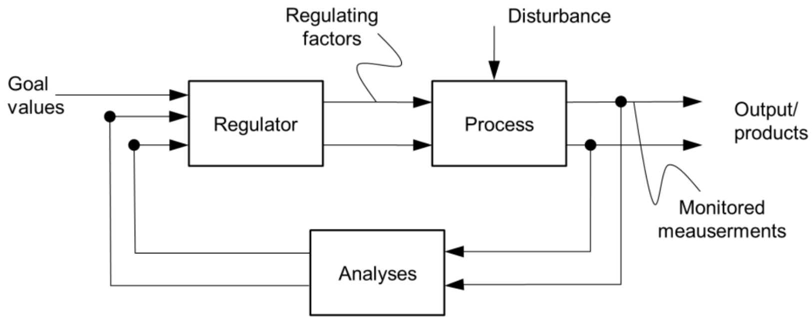


Figure 3:1 The cybernetic feedback loop is the generic steering mechanism of systems, e.g. business organizations or production systems.

It is the feedback loop that provides the system with the ability to achieve and maintain its desired performances, despite disturbances from the external and internal environment (Ogata, 2010), e.g. product parts delays or product quality failures. The disturbances can create an output error, i.e. difference between the goal and the actual output of the process. Information about the error is, in closed-looped control system, fed back to the regulation function for reduction of the error in the forthcoming process execution (Wiener, 1948). Therefore, information about the system's different parts, the parts interdependencies and the process status is used and this is necessary for regulating the system. New information about the system is not added, except the status of the monitored processes output. Therefore, cybernetic control systems works best in relatively stable environments where the internal factors are known, e.g. as the case is for mass production systems (Hofstede, 1978). Information of what to do, how to do it, and which regulating parameter to change have to be in place and available for the controller (e.g. Dosi et al., 2008; Choo, 1991).

When the controller of the system neither has adequate information about the internal nor the external factors, cybernetic control is not an appropriate steering mechanism (Hofstede, 1978). This often is the case in construction projects and firms (cf. Pich et al., 2002; Brun et al., 2009), but if a project *per se* may have the adequate information for managing the work in accordance with the cybernetic principles (Dobre, 2007), its objective is often contradictive to the organizational strategic objectives (e.g. Thiry and Deguire, 2007; Bresnen et al., 2005). Further, organization management is further complicated by the use of controlling managers at different hierarchal levels and sub-systems. These are often sitting with different kinds of information and contradictive objectives (Potocan and Mulej, 2009; Bjelkemyr and Lindberg, 2007; Winters and Thurm, 2005).

### 3.1.2 Cybernetic management at different organization levels

In business firms the management or control processes differ depending on what hierarchical level they are performed at due to: dissimilar work procedures, diverse information types, and different time frames. For example, the closer the controlled process is to the production operations, the more tangible is the controlling information, and the more immediate the control can be.

Umpleby and Sadovsky (1991) and Schwaninger (2001) identify three different levels or orders of cybernetic in business organizations: operation level ($1^{st}$ order of control), tactical and management level ($2^{nd}$ order of control), and strategic level ($3^{rd}$-order of cybernetic control). The $1^{st}$ order of cybernetics is the regulation of the operational processes (Scott, 2004), and the focus is on the process setting and output (Potocan and Mulej, 2009). The goal is to achieve operation efficiency or *"to do things right"* (Schwaninger, 2001). The $2^{nd}$ order is mainly at managerial level and deals with tactical plans, guidelines and improvement of the operational processes. (Scott, 2004; Umpleby and Sadovsky, 1991). The purpose is to create system effectiveness, i.e. secure that the each process is making *"the right things"*. The $3^{rd}$ order of control is the process of developing a mission, norms and strategies for the firm, so it can survive in the long run (Potocan and Mulej, 2009). According to Schwaninger (2001) it is about creating legitimacy, purpose and objectives of the business. Norms and beliefs create framework for the interpretation of the situations and decision making in $2^{nd}$ and $1^{st}$ order of control (cf. Schein, 2004).

Rowe (2010) expands these ideas and asserts that the operational control is about management of details for use in mechanistic controlled systems, e.g. the material flow in an assembly line. The purpose of the $1^{st}$ control order is to compare the current state of a work process with the tactical plans (see figure 3:2). The $2^{nd}$ and $3^{rd}$ order of cybernetics are considering the future of the corporation; the tactical level changes and improves the settings of the first level, so the output from the strategic level can be achieved. In addition, Umpleby and Sadovsky (1991) assign the tasks of development and improvement of control systems the strategic level, in the sense that these tasks are guided by the strategy, but implementation appears on tactical level. The figure 3:2 illustrates how each control level manages different type of goals, has different time frames, and includes different information complexity.

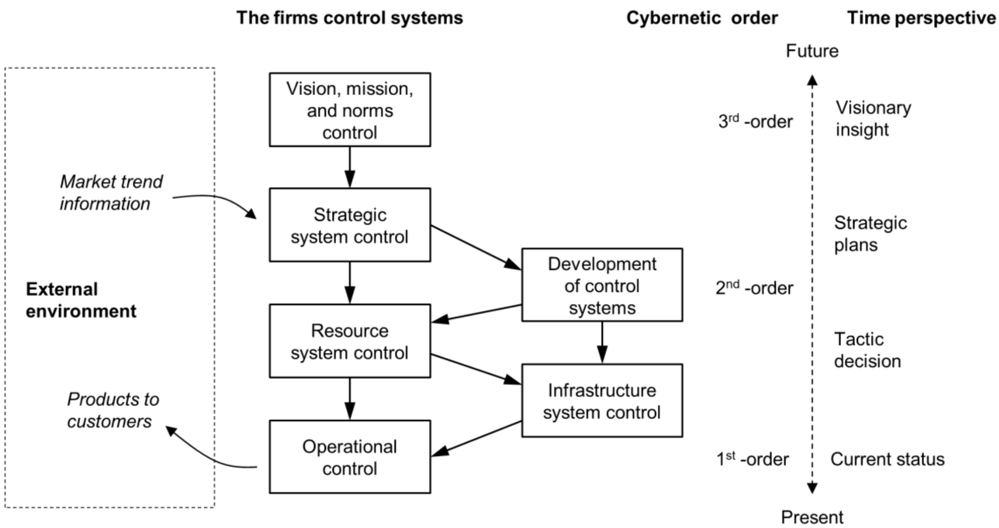


Figure 3:2 Different control systems of a business firm and their contribution to present and future managerial issues. Sources Rowe (2010), Schwaninger (2001) and Umpleby and Sadovsky (1991).

However, Winters and Thurm (2005) criticize the different cybernetic orders and control systems as being too theoretical, hard to identify, separate and interpret in real life business context. Similarly, Jackson (2009) and Senge (1995) acknowledged that cybernetics had much in common with systems theory and learning – all three concepts had to be considered when developing an organization.

### 3.1.3 Organizational learning as a cybernetic mechanism

Organizational learning uses three similar loops as cybernetic for describing how learning proceeds (e.g. Yeo, 2005; Argyris and Schön, 1996). Learning relies heavily on feedback mechanisms, which further can increase the understanding of the different iterative cycles (see figure 3:3, p. 21). The first one, single-loop learning, is about instrumental learning, i.e. regulated and routine-based activities that is accomplished by individuals (Yeo, 2005). The repetition of actions allows the individuals to continuously perform the operation faster and deliver the output with more accuracy through small corrections of the actions (Jensen, 2005). Double-loop learning means that the wanted performance cannot be achieved unless the activities are changed. According to Yeo (2005) inspiration to change or develop the current activities can be obtain from others' experiences (compare to $2^{nd}$ order of cybernetics). The authors call this team-based learning, and assert that the interaction and development process is usually of non-routine type. However, Jensen (2005) claims that learning, i.e. improved knowledge or performance, only occur if the "developers" can understand how current and new operations interact and affect each other. Therefore, Senge

(1990) assert that organizational learning is about employees who can learn to oversee and restructure their mental models. Similarly, Jensen (2005) and Yeo (2005) assert that there are situations when it is impossible to achieve the desired performances in the current context. The organization has to liberate itself from the pervasive culture, norms and strategic orientation to develop new ones, the triple-loop learning. This triple-loop of learning has major impact on the other two loops, due to that it affects the perception of the context and gives the direction of goal setting (Potocan et al., 2005), and is very similar to the 3rd order of cybernetics.

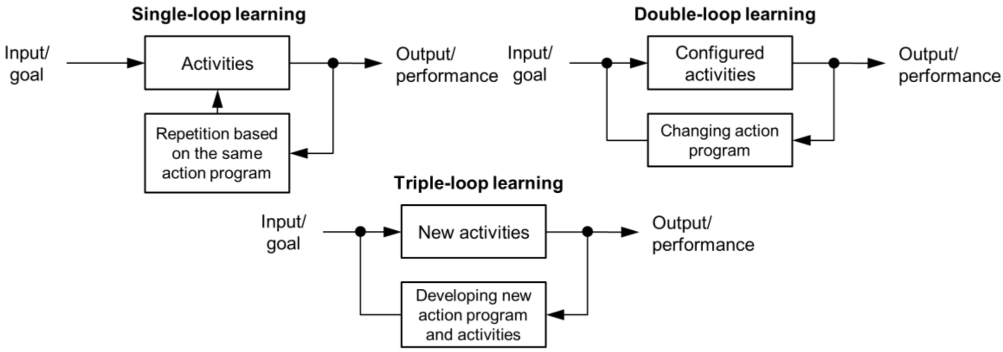


Figure 3:3 The three learning loops. Note the similarity to the cybernetic loop in figure 3:1 (p. 18) and the different cybernetic orders in figure 3:2 (p. 20). Based on Jensen (2005).

Potocan and Mulej (2009) recognized a fourth loop of cybernetics, the zero order, which considers the control of ad hoc systems. It is heavily experience based with no agreed prescribing regulating information among the members of the system; instead the practice happens as it is at the moment. In contrast, Yeo (2005) acknowledge a zero-loop of learning, where an individual only responds to changes by following the imposed rules without any reflection and trial and error. The latter case provides interesting similarities with the performing resource in the 1st order of cybernetics, e.g. when an assembler is strictly controlled by the supervisor in a mass production factory of the past (cf. Ford, 1924).

This shows that the two disciplines of cybernetic and organization learning have different focus. Cybernetics is about steering organizations' processes towards identified goals regardless of the disturbances, as long as the actual output and the desired one is in harmony the control mechanism is inactive. Organizational learning is more about the change of the performing resources, the employees, and to continuously improvement of their performances. For example, in zero-loop learning it is the individual that could suffer of scarce learning, but someone else had knowledge to develop the imposed rules and instructions. However, this setting had been developed for comprehensive control of the organization as a whole to deliver performances in highly stable environments, i.e. the need for individual learning is limited. In zero-order cybernetic the situation is the opposite, for an individual this is a high learning environment, but in most cases the knowledge stays implicit and does not increase “the general organization understanding” of that particular task. These working conditions can be found in businesses where routine tasks hardly exist. The implication is that managers and staff either has no time or not enough knowledge for developing control mechanisms (instructions) for each potential task, compared to situations in conventional construction. By creating an environment for individual learning the organization can reduce the amount of necessary managerial control.

In conclusion, the theory of organizational learning acknowledges where the information should be placed within the organization and how it can be developed. Business cybernetic or steering relies on this stored information for use when managing the organization. However, both organization development and steering require that implicit and individual knowledge is processed to become explicit information (Goh, 2002), i.e. to be suitable for storage within the system and easy to use for others (Lucas, 2010; Dosi et al., 2008).

### 3.1.4 Cybernetics and information

Ashby (1956) asserts that cybernetic systems are prepared to manage or use a certain amount of information. Further, the system can only respond to disturbances if the controller has adequate information about the internal parts and their contribution to the output. If there is a lack of information, uncertainty on how to achieve the desired performance appears. The situation can only become more certain and solved through an increased understanding, i.e. through information processing or learning. However, this additional action consumes resources and the process therefore become less efficient than if the situation was certain (Galbraith, 1974). Uncertain situation may also hamper the feedback-loops necessary for forthcoming process control and improvements. If the feedback loop is scarce, due to too different settings of the current and future system, the entire system has to be developed, i.e. major amounts of information need to be processed for each system (Daft and Lengel, 1986). In construction, a typical project is perceived as novel and unique (Wikforss and Löfgren, 2007; Dainty et al., 2006), which explains why construction firms have problems to improve their productivity and learn from one project to another. Further, it also explains why the most commonly used ICT-systems, e.g. *Building-Information-Model* (BIM) and *Electronic-Document-Management* (EDM) are tools *“to support intra-organizational processes such as planning and following up”* on project level (Gustavsson et al., 2012: p. 527).

In summary, the cybernetic control theory rely heavily on the stored information the system possess, and can therefore hardly be applied for systems in equivocal and uncertain environments which may require development of new information for each regulation (Pich et al., 2002; Hofstede, 1978). The iterative loops within cybernetic control systems allow very little new information to be added without major changes of the entire system. Yet, this theory is applied when explaining or designing mechanisms for most systems. In order to be useful when clarifying why and how different production strategies require different control modes it should be complemented with information processing theory (cf. Jackson, 2009).

## 3.2 Firms as information processing units

Firms can be seen as entities that use information in order to coordinate and control its processes (Jensen et al., 2009; Olivera, 2000). Organizations need to process new information in order to respond to new requirement of the market and disturbances that affects their processes (e.g. Trautmann et al., 2009; Burke, 2003). Information processing includes the following steps; the gathering of data, the transformation of data into information, and the communication and storage of the information within the organization (e.g. Scott, 2004; Egelhoff, 1982; Tushman and Nadler, 1978). In the context of cybernetic control, it means that when the system was developed information about how to control the system was processed and then stored. The task of steering processes, i.e. the actions of monitoring, analyzing and regulating the operations, also process information but to a much smaller extent (see figure 3:1).

When developing the organization firms strategically process information to minimize future processing needs on an operational level, i.e. 1st order of cybernetic. Information is also processed when the organization exchange information with its market; strategically when the strategies (3rd order) and the competitive priories are developed (2nd order), and operationally when the orders are specified and delivered (cf. DeCanio and Watkins, 1998). The information processing load depends on the firms' chosen market, the customers' needs, the product complexity, and the need to respond to changes (e.g. Brun et al., 2009; Galbraith, 2002). Tushman and Nadler (1978) emphases that even the need for interaction among sub-units within an organization impacts the processing load. The more inputs and coordination a work process needs from other work units, the more information must be processed.

In order to be effective, firms must meet the information requirements with its capacity to store and process information (Trautmann et al., 2009; Daft and Lengel, 1986). The capacity to store information is the firm's ability to store useful information in the structure, processes, routines, machines, management systems (Linderman et al., 2010; Dosi et al., 2008). The stored information is the foundation for processing an appropriate amount of information when executing work processes. Hence, the organization design should provide a systematic way to continuously integrate the information storage and processing capacity (see figure 3:4).

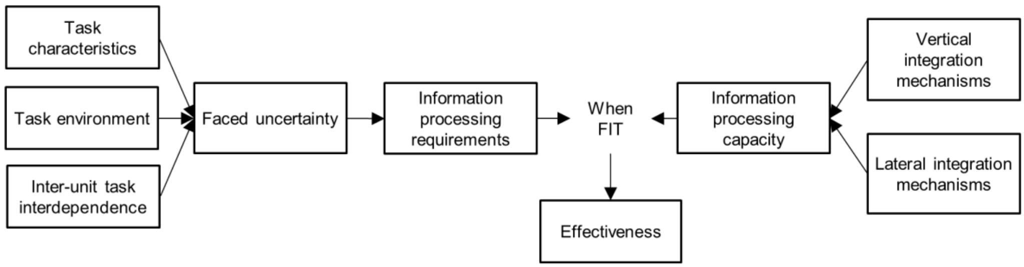


Figure 3:4 Effectiveness is created by the fit between the information requirements and organizational capacity to process information (adapted from Tushman and Nadler, 1978).

Conversely, the organization design has a major impact on how much information it can manage (cf. Daft, 2009; Galbraith, 1974). If there is mismatch, e.g. when the information requirements' overloads the capacity, the organization will be unable to meet the objectives. If the capacity exceeds the requirements' the work will consume unnecessary resources and the firm will be inefficient (Jensen et al., 2009). Therefore, a firm's information processing need has major impact of the choices of organizational design and the production system topology (e.g. Trentin and Forza, 2010; Flynn and Flynn, 1999, Daft and Macintosh, 1978).

### 3.2.1 Certainty, uncertainty and equivocality

Information processing can be divided in three types: certainty, uncertainty and equivocality. These types force the organization as coordinating mechanism, into two different directions.

***Certainty***

When the situation is certain only minor information processing is necessary, because based on current knowledge the situation is predictable and manageable. There is only a need for some additional specifications of predetermined values (Schrader et al., 1993). For example, in mass production systems only a limited amount of information processing is needed, when to start and stop the production, production volumes, and in minor degree for regulation of the material flow.

***Uncertainty***

Uncertainty is the absence of information necessary when accomplish a specific task (O’Neill et al., 2001). By acquiring appropriate information the uncertainty will be reduced, e.g. by asking explicit questions such as yes-or-no questions (Schrader et al., 1993). Similarly, Galbraith (1974, p. 28) asserts; “*the greater the uncertainty is, the greater the amount of information must be processed among decisions makers and tasks executors in order to achieve a given level of performance”.* When uncertainty initiates acquisition of the necessary information, the information is objective in the sense that it will be interpreted in the same way regardless of the interpreter (Daft and Lengel, 1986). For example, in mass customization firms the customers are asked to specify which product attributes each order should include in the product configuration process (Hvam et al., 2008). The customer choices are often limited by a predetermined range of choices in order to reduce information processing needs for the producer and reduce the risk of misinterpretations. See case study B and D in chapter 7 for two business examples.

***Equivocality***

Equivocality means ambiguity and confusion of the work situation, which implies that there are multiple and conflicting interpretations regarding the task (O’Neill et al., 2001). According to Weick (1976) and Daft and Macintosh (1981) the consequences of equivocality is poor understanding of the current situation and the potential solution; thus, yes-or-no questions are not enough to clarify the task. In fact the acquired information may lead to subjective interpretations in the sense that each person will interpret the information differently, possibly for the problem and the solution (Daft and Lengel, 1986).

For instance, conventional construction firms produces what the clients want, which results in extreme diversity regarding; contract forms, product complexity, estate location, time schedule, supplier relations, project organization settings etc. (Mossman, 2009; Bertelsen, 2004). Similarly, Engström (2012) and Kamara et al. (2001) assert that the interpretation of what the clients want for each project, and what the contractor can accomplish from a client’s point of view, is a highly equivocal business situation. To what extent the actual building corresponds to the participators desired mental model, is severely depending on the project stakeholders’ efforts to clarify the project situation and objectives (e.g. Engström, 2012; Atkin and Skitmore, 2008), and their skills to realize the objectives (Arslan and Kivrak, 2008; Griffith, 2007).

Schrader et al., (1993) attribute equivocality three aspects: variables, values, functional relations. A situation is uncertain if only the values of the variables are unknown; in all the other cases the situation is equivocal. Thereby, three levels of equivocality appear: first, when the variables and the values are known, but not the relation aspects; second, when the variables are known, but not the values and relations; and third, all aspects are unknown. The authors also claim that the information processing can be performed in five sequenced steps depending on how much complexity of the knowledge gap (see figure 3:5).

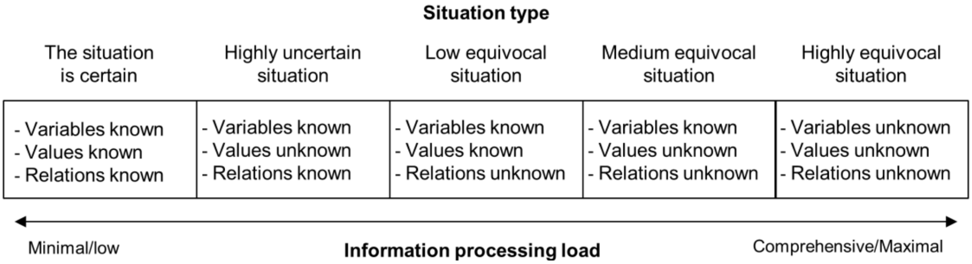


Figure 3:5 The five ways of information processing considering the uncertainty and equivocality degree (extracted from Schrader et al. (1993)).

Schrader et al. (1993, p. 8) summaries the differences between uncertainty and equivocality by following words;

> *"Whereas uncertainty refers to the determination of the value of variables, ambiguity [equivocality] relates to the determination of the set of relevant variables and of underlying relationships"*.

In summary, the amount of uncertainty and equivocality a firm experience affects its ability to be proactive respectively to be responsive to the market's and customers' requirements (Egelhoff, 1982). For example, in a conventional construction firm the projects are business situations with high degree of equivocal information, which had to be processed in order to realize the building with specific characteristics. This is a reactive behavior because the firm process new information only when it is needed, i.e. when a project is initiated.

### 3.2.2 Management of uncertainty and equivocality

Management can be seen as the reduction of equivocal and uncertain situations into more certain and controllable actions through information processing. Acknowledge that this process consumes resources; it can be assumed that the lesser the need is for information processing per order, the more efficient the production of the products is (cf. Daft and Macintosh, 1978). If the production processes is repeatable, the efforts to process and store information in advance can be spread out on all the products that are using this information. *Per se*, this favor a mass production strategy; however, due to the market situations, a firm should balance the product flexibility with the production cost in order to be competitive.

According to Flynn and Flynn (1999) the strategic objectives and their impact on design choices, e.g. product customization, organization flexibility, and manufacturing technology, explain much of the differences in information requirement the corporations' experience. This indicates that a firm can work in two different ways to manage the required information efficiently. First, it can process information in advance and design the organization so it facilitates information use continuously regardless the order, i.e. it reduces the goal diversity and work with standardization. For example, when a construction firm industrializes its processes, it implies that the market segment has to be narrowed to be clearly identified, the product offer width becomes limited; the processes standardized and the managerial procedures systematized (Gerth, 2008). Second, business firms can design the organization for major comprehensive information processing per order due to external drivers of diversity, e.g. customers need of unique products or different location of the real estates for each project (cf. Galbraith, 1974). These two strategies can be accomplished and managed by several organizational mechanisms for information processing (see table 3:1).

Table 3:1 Strategies and mechanisms for managing the necessary information (from Galbraith (1974)).

| Strategy | Mechanism | Explanation |
|---|---|---|
| Reduce the information processing requirement | Slack of resources | The firm uses the slack of resources to absorb uncertainty which can appear due to disturbances, i.e. differences and fluctuations within inventory of material, lead times, staff, and machines. Thereby, the need for deep process information or comprehensive control work is reduced for planning and management units. |
| | Self-Contained | The sub-units' goal diversity is reduced for managers by decentralize the planning and execution responsibility to the sub-units. This also implies reduction of the interrelation ships need between the subunits. |
| | Market/product offer reduction | By focusing on a narrower market or customer segment the firm will reduce internal diversity, e.g. among product models, processes, employee roles and skills, technologies, customer and supplier relations/contracts. |
| Increase the information processing capacity | Vertical information and communication systems | User friendly ICT-systems increase the use information in databases, support, and control systems which increase the amount of information that can be interpret, stored, transferred and controlled regardless of the time frame. |
| | Lateral relations and coordination | Mechanisms that consider and transfer information among many different functions and roles at different places within the organization, e.g. group meetings, task forces, and liaison devices. |

Daft and Lengel (1986) developed the *information-richness-model*, which integrates the amount of information requirements with the organizational capacity to process information. It considers both uncertainty and equivocality, and is thereby an extension of Galbraith's (1974) model which only regards uncertainty. According to Daft and Lengel (1986) is the key for manage equivocal information to design the organization in such a way that the use of the devices supports and facilitate processing of rich information. Rich information is here understood as information that has the ability to change individuals understanding of the task within a limited time interval. See figure 3:6 for examples of organizational procedures for information processing capacity. However, the model mainly considers different ways for organizations to increase the information processing capacity. The focus is on how to increase the responsiveness or information processing for immediate changes at operational level.

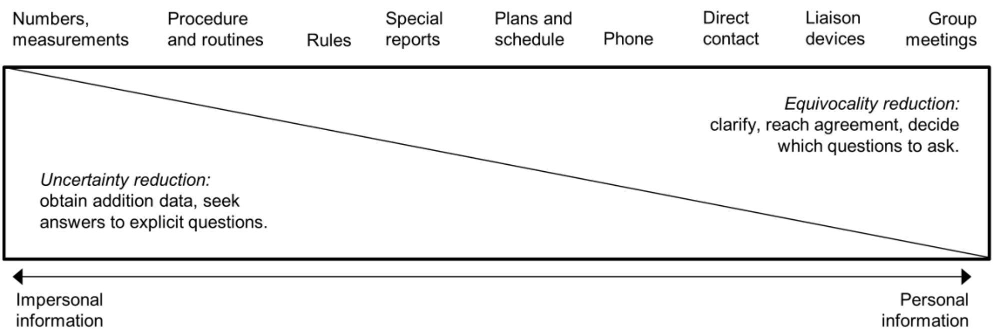


Figure 3:6 Examples of information processing devices that communicate data and their characteristic regarding uncertainty and equivocality. Source Daft and Lengel (1986).

The founding idea of the *information-richness-model* is that vertical organization structures mainly support cybernetic control, which has limited ability to manage equivocal or highly uncertain contexts (Daft, 2009). Many organizational design parameters, e.g. division of labor, chain of command, rules and process descriptions, and plans, are mechanisms for achieving vertical control (Robbins, 2000). The more uncertainty and equivocality there are, the more horizontal interacting mechanisms the organization must use in order to increase its information processing capacity. Further, the more horizontal coordination and more communication a devices supports, the more resources they consume (Daft, 2009).

Schrader et al. (1993) suggest that information processing of uncertain and equivocal work situation types require fundamentally different solution devices. Indirectly this is a critic to the information processing richness model, which puts equivocality and uncertainty in a single continuum. An organization cannot experience high equivocality and low uncertainty for the same situation; instead the authors suggest that equivocality precedes uncertainty and certainty. However, even if they have a point, they perceived each organizational mechanism of information processing in "*black and white*", which seldom is the case in practice. A situation probably starts in one of the five steps (see figure 3:5, p. 26), during the information processing the work situation evolves until it becomes certain, possibly by the use of multiple procedures exemplified in figure 3:6, p. 28.

The current information processing theory claims that it embraces generic principles of organizational design, and predicts how firms can create integration. In order to improve mass producers' responsiveness the focus has been on development of the processing capacity through lateral coordination while the vertical structure is assumed to be intact (e.g. Daft, 2009). Others, e.g. Engström (2012), Brun et al. (2009) and Pich et al. (2002), have concentrated on solving the information process issues with focus on temporary situations and projects. However, neither of these two streamlines shows the vertical organizational structure enough interest as a control mechanism (Jensen et al., 2009; Trautmann et al., 2009). Information processing drives integration of the sub-units, but the vertical structure directs and creates interdependences between the sub-units (Macheridis and Knutsson, 2007). Therefore, the entire organizational design should be changed when changing the information processing strategy.

Information processing research does not show much interest in how to store the processed information for future work with reduced need of processing (Lucas, 2010). According to Linderman et al. (2010), Olivera (2000) and Mintzberg (1979) are organization structures, processes and management systems mechanizes that store information on how to steer and control the work of the organization. Similarly, Dosi et al. (2008) and Jensen (2005) argue that processes, formal methods, blue-prints, machines, tools etc. are codified knowledge ready for use in a given situation. This indicates that the inherent information in these artifacts are developed to reduce future information processing needs, when controlling the production output in accordance with strategic objectives.

## 3.3 Information processing and business steering

The previous sections indicate that the concepts of cybernetic control and information processing complement each other when trying to understand the interaction between production topologies and organization design. This section considers how the cybernetic mechanism relies on information storage and processing to control the organization and production system's performances.

### 3.3.1 Cybernetic constituents' capability of information processing

The cybernetic control mechanism consists of similar parts that can be found in the organization design theory. For instance, the goal of the system is similar to the objective of the business, which is identified in the strategy, and determines the market and product offer (Kates and Galbraith, 2007). The goal determines the external information load that the organization has to respond to, i.e. process and manage, which imply that a change of goal can increase or decrease the information processing need (Flynn and Flynn, 1999; Galbraith, 2002a).

The controlled object is in cybernetics the same thing as the steered process in organizations. The process consists often of formal operations in sequence and has dedicated resources as employees and machines. It is the performing resources that are regulated (Thomas, 2008) through use of information, materials, and energy (Sohlenius, 2005). From an information approach, the formal description of the process, the machines and the tools contain information which is complemented with performing employees' skills and knowledge (e.g. Linderman et al., 2010). These artifacts includes pre-processed and stored information with the purpose to reduce the information processing need when disturbances or new order specifications enters the production process (Wong and Naim, 2011). Even the necessary working skills and knowledge the employees possess are acquired in advance the operations are performed.

Control actions, e.g. adjustment of operational settings, implies information processing in varying degree depending on the scope of changes (cf. Schrader et al., 1993). The changes are initiated by a regulating unit which implements steering signals, i.e. the executing orders by managers (cf. Thomas, 2008). All orders are initiated and executed based on plans for a given business situation and in a specific time interval. The output of the process is monitored, measured and is fed back to the regulating unit. Depending on the error type, more or less information has to be processed to analyze and perform the adjustments of the system (Flynn and Flynn, 1999). In most cases, this closed-loop control process is conducted by many roles at different places within the firm, e.g. workers, quality engineers, production planers, and line managers (Mintzberg, 1979). This indicates that the control mechanism requires that information flows both vertically and horizontally.

### 3.3.2 Control, uncertainty and equivocality at different levels of the firm

The three different levels of control and information processing seem to be natural phenomenon of business firms (cf. Rowe, 2010; Espinosa, 2006; Jensen, 2005; Mintzberg, 1979). However, the control mechanisms appear and behave in different ways depending on the firm's strategy and the information type each controller must correspond to (cf. Ouchi, 1979; Winter and Thurm, 2005).

From a systems approach organizations consist of agents, i.e. performing units, and relations between these (cf. Monostori et al., 2006). The organizational chart describes how the agents, or departments and groups, are related from top-down control perspective, while processes and the decision flows may indicate their relations (Mintzberg and Van der

Heyden, 1999; DeCanio and Watkins, 1998). In fact, these mechanisms are based on processed information about the business environment of the future (Burke, 2003), i.e. strategically processed information in accordance with the 3rd order of cybernetic (see figure 3:2). When the equivocal information is processed and becomes explicit it can be stored and work as a part of the control mechanism on a long-term basis. The chart and the division of labor, dedicated groups and employees are means for work specialization in order to achieve work efficiency. These reduce the need for direct managerial information processing per task and order. The organization structure also determines who report to whom and favors special communication patterns between the roles (Mintzberg, 1979), i.e. it determines the information flow in the control loops (Burke, 2003).

The process of implementing and aligning the organization with a new strategy is often a long comprehensive task for the tactical level (2nd order of cybernetics). This control level is performed by middle line managers and staff, who control the operating processes and improve management and operational processes (e.g. Gratton, 2011; Styhre and Josephson, 2006). Thereby, the time frame automatically becomes more narrowed than the above level, but wider than the subordinated. The monitoring of the outputs at operational level (1st order) does not necessary contains more certain information, but the understanding of how these measures affects the process' parts and what to adjust are less complex than for the above control levels (2nd and 3rd order).

In summary, a firm's operational process level is more immediate to control and manage than the control of the tactical or strategic process levels. However, the more novel the operations are, the more hampered the direct use of regulating feedback loops become and may require additional information processing for adjustment of the next process settings (Weick, 1976).

## 3.4 Information processing in producing organizations

Business organizations are units that store and process information in order to be able to steer and control the production system performances towards the corporate objectives. Companies process information strategically in advance; i.e. they develop and formalize knowledge on what to produce, how to manage and produce this, and store this information within the organization and the production system. The information is stored for repeatable use when accomplishing the work of several product orders. Depending on the order situation, the business strategy may create necessary additional tactical and operational information processing needs, e.g. when mass customizers configure the product order in accordance with the customer requirements (see figure 3:7, p. 32).

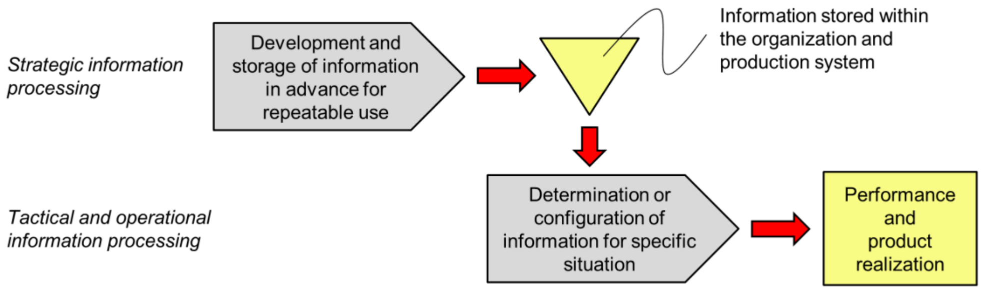


Figure 3:7 Illustration of the necessary division of information processing into strategic and tactical/operational information processing. The figure shows that operational and tactical information processing is based on strategic processed and stored information.

The current information processing theory does not make this necessary division explicitly. Thereby, it cannot explain why and how the control mechanism of different processes at diverse places within the organization should be designed differently. The dominating focus on processing also tend to favor more operative devices to accomplish the work on the expense of latent and rigid knowledge storing mechanisms. Therefore, the current information theory can hardly explain why certain configurations of the organization design or production systems are more appropriate in certain market situations than others.

In order to clarify how the necessary division of information can be used to explain and predict why and how changes of the production topology are inducing a re-design of the organization, theories of production systems and organization design must be reviewed.

# 4 PRODUCTION SYSTEMS AND TOPOLOGIES

*The chapter identifies the purposes of production system, its structure and necessary interaction with other units in the organization. Theories about production flexibility and product configuration are also considered in order to explain the four common production topologies. The reviewed concepts are related to information storage and information processing in order to clarify why and how the common production topologies differ.*

## 4.1 What is production?

The term production comes from Latin "*Pro Ducere*" which means bring or carry forward, and the word manufacturing can be traced to "*Manus Factus*" meaning the hand makes (Sohlenius, 2000). In the thesis the terms often will be used interchangeable, but when there is a need for differentiation, manufacturing is assumed to be a part of production. In definitions of production and manufacturing the transformation process is often emphasized:

> *Manufacturing is the transformation of material into something useful and valuable, using information and energy to control (Sohlenius, 2005:120) various production methods and techniques (Kalpakjian, 1995:1).*
>
> *Manufacturing systems management is a functional domain that involves the major activities, such as design, implementation, operations and monitoring, etc., that are needed to regulate and optimize the manufacturing system as it progress through its life cycle (Wu, 2001:446).*
>
> *The production function involves transformation (conversion) of resource inputs into useful products and services. The managerial process emphasizes management of this production function. The activities such as planning, organizing, leading, coordinating, and controlling are accomplished by managers within the production function. (Adam, 1983:367)*

The definitions indicate that production or manufacturing focus on management of the transformation process through control and utilization of the necessary resources (Kumar and Suresh, 2008). The focus is often the technological system, procedures and methods for direct steering of the transformation process' progress, in contrast to organization research which focus more on managerial methods and social interactions (cf. Ott et al., 2011; Slack et al., 2005). However, both disciplines acknowledge that the implementation of a new production topology may imply change of both the production system and the organization design. Therefore, the forthcoming sections of this chapter present founding production systems theories: the next chapter continuous with theories about organization structure.

## 4.2 Production system structure and organizational interconnections

The production system is the part of organizations that transforms the input to the output, i.e. realize of the product offer in accordance with competitive priorities. According to Aganovic (2004) a production system consists of all structural procedures, managerial systems, and resources necessary for systematic development of products, planning and producing them, i.e. most processes within the value chain (cf. Bellgran and Säfsten, 2005). Wu (2001) assert that the production system consists of three generic mechanisms that are necessary for the production system to function: (1) the physical infrastructure, i.e. the "hard" elements of the production layout that describes the material flow throughout the system; (2) the human and organizational structure represents the system that considers the interaction of employees within the production system. It describes the employees' roles, responsibilities and tasks; and (3) the information and control architecture considers how the production is planned and controlled. It also describes the flow of data and information in all formats, e.g. documents, blue prints, visual signal systems, and computer communication.

These generic mechanisms are connecting the production system with its business and organizational context in both horizontal and vertical directions (Shewchuk and Moodie, 1998). Figure 4:1 indicates the authority structure and that the production system design is managed from a top-down approach.

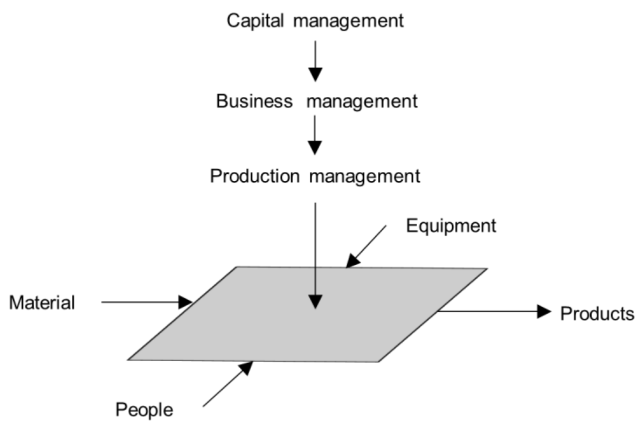


Figure 4:1 A principle model of a production system structure with its major internal stakeholders, the control levels and the required input (from Sohlenius (2005) and Sandkull and Johansson (2000)).

The figure puts the production system into an organization context, but it is too general to increase the understanding on how different configurations the production system's elements and parts are placed and interconnected in the organization structure.

### 4.2.1 Production systems' hierarchical structure

The production hierarchical structure is important to consider when trying to understand how the different production systems parts can be designed in several different ways (e.g. Löffler et al., 2011; Shewchuk and Moodie, 1998). For example, Nilsson and Nordahl (1995) claim that flexibility appears on three different levels in producing firms; market and business level, organization and production system level, and on resource level. With an appropriate design of the parts and the structure, the production system can contribute to the specific product order characteristics as well as to the firm's long term capability (Klemke and Nyhuis, 2009).

The following hierarchical levels of the production system have been identified:

- Network (including the suppliers and distributors)
- Production system (all internal producing units)
- Manufacturing system (location of factory)
- Line of processes or cells (within a factory building)
- Processes and cells consisting of operations (working area within a line)
- Operation or station (working place within a process)
- Activities (movements or specific action within an operation)

Flexibility, at manufacturing process level, is often discussed from three categories: product, operations, and capacity flexibility (Wiendahl et al., 2007; Oke, 2005; Gerwin, 2005). *Product flexibility* is the ability for the process to introduce and make different products or components with the same equipment. *Operation flexibility* enables the manufacturing system to produce a set of items using different resources, e.g. operations, machines, tools, and materials, or in different sequences. *Capacity flexibility* refers to the ability to vary the production volume based on aggregated plans fast, and/or change the planned delivery date, while remaining profitable. These three flexibility categories are all closely related to the structure of the production system. This means that different enterprises may create various degree of flexibility on these different hierarchical levels in order to achieve suitable production capability.

## 4.3 Production system flexibility

There are many definitions of production flexibility and they can imply the change of production volume, configurability to produce variances of products, change of operation setup etc. Boyle (2006) and Sethi and Sethi (1990) identifies elven types flexibility mainly based on the hierarchal level and where it appears in the business firm, see table 4:1. ElMaraghy (2006) uses these also, but assert that market flexibility is not a key issue for the production management. However, market changes clearly impacts the production unit and will be an issue for the production manager (see table 4:1).

Table 4:1 Production flexibility types and hierarchical levels of the firm (from Sethi and Sethi, 1990).

| Flexibility type | Description |
|---|---|
| Machine/tool | The different operations that the machine can perform without requiring a setup-change or switching from one operation to another. |
| Material handling | The ability to move different types of items efficiently for processing through the manufacturing facility. |
| Operation | The ability to plan and produce a part by using alternative operations or sequence of operations. |
| Process | The set of different types of parts that the system can produce without major setups changes, i.e. the operations sequence is more or less the same. |
| Product | The ease with which new products or parts can be added or substituted within an existing mix of products or parts. |
| Routing | The ability to produce a product by alternate routes through the system. |
| Volume | The change-ability to produce different quantities of products with the correct characteristics and to determined profit. |
| Expansion | The ease with which the manufacturing unit's capacity and capability can be increased when needed. |
| Program | The ability of the production unit of factory to run itself with a minimum of human involvement through the use of digital factory and virtual control. |
| Production | The number of product families and part types that the manufacturing system can produce without adding major capital equipment. |
| Market | The manufacturing system's ability to adapt to changing market needs considering customer requirements, product features, production volumes etc. |

Gerwin (2005) asserts that when changing the production flexibility it cannot solely be studied on one specific level. All hierarchical levels are interacting and may require adjustment if a certain flexibility capacity is going to be realized (Barki and Pinsonneault, 2005). The figure below identifies five different classes of flexibility which is directly correlated to a firm's ability to respond to market changes and customer requirements on the products, see figure 4:2 on the following page.

*Changeover ability* is the ability of a single operation, e.g. within a work station by a worker or by a machine, to perform particular work on an item or subassembly at any moment with minimal set-up effort and delay. *Reconfigurability* refers to the operative ability of a cell or process to switch for managing a different family of work pieces or subassemblies with minimal effort and delay. *Flexibility* is the tactical ability of a manufacturing system or factory to switch with reasonably little time and effort to produce new families of components by changing the processes, material flows and logistical functions. *Transformability* describes the ability of the entire production system to switch to make a different product family. This calls for infrastructural changes in the organization structure and process, in the managerial area, management procedures, in the production flows and processes and the logistics. *Agility* means the strategic ability of an entire company to open up new market segments, i.e. development of new products and services, and to build up necessary manufacturing capabilities and capacity (Wiendahl et al., 2007).

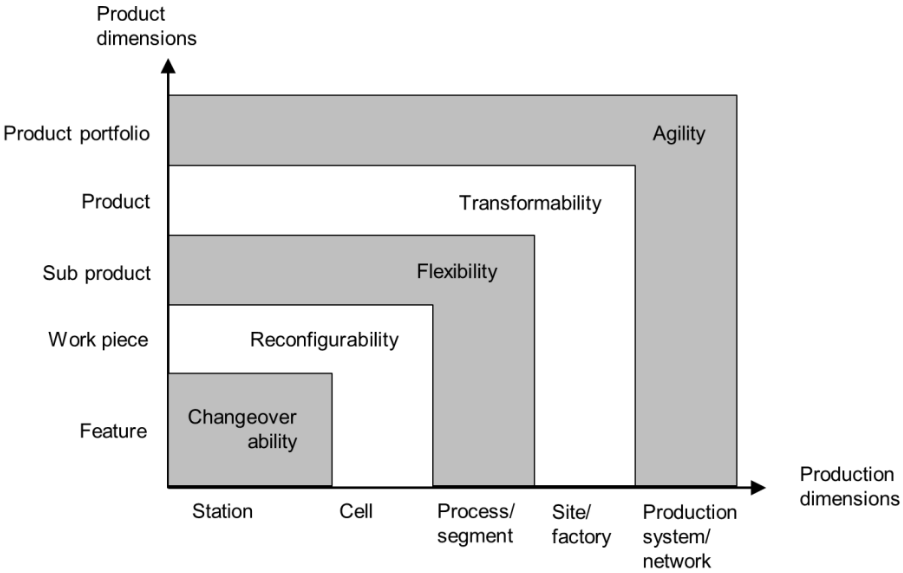


Figure 4:2 Levels of product and production flexibility and the required relations (From Wiendahl et al., 2007).

Klemke and Nyhuis (2009) and ElMaraghy (2006) assert that each level have their own means and requirements to achieve its objectives. Each level is in principle designed based on the same mechanisms as Wu (2001) identified (see p. 34): thus, (1) physical infrastructure, (2) information and control architecture, and (3) the human and organizational structure. These can be seen as different control mechanisms that have to be interconnected to make the firm functional. Therefore, ElMaraghy (2006) levels the two first mechanisms in two different, but interacting, streamlines (see figure 4:3 on p. 38).

In conclusion, the structure of the production system has a major impact of firms' flexibility and the more flexible the production is the more agile the structure must be both vertically and horizontally (cf. Wiendahl et al., 2007). From an information approach the conclusion is that the more flexible the production is the more information must be processed per order and managed on each hierarchical level. Chapter 5 adds the organization mechanism to these and deduces the functions and roles for developing, managing and operate the production system to different locations in the organizational structure.

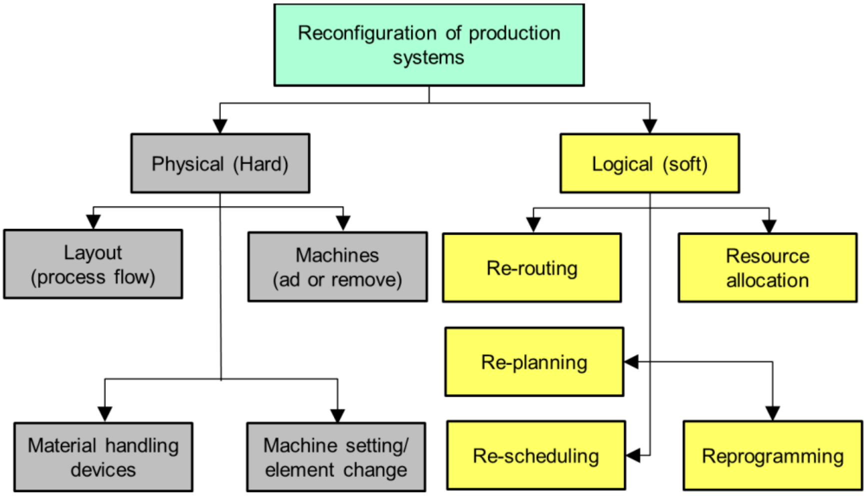


Figure 4:3 The two mechanisms of the flexible production system, the physical system to the left and the logical control infrastructure or management actions to the right (from ElMaraghy, 2006).

However, the presented models of production system flexibility indicate that there is an interaction between different business departments of the firm (e.g. Kumar and Suresh, 2008).

## 4.4 The product realization process and other business processes

When a firm changes their production flexibility it will impact the product realization process, which drives a need for re-considering how the firm's organization departments are interacting. In flexible production system, especially those that that customize products, the internal management and control operations must consider external suppliers capability and the relationship with customers in order to be effective (e.g. Blecker and Abdelkafi, 2006a; Goldsby and Garcia-Dastugue, 2003; Pine, 1993). Figure 4:4 on p. 39 illustrates important business processes that have a direct impact on the production function (cf. Sackett et al., 1997).

These business processes may impact firms' strategic capability as well as the short-termly production performances per order. Considering the product realization process, this becomes obvious especially when comparing how construction projects and trucks are realized by producing firms (see case study A and D in chapter 7).

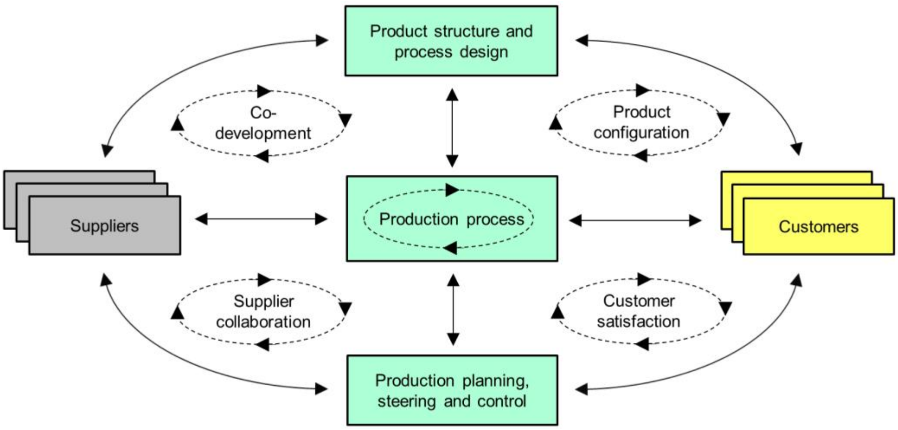


Figure 4:4 Import business processes that have a direct impact on the production system performances (adapted from Sackett et al., 1997).

### 4.4.1 The product realization process

Product realization is about both development of the product and producing it, and includes according to Bellgran and Säfsten (2005) the following steps: product development, product planning, engineering, production process planning, and manufacturing. Sohlenius (2005) and Mårtensson (2006) divide the process into three major steps, very similar to the five above (see table 4:2).

Table 4:2 The major process steps in the product realization process (from Mårtensson (2006)).

| Process step | Description |
|---|---|
| Product development | In the design process a product's functions, features and technical parts are identified, developed and determined. The starting point is knowledge of the potential market or customer needs and technological opportunities. |
| Production process design and planning | The process design and plan determines what operations and their sequence that is necessary to convert the raw material or components to the specific product. In the process plan it is decided how the products technical features will be realized in order to meet the competitive objectives, i.e. product quality, cost, delivery time and volumes. |
| Production and manufacturing | When the physical production plant had been the developed and equipped, the daily work is about planning, monitor, control and adjustments of the resources that executes the transformation operations. |

The business strategy is the foundation for the product idea and the design process. It is followed by the development of the production system, manufacturing and assembly of the product. Thereby the strategy will have a major impact on how the firm will organize its production system around the product realization process (Clausson, 2006). For example, a firm that develops one standardized product for large scale production, e.g. a mass producing car corporation, will have a very different organization structure in comparison to a firm that develops and produces one-of-kind products, e.g. a conventional housing firm.

Interesting to note is that regardless the business types the product realization processes seems to follow the same pattern, compare e.g. Winch (2003) and Bellgran and Säfsten (2005). Instead the major difference between firms is how many products of a certain type that are produced within a particular production system without re-configuration. The product realization process' interaction with the corporate strategy directs the procurement and development of the organization's resources (Linderman et al., 2010; Sine et al., 2006). This creates more or less rigid frames for what can be produced and how to produce it (cf. Marcus and Jacobson, 2008). Therefore, each production system produces more than one product, but if the product is of one-of-a-kind type or customized the general production process requires major reconfiguration and additional development of details to be able produce the product (cf. Mossman, 2009; Koskela, 2000).

### 4.4.2 Information management within flexible production

In summary, the greater the production flexibility is the more comprehensive is the production structural changes. This impacts the configurations of the sub-levels and the product realization process. In essence, the flexibility drives information processing in order to re-configure the production system. Figure 4:3 on p. 38 shows how the managerial information is necessary to steer the physical system. However, depending on how many products the manufacturing process is dedicated to produce without pure development the more information can be stored within the system. If the products are standardized or configurable (see section 4.6) information on how to produce them can be processed and stored in advance for repeatable use when producing the orders. The forthcoming section will differentiate and describe various production systems and related to different type of products.

## 4.5 The differences between production systems

In order to clarify how a change of production topology impacts the design of the organization structure for realizing products effectively, the production system must be understood. There are many ways to explain and differentiate between manufacturing systems. This section describes some common classification approaches to extract the most important production parts and mechanisms, which are interrelated with the organization design. Five common classifications approaches were identified:

- Product industry/sector type, e.g. construction or automotive
- Production technology level
- A continuum between product variety and production volume
- Stock and volume relationships
- Postponement

### 4.5.1 Product industry type

The industry type differentiation is probably the most common one, but least helpful to understand the production principles (Porter et al., 1999). The variations mainly considers the dominating product and business characteristics for each sector, e.g. for buildings or trucks (Rumelt, 1991). The differences among the firms within each industry are not considered. For example, within the housing industry there is both production systems based on conventional construction firms that relies on craftsmanship, and industrial construction firms that uses industrial factories to realize the buildings. In the automotive industry, there are corporations that rely on mass production technology, while others offer highly customized products for each customer.

However, within every industry there are several markets trends and paradigms that will drive the development of the general production systems in different directions (Winch, 2006; Levitt, 2004). This indicates that the different business logic will affect the third order of cybernetic, which indirectly will affect the others. A result can be a dominating perception of the sectors business, i.e. in each product sector there will be a dominating production paradigm (cf. Jovane et al., 2003). For instance, construction is still in the craftsman paradigm, which affects the way of making business regardless if the producer uses industrial technology or not (e.g. Höök and Stehn, 2008a). In the automotive industry the mass production paradigm is present, and even if there are flexible systems the over-production capability and the relation between sold/produced cars are too high (e.g. Erixon, 2009). The product sectors classification introduce an understanding of different information processing needs, based on the complexity of the product; but, this only makes differentiation between not competing products (i.e. between product types). In order to explore the industrialization of construction firms the differentiation of production systems must be clarified instead of the separation between the product types.

### 4.5.2 Production technology level

The production technology is another way to distinguished between different systems (e.g. Frohm, 2008; Melcher et al., 2002; Jovane et al., 2003). The various levels of production technology refers to in what extent the accomplishment of operations are based on human skills supported by mechanic tools, automated machines, robots, and computers (cf. Fasth, 2012). Similarly, Dencker (2011) assert that automation is the replacement of the human effort by mechanical devices, even though she considers the physical operational work. The major difference between the levels are the explicitly formulation on how to perform the tasks and the mechanization of the operations (Almannai et al., 2008). It is obvious that the production technology has a major impact on the blue collar-workers' involvement when conducting the operations and the necessary skills. Frohm (2008) identifies seven levels of automation which differentiate between physical operations supported by mechanical equipment and how the operations are cognitive controlled (see table 4:3).

Table 4:3 Summaries of the seven automation levels there the operations technology corresponds to the cognitive level (human-technology interaction). Source Frohm (2008).

| No | Operations technology | Cognitive control |
|---|---|---|
| 1 | *Totally manual:* totally manual work, only the operators' own muscle power is used to perform the activity with no support of tools. | *Totally manual:* the user creates his own understanding of the situation and develops the action based on his/her earlier gained experiences and knowledge. |
| 2 | *Static hand tool:* manual work with support of a simple and static tool, e.g. screwdrivers, hammers, and jigsaws. | *Decision giving:* the worker gets information about what to do and a proposal for how the task can be achieved, e.g. working order. |
| 3 | *Flexible hand tool*: manual work with the support of a mechanical flexible tool, e.g. an adjustable spanner or a cramp. | *Teaching:* the user gest instructions about how the task should be achieved, e.g. manuals and checklists. |
| 4 | Automated hand tool: automated tools which facilitate the manual work e.g. hydraulic bolt drivers. | *Questioning:* the technology if the questions the execution of work differ from what the technology considers as suitable, e.g. verification before action. |
| 5 | *Static machine/workstation*: the work is automatic and supported by a machine that is designed for a specific task, e.g. a lathe. | *Supervision:* the technology calls for the users' attention and directs the work to the present task, e.g. by alarms. |
| 6 | *Flexible machine/workstation:* automatic work performed by a machine that can be configured for different tasks, e.g. CNC machines. | *Intervene:* the technology takes over and corrects the action if the execution deviate from what the technology considers as suitable, e.g. thermostat. |
| 7 | *Totally automatic work:* totally automated work, there the machines solve all deviations and problems that occur during the process by themself, e.g. autonomous systems. | *Totally automatic work:* all information and control are managed by the technology. The user is newer involved in the actual operations, e.g. autonomous systems. |

The table indicates that the more advanced the technology is the more it impacts the human effort of the operation. However, it only considers how the operator is facilitated by the mechanical equipment and the cognitive control devices. It does not consider how the production management procedures are affected or the technical staff who develops the automation systems.

Further, if the table is applied to conventional construction a mismatch is identified. It is common for craftsmen to use tools up to technology level 4, but the corresponding cognitive level does not seems to be appropriate. Instead it seems to stay at a mix of cognitive level 1 and 2. This mismatch can probably be explained by the fact that Frohm (2008) developed it for industrial manufacturing environments. It also indicates that if craftsmen are considered, the model must be further developed.

***The differences between craft and industrial production***

The dominating mode of managing production in construction is the use of craftsmen and craft-based technology. The craft-based technology level is fundamentally different from the others, even manual work (Costin, 2001). Therefore, it is often categorized into the paradigm of craft production (e.g. Fleischman, 2000; Jovane et al., 2003). In the manufacturing industry the dominating mode is industrial manufacturing technology, which relies on the industrialization principles (Gerth, 2008; Taylor, 1967; Ford, 1924) (see appendix A). Within the manufacturing research today, it is even suggested that the levels of automation should be closely correlated with the firms' production strategy (Lindström and Winroth, 2010). This actually indicates the amount of development work that is necessary to accomplish if a firm is going to increase the automation level – even within an industrial firm.

***The craftsman and the production technology***

The concept of craft work in comparison to industrial manual work is often misunderstood as equal in both disciplines (cf. Frohm, 2008; Maas and van Gassel, 2005; Taylor, 1967). Craft-based production relies on highly educated and skilled craftsmen, which is necessary to perform enlarged individual jobs and when the working teams are autonomous. For example, in Sweden almost all the craftsmen have a high school diploma (construction craftsmen program) and 3400-6800 hour of apprentice program within a company. During this time the norms and standards for the sector and the firm is "socialized" (cf. Mintzberg, 1979). Interesting to note is that the craft-based technology is a mechanism to reduce the information processing per order, through its ability to create slack of skills for the company (Galbraith, 1974). Thereby, the use of craftsmen reduces the staff and managers' need for controlling (detail planning, order giving and monitoring) the operations performed by the craftsmen. Instead they can concentrate on overarching resource allocation and general project planning (cf. Rowe, 2010; Taylor, 1967). The use of simple tools and materials also reduces the need for infrastructure direction and control of the physical flow, in comparison to industrial systems.

***Industrial laborer and production technology***

Industrial laborers do not have that comprehensive apprentice program but rely on work specialization and detailed work instructions to perform each operation regardless the order (Shafritz and Ott, 1996; Taylor, 1967). Manual work and related technology is often found in the flexible production or in assemble lines, while the use of the other technology levels are more common in continuous and manufacturing processes (Bellgran and Säfsten, 2005). When a process or a cell is performed by machines and robots, it is fundamentally prepared in advance, tactically and operationally, by specialists. The operators' duties have been reduced to monitor, re-load, and maintain the machines. In automated lines entire processes are dominated by machines, and the blue-collar workers' tasks have been further reduced or completely replaced. This technology level is so advanced that major parts of the work can only be accomplished by specialists (cf. Mintzberg, 1979).

In summary, in industrial factories major developments have been accomplished in advance to identify how to produce and which technology to use for each operation. The higher the degree of technology is, the more is the information and physical flow controlled by the technology. Even the planning and the resource allocation will be more predictable, which further reduces the information processing need per order. It is, thereby, obvious that technology and the related managerial mechanisms possess information that is used during the product realization process.

***Industrialization of construction***

In order to consider the craftsmanship in conventional construction during the transition towards industrial construction, four categories of different technology levels have been developed by Gerth (2008), see table 4:4, which will be used in the thesis.

Table 4:4 Different types of production technologies (from Gerth, 2008; Frohm, 2008; Taylor, 1967).

| Technology level | Description |
|---|---|
| Craftsmanship and hand tools | Craftsmen using simple hand tools for certain operations. Craftsmen decide how and when to use the hand tool and thereby it is not affecting how the working process is accomplished. |
| Manual work and machines | Laborers that are supported by jigs, technical facilities, and simple machines necessary to perform the operations. How to use the machines are regulated by instructions, thus the working process is impacted. |
| Machines and robotics | Simple or advanced machines grouped into cells, advanced machines or robots that reduce the work content of the operation. Thereby, the work flow and the laborers work are severely impacted. |
| Automated lines | Highly automated lines or factories with self-regulating robots, which implies the technology controls the operators' work by reducing it to only include monitoring the process. Their work is reduced to turn on/off, load the machines with inputs and to solve simple problems. |

However, these categories do not say anything about how the technology is correlated to product variations and production flexibility.

### 4.5.3 The product variety and production volume continuum

Production systems can also be categorized based on the dominating process types, flows and layouts. In general there is a trade-off decision between the product variety and production volume, which have a major impact on the product system design – or as Skinner (1974, p. 115) puts it; *"a factory cannot perform well in every yardstick"*. The decision favors a certain kind of infrastructure based on the production flow, process type, and production layout (see figure 4:5).

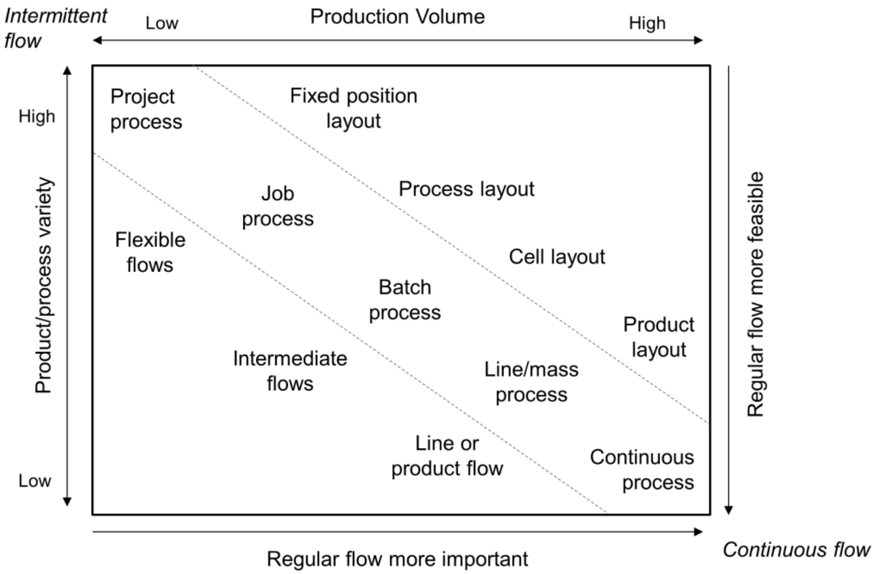


Figure 4:5 The continuum of product variety and production volume, the corresponding production flows, processes and layouts (cf. Slack et al. (2005), Krajewski and Ritzman (2000) and Hill (1995)).

The figure indicates the close relationship between the production system design and firms competitive priorities, especially regarding product customization and production flexibility.

***Production flows***

The production flow takes a top down approach and assumes that every firm produces many products, but considers the products' standardization degree and the production volume of each product (Tangen et al., 2008). The dimension describes how the product realization process and its dedicated resources are organized to accomplish the work and indicates the connection between the produced products (Bellgran and Säfsten, 2005).

One extreme is the intermittent flow that is predominant when there are no process similarities between the orders. This implies that the production resources and its organization must be developed and procured for each order, such as the case is in conventional construction and housing firms. The other extreme is the continuously flow, which denotes when every product is produced in the exact the same process and resource arrangement, e.g. paper mills or petroleum refiners (Krajewski and Ritzman, 2000).

Between these extremes the more common modes can be found, i.e. the flexible, intermediate, and line/product flows. For the flexible and intermediate flow the corporation owns the different types resources and processes with dissimilar set of skills and capabilities. These can be combined in novel ways to realize products with diverse features in low volumes. For the line or product flow resources and operations are organized around a specific product for high volume production. All the resources are highly dedicated to narrow set of operations in order to be achieve low cost and short delivery times (Slack et al., 2005). Typical examples are mass producing automotive corporations, small house producers or element prefabricators.

***Process types***

The differences between the dimensions of production flow and process types are mainly found on detail level. The processes can be distinguished based on their capability to deal with variations regarding production volume, product customization, and product variances (cf. Hill, 1995). Project processes is used when the product orders' features are highly diverse and require fundamentally different production processes and different kinds of resources, e.g. construction of houses or factory plants. Often a number of different business organizations are involved for each project (Slack et al., 2005). Job processes are similar to the project type, but manage smaller and moveable products for production in factory environments, e.g. special tools or custom made furniture. The operating resources are in place before the order enters the firm, but these are highly adjusted to fit customer requirements. Thereby, larger product quantities, than for the project process type, can be produced (Krajewski and Ritzman, 2000).

Mass and line processes are used in order to produce standardized products in high volume as effective as possible. The highly specialized performing resources and ingoing materials are organized around the production process for a specific product. For every product the operations are performed in the same sequence with the same tact time (Hill, 1995). Batch production means that predefined quantity, or batch, of identical products or components are produced, before the production process is switched to produce new quantity of products with different features, e.g. of different car models (Slack et al., 2005). The extreme of the process types is continuous processes, which are used for production of inseparable products, e.g. chemicals and energy plants (Heizer and Render, 2011).

***Production layouts***

Production layout is the physical arrangement of operations, performing resources and ingoing materials (Zandin, 2001). Usually the layout is connected to the product characteristics and the volume the production system is designed to realize (Slack et al., 2005; Ståhl, 2006). Thereby, respectively flow and process type require different production layouts (Bellgran and Säfsten, 2005).

The fixed position layout is most common when products are immobile and require that material and resources have to move to the site there product will be produced, e.g. buildings and houses. Therefore, all the resources have to be mobile for re-arrangement both within the production of a specific order and between orders (Bellgran and Säfsten, 2005). A factory that has clustered similar operations and machines, e.g. grouping drilling, milling, and cutting machines together, has a process or functional layout. This layout type balances the need of creating different product features and the utilization of resources (Zandin, 2001). Every specified order has a detailed route of operations and what features to be accomplished. Different orders can have different feature specifications, and have therefore altered routes through the production plant (Slack et al., 2005).

The cell layout is used when work operations are sequenced to complete the immediate work and to reduce the movements of *work-in-process* (WIP). It is an appropriate flow for products with similar features to reduce the downtime of converting of the operation. In production systems' with many cells, the cells can be arranged in a process or line layout, so the product order flows from cell to cell (Bellgran and Säfsten, 2005). Product layout is appropriate when the entire production process is dedicated to a standardized product for production in very large quantities. The layout is designed to optimize flow of material and to perform standard operations identical for each product (Slack et al., 2005).

***Information processing reflections***

In summary, the product variety and production volume continuum can be used on a general level to classify producing firms. The design of the production flow, processes and layout types are organizational mechanisms that have been developed before the production of the products are initiated (see chapter 5). These mechanisms possess stored information on how to produce and manage the product offer. Depending on the production flexibility additional information processing may be needed, regarding product specification, process route within the factory layout and production volume. The continuum also indicates that the more flexible a production is, the more information must be processed per order.

The continuum model is, however, too production oriented to increase the understanding of how the organization structure and management devices will be changed if a firm's production flow, processes and layout are changed. For instance, if a conventional housing firm implements an industrialization strategy and accomplish most of its work in a factory and the rest on-site; how should the organization and management system change considering that the firm will use both a process or cell layout and a fixed position layout?

### 4.5.4 The continuum of planning horizon and production volume

The *"planning horizon and production volume"* continuum classify manufacturing system based on the production planning tactics, i.e. the amount of forecast or stock driven production respectively order driven processes (Porter et al., 1999). Stavrulaki and Davis (2010) and Świerczek (2010) identify four generic production systems through literature reviews: *engineer-to-order* (ETO), *manufacture-to-order* (MTO), *assemble-to-order* (ATO), and *make-to-stock* (MTS)[1] (see figure 4:6).

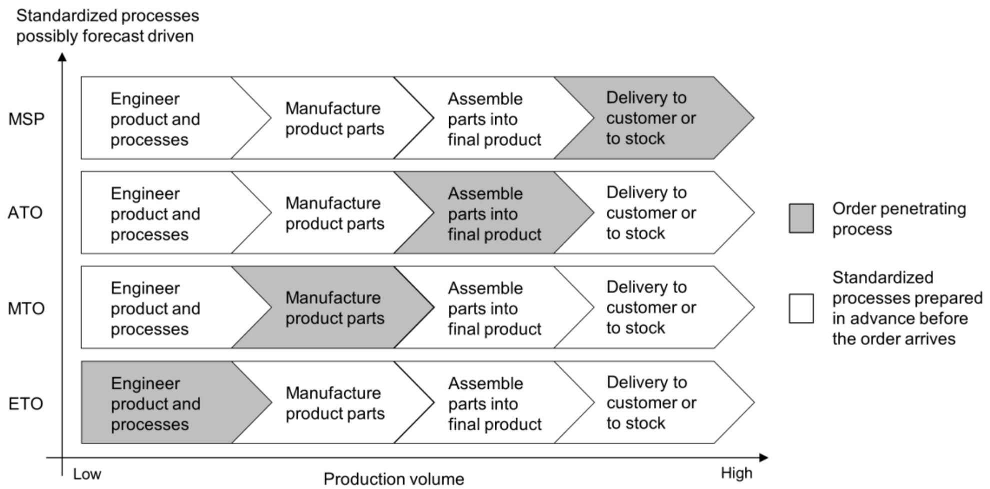


Figure 4:6 The four common production topologies considering the planning horizon and the production volume. The OPP may induce re-configuration of the penetrated and subsequent processes.

These different production types are related to where the *order-penetration-point* (OPP) is located in the product realization process (Olhager, 2010). Sharman (1984) define OPP as the point where product orders become frozen, and as the last point at which inventory could be held. Figure 4:6 illustrates how the product realization process is started by engineering

[1] In this thesis the MTS-topology is denoted *make-standard-products* (MSP).

activities of both the product and the production process. Therefore, the ETO-system is placed at the lower left corner in the figure. In the right upper right corner, the OPP is placed at the delivery process and creates the MTS-system, and the entire product realization process is managed on forecast. Between these extremes the two intermediate systems ATO respectively MTO are placed in order to balance the lead times, buffers and stocks.

However, the denotations of these diverse production systems are misleading, which explains why they are often misunderstood. For example, in construction it is common to assume that standardized products always are produced in MTS-systems (cf. Winch, 2003). Another example is Lennartsson (2012), who asserted that all type of construction is ETO, regardless of the product standardization and the process preparations in advance. The industrialized topologies do not mean that the production of products or parts always have to be executed on forecasts and to stocks. It can imply that everything is standardized and prepared ready for action when the order arrives (Swierczek, 2010): thus, it can be more economically beneficial to wait with the production until the order arrives (van Hoek, 2001).

***Engineer-to-order (ETO)***

In production systems based on ETO[2] the entire product realization process is developed when the order arrives (Wortmann, 1992). This includes everything from designing and engineering the product and the work organization and the processes, even the procurement of material suppliers and sub-contractors may be necessary (Gosling and Naim, 2009). This type of production systems is common when products are of one-off-kind type and have long lead times, e.g. conventional construction projects (c.f. Winch, 2003).

In conclusion, due to placement of the OPP at the engineering phase indicates that very little is prepared and planned in advance because the firm does not know what, when and how to produce the products. Everything has to be, more or less, developed from scratch, when the order is initiated, i.e. neither blue prints nor physical components of product or the production process can be stored (Gosling and Naim, 2009; Wortmann, 1992).

***Manufacture-to-order (MTO)***

In a MTO-system, the entire production process is managed on order (Hemmati and Rabbani, 2010). The firm has developed a product structure, the production system, and suppliers are procured before the product orders are requested (Porter et al., 1999). The product structure may be of configurable type (see section 4.6), which in such cases induces re-configurable processes. Rudberg and Wikner (2004) discuss a similar topology under the

[2] Design to order (DTO) and Build to order (BTO) are similar topologies, see e.g. Yang et al. (2007), Winch, (2003), Goldsby and Garcia-Dastugue (2003), Porter et al. (1999) and Sharman (1984).

term engineer-to-stock (ETS), which indicates that MTO-systems can be considered as a production system with products that are totally or partly standardized. Further, everything is prepared for realization of the products, but the manufacturing will not be executed before there is a need (cf. Sharman, 1984). For example, for large products, e.g. standardized catalogue houses, it could be more economically beneficial to prepare everything but wait with the production until the product order arrives. Even parts of small houses, e.g. standardized walls or ceilings, can bound too much capital or be too large to produce on forecasts and keep in stock.

The MTO-topology is appropriate for relatively certain or uncertain market conditions due to the amount of information that needs to be processed and stored in advance. The products’ lead times are often shorter, the production costs more predictable and lower than for the ETO-topology (Slack et al., 2005). In general, this also allows higher production volumes than typically ETO-firms manage.

***Assembly-to-order (ATO)***

If the OPP is placed at the assembly process, everything before this point is standardized and can be produced on forecasts (Hill, 1995). The final assembly to complete the product is postponed until there is a planned need or when a customer order arrives (Porter et al., 1999). The assembled products could be of standardized type or of configurable modular type to allow the offering of product variants (Hvam et al., 2008). Thereby, it is only the assembly process that is demand driven and may require a process re-configuration per order. This implies that there can only be component or part buffers in the manufacturing process. In relation to the MTO-systems, this reduces the production planning efforts, the delivery time and production cost per product but increases the production volume capacity (Olhager, 2010; Swierczek, 2010).

However, because of the performances of ATO-topology relies on information processing and storage in advance; strategically for the development of the product structure and for the production system, and tactically for making forecasts of the production volumes, it is a suitable mode for relatively predictable and stable (certain) market conditions.

***Make-to-stock (MTS) or make-standard-products (MSP)***

This production topology is the classic mass production system; there the demand of the standardized products is forecasted and produced in high volumes (Hemmati and Rabbani, 2010). The entire product realization process is accomplished based on forecast and the products are placed in stock, from which the customer can receive products immediately after the purchase (Porter et al., 1999).

The MTS-system relies on comprehensive planning in advance, e.g. business plans, aggregate planning, material resource planning, and operational planning (Krajewski and Ritzman, 2000). These different types of plans are often conducted on various organizational levels and departments (see chapter 5.3). The only way to create this kind of predictable performances is to standardize everything, e.g. the products, the organization structure, the processes and resources. Therefore, the MTS-topology is only appropriate in stable and certain environments (cf. Womack et al., 1990; Ford, 1924). What differentiate this topology from the other topologies is in principle that all necessary information is processed in advanced on a strategic, tactic and operational level.

***Information aspects of production planning and volume continuum***

The planning horizon and production volume continuum indicate the major difference in the information processing degree between the production topologies. It is obvious that ETO-firms stands out, and require a huge amount of information processing for developing the entire product realization process for each product order or project. Very little information is stored for repeatable use when developing and planning the project orders. Thereby, this production system-type limits the use of feedback for planning, optimization and productivity improvement between the orders.

For MTS-systems the production of every product is produced based on forecasts, i.e. comprehensive information processing effort has been performed in advanced. From a strictly planning approach, no information is processed per custom order, but on strategic and tactical level. This also increases the closed-loop control mechanism for e.g. production scheduling precision and performance optimization. The topologies MTO and ATO use both stored information in advance and process it per order. These systems are also appropriate for mass customization, i.e. allow product customization at the OPP, which increases the complexity in comparison to both the ETO and the MTS-system (Blecker and Abdelkafi, 2006a). Note, that the "*continuum of planning horizon and production volume"* differentiation approach originally did not consider the degree of customization, but solely the division of forecast and demand driven production in correlation to the manufacturing volumes.

However, the confusion or carless use of this continuum's topologies and customization is even common within the manufacturing discipline (e.g. Tangen et al., 2008; Goldsby and Garcia-Dastugue, 2003). In order to clarify how product customization impacts the production systems' flexibility the postponement theory can offer some insights.

### 4.5.5 The postponement theory

The postponement theory distinguishes between different production systems based on where the *customer-order-decoupling-point* (CODP) is positioned in the product realization process. The CODP is used instead of OPP to clarify that it is the point where a particular product is linked to a specific custom order (Olhager, 2003) and can be customized (see also section 4:6). The concept is about delaying some process activities and the product differentiation until the customer enters the product realization process, while the others are produced in advance based on forecast (Wikner and Wong, 2007; van Hoek, 2001).

Considering the previous production classifications (section 4.5.1-4.5.4), it is easy to get the perception that technology, process or planning mechanism are the same regardless of where these aspects are used within a firm. The postponement theory acknowledges the differences within an organization’s value chain and the sub-processes’ different characteristics, e.g. process flexibility, technology, and planning (Swierczek, 2010).

***The product realization process and CODP***

The postponement concept separate the processes before (pre) and after (post) the CODP, because these will possess fundamentally different characteristics, regarding infrastructure and managerial mechanisms (Olhager, 2010; van Hoek, 2001). Figure 4:7 illustrates how the CODP divides the product realization process.

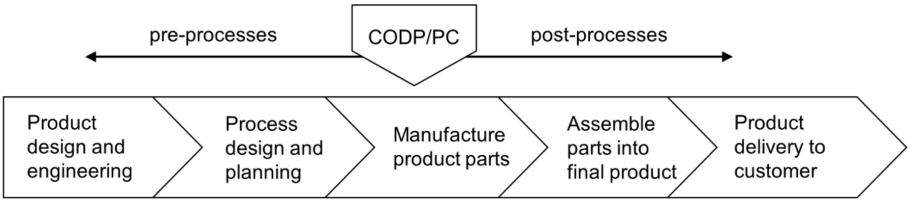


Figure 4:7 Illustration of how the product realization process can be divided by the CODP into processes of pre- and post-CODP/PC. The product configuration (PC) denotation is added to the figure to emphasis that configuration process enters the product realization process at the CODP.

The processes upstream of the CODP are forecast driven, managed and improved by lean production methods. Processes downstream CODP are customer initiated and rely on agile management for low volume production (see table 4:5). Swierczek (2010) assert that the placement of the CODP indicates how deeply the customer affects the product realization process for each order. The deeper the customer involvement is the more uncertain and risky the business becomes.

According to Wikner and Wong (2007) the concept is an effective method to reduce risks that often emerge due to product customization, such as increased operation cost. Yang et al. (2007) explains that the concept introduces a time buffer to those points where the lack of information can disturb the production process, which drives cost and delivery time.

***The CODP-position and its impact on production system***

Where the CODP is located in this product realization process depends on the firm's strategy and which the competitive priorities are. Sackett et al. (1997) assert that it is the CODP that fundamentally determines the production topology of the firm. The production system characteristics also depend on what is happening at the order point (Olhager, 2003). It can be the point where highly standardized products are ordered (van Hoek, 2001), or the point where the product configuration or customization process is performed (e.g. Wong et al., 2009; Rudberg and Wikner, 2004). Thereby, this theory integrates and complements the previous production system classifications for a single firm and explains why and how different processes have various features, see table 4:5.

Table 4:5 Key characteristics of pre- and post-CODP processes and product structure aspects (adapted from van Hoek, 2001; Wikner and Rudberg, 2005; Olhager, 2010).

| Aspect | Pre-CODP | Post-CODP |
|---|---|---|
| Strategic objective | Productivity and effectiveness | Customization and responsiveness |
| Product model types | Standardized components and modules | Configurable product model |
| Process design and type | Standardization, high volume capacity, mass or line processes | Flexible, low volume capacity, project, job and batch processes |
| Planning and control principle | Forecast driven, push, lean | Demand driven, pull, agility |
| Supply chain | Supplier selection/relation based on cost and lead time | Market responsiveness capacity |
| Inventory | Possible until the CODP | Minimal or none |

From a production planning approach postponement suggests that the dedication of resources to a specific order should wait until the order has a committed customer (Trentin and Forza, 2010). This suggests that the production management and resource allocation should be different for processes pre CODP and post CODP, because production processes should focus on a narrow set of tasks (Hallgren and Olhager, 2006). The design of the sub-processes and their control mechanisms should therefore be based on different logic, i.e. having product, process, or customer focus and having different planning horizons. Olhager (2010) assert that the entire structure of the supply chain planning becomes different depending on placement of CODP.

***Push and pull controlled processes pre- and post-CODP***

In the context of postponement processes performed pre-CODP are often denoted as push-driven and processes post-CODP as pull-driven (e.g. van Hoek, 2001; Blecker and Abdelkafi, 2006b). However, Spearman and Zazanis (1992, p. 521) argue;

> *"push and pull refer to the means for releasing jobs into the production facility. In a push system, a job is started on a start date that is computed by subtracting an established lead time from the date is required, e.g. for assembly. A pull system is characterized by the practice of downstream work centers pulling stock form previous operations, as needed. All operations then perform work only to replenish outgoing stock. The work is coordinated by using some sort of signal, e.g. kanban."*

Hopp and Spearman (2004) emphasis that neither push nor pull systems are the same as manufacture a product based on forecasts or on order. Instead they suggests that pull is a mechanism of limiting the WIP that can be in the production system. On the contrary, push system has no WIP-limit because it releases work according to a master production schedule without consideration of the production status. This mean that both the push and pull mechanisms can be applied in the upstream and downstream processes. However, in ETO-topologies it will be extremely hard to use a push system to realize the jobs, because there are a limited number of employees that can design the product and be responsible for its realization to delivery. Similarly, firms that offer customized products will also have problems to use push systems in the process after the CODP/PC. The reason for this is that the product configuration process (the customization process) determines what and when to produce (see the next section). If the necessary product components cannot be coordinated with the necessary production resources to a specific time the customized order cannot be realized.

***The postponement theory indicates information and organizational requirements***

Postponement is a concept for firms to deal with uncertainty (which emerge due to market trends and needs) through forecasts and respond to actual customers' product demands (Wong and Naim, 2011). It highlights important areas to consider when a producing firm changes the business strategy in such a way that the CODP moves along the product realization process (Yang et al., 2007). This becomes evident when investigating the differences between a conventional house builder and industrialized housing firm. For example, comparing the differences between case study A and B in chapter 7, it is showed that the organization structures as well as the supply chains are different and impose dissimilar management devices and resources.

The concept of CODP or postponement corresponds with the information processing theory, by indicating that processes pre and post CODP have different needs of information storage and processing. Thereby, it acknowledge that production systems' behavior depends on: the processed information in advance; the storage of information for use in forecasted production in processes pre CODP; and the use of additional information processing managing the processes after the CODP. However, in general the postponement concept considers industrial production systems, i.e. of MTO, ATO and MTS type, and hardly the ETO-topology. It should also be complemented with theories regarding product configuration and product structure in order to capture how different production topologies can be managed.

## 4.6 A product customization approach to production flexibility

Considering production flexibility with the objective to realize customization the product structure and the product configuration are very important dimensions. In most cases the design of the product determines what the necessary production operations and the resources are. Depending on how comprehensive the customization degree is it puts fundamentally different requirements on the product structure and the configuration capability (e.g. Hvam et al., 2008; Wikner and Rudberg, 2005). For example, mass production firms manufacture standard products to a low cost by extreme utilization of standardization of processes and economics of scale. Firms' that offer extreme product individualization to each specific customer use exceptionally agile processes and resources, such as conventional housing companies do by using project processes and craftsmen. From a product point of view, the former firms rely on a standardized product model that is development in advance; the latter case relies either on products being developed from scratch for each project or customer order (cf. Nambiar, 2009, Winch, 2006).

Industrial firms that offers some kind of product customization is here denoted mass customizers (cf. Blecker and Abdelkafi, 2006b; Piller, 2004). In order to accomplish this, these firms have generic product models that can be configured for each customer specific need (Pine and Gilmore, 2000).

### 4.6.1 Product configuration and customization strategies

The product configuration or customization is a firm's ability to generate different product features for each order (Helo, 2006). Jiao and Tseng (2000) assert that product configuration is the process where the pre-developed product structure is synthesized by determining which components and sub-assemblies the final product should consist of and how these should be arranged in space. According to Forza and Salvador (2002), is product configuration a process where the customer requirements are translated into product order information, which is needed for producing and deliver the order (see figure 4:8, p. 56). It is an iterative process where both the producer and the customer must control and approve the configuration. The firm has to control the configuration so that the product can be produced, and the customer must check whether the order can meet the needs (Hvam et al., 2008).


Figure 4:8 The product configuration process and its relation to the production process. Observe that the four first sub-processes are carried out at the CODP/PC in figure 4:7 on p. 52.

### *Customization strategies*

The extent of the product configuration is determined on how the firm will compete and satisfy its customers. Strictly speaking, it is only mass customizers that are managing product configuration, ETO-firms develop new products and MTS-corporations do not adjust the product at all. However, in order to differentiate between the productions topologies four different strategies to satisfy the customers are explained in table 4:6.

Table 4:6 The four different customization strategies for meeting the needs of different markets and customers (adapted from Hvam et al., 2008).

| Configuration strategy | Description |
|---|---|
| *Select-product-variant* (SPV) | Standard product production, no customization is possible. The customer can only select a product variant (if the firm produces more than one variant) from warehouse or retailer. |
| *Configure-to-order* (CTO) | Product features are chosen from predefined spectrum of choices. The specification initiate the assemble phase, so the manufacturing process can be managed on forecasts. |
| *Modify-to-order* (MTO) | Product features are chosen from predefined spectrum of values. The specification initiates the entire production process, i.e. it starts with the manufacturing phase. |
| *Engineer-to-order* (ETO) | For each order the product feature are fundamental different, i.e. the product is developed and engineered for each order. |

The table indicates that in order to accomplish customization through product configuration the various market needs must be identified and translated into functional and product structural entities and components. These are the foundation for developing the generic but configurable product model (Hvam et al., 2008; Pine and Gilmore, 2000). Thereby, mass customizers have targeted a defined market segment and reduced the features of the product offer, because the generic product models cannot generate endless amounts and variants of functional features (Du et al., 2003).

In firms with a customization strategy of ETO-type there is no product model developed in advance – they rather perform *new-product-developments* (NPD) for each project (e.g.

Bertelsen, 2004; Kornelius and Wamelink, 1998; Winch, 1989). Therefore, such companies can always turn to markets with more diverse needs than firms with a product configuration strategy (Ulrich, 1995).

***Product configurators***

When conducting a product configuration process information from most parts of the organizations is used. It is necessary in order to determine what product features that are possible, when the specific product can be produced and what the prize will be (Hvam et al., 2008). In most cases both the products and the production systems are too complex to efficiently manage the configuration manually (Brown, 2003). Every component, part and their relations in the product model need to be identified and correlated to specific production operations in order to secure that the specific product attributes can be realized (Jensen et al., 2012). The management and control of mass customizers becomes very complex, because the product configuration drives production system re-configuration (Blecker and Abdelkafi, 2006a).

According to Burgess et al. (2005) and Mesihovic and Malmqvist (2000) the necessary information is stored within the firms' IT-systems, such as CAD, CAM, ERP, MRP, and PDM. It is the product configurators that communicate and combine necessary information from these IT-systems (Blecker et al., 2004). Similarly, Helo (2006) asserts that product configurators are software that allows customers to specify products features from a predetermined range, by combine information from many other information systems. Thus, product configurators are used for fast creation of customized and producible products already in the sales process, i.e. at the CODP (e.g. Yang et al., 2007; Hvam et al., 2008).

In summary, product configuration is an information processing activity but reconfigures stored information into very certain and exact order specifications. Before the product order was customized the firm did not know what to produce to achieve the given level of performance (cf. Schrader et al., 1993). The product configurator is a software tool which combines and configures information from different IT-systems. This indicates that this information have been processed and stored in advance before the customer order arrived (cf. Blecker et al., 2004). However, the foundation of product configuration is the product structure.

### 4.6.2 Product structure models

All products have some kind of product structure regardless if it is of standardized type produced within mass production firm or of novel type such as building projects (Jiao and Tseng, 2000). The product structure model consists of information about each part and components, how these interact and are arranged in order to create the desired product characteristics (Simpson, 2004). Ulrich (1995, p. 420) define product structure as;

> *"the scheme by which the function of the product is allocated to physical components… more precisely as: (1) the arrangement of functional elements, (2) the mapping from functional elements to physical components, (3) the specification of the interfaces among interacting physical components".*

According to Jensen (2010) a typical product structure can be decomposed in the following levels: (1) product family/line, (2) product, (3) modules, (4) components, and (5) raw material or pieces. Comparing these levels to figure 4:2 (p. 37) the relevance to investigate production flexibility, product structures and customization separately can be discussed (Wiendahl et al., 2007; ElMaraghy, 2006; Wikner and Rudberg, 2005).

***Different types of product structures***

In principle, are there two different categories of product structures models – integrated and modular (Ulrich, 1995). An integrated product model implies that the components are directly related to each other in a unique way to create the final product's attributes. The structure is design for only one specific product, and the replacement of a component in a finished product can hardly be done. A modular product structure is designed for creating different products based on the same parts (cf. Jiao et al., 2007). According to Baldwin and Clark (2003), these models consist of modules, in which a group of highly interacting components gives the modules its attributes. To reduce the unique numbers of components within the product model the design can be based on commonality. This means that if a component is replaced with another it will change the attribute of the final product feature. It is common that modular product structures consist of more components and modules than a specific product order consists of (number unique parts). However, considering all the numbers of product variants these unique parts can generate, it is still much fewer unique parts than the same numbers of integral product structures consists of (e.g. Simpson, 2004).

However, there are different approaches to arrange the product structure parts depending on how it will be modularized and configured. For example, Ulrich (1995) identifies three types of modular product structures: slot, bus, and sectional modular structures. Slot structures mean that each part in product model is interconnected individually through standardized interfaces, so the various parts cannot be interchanged. Bus structure is the ability to add parts to an existing product platform based on standardized interfaces between the different types of parts and the platform. The sectional structure is when the parts or modules have standardized interfaces which result in that the modules can be arranged in different ways (Jensen, 2010).

***Configuration driven product structures***

Leckner and Lacher (2003) have developed a product structure model based on how the product can be configured more explicitly than Ulrich's model does. The authors distinguish between what is configured, i.e. the parts and the rules that determines how the products can be configured. Thereby, they identified four types of product models: (1) alternative and (2) optional component models, and (3) enumerable spectrum and (4) numerical interval model. Alternative component model is the structure that allows the customer to choose exactly one product configuration from a range of alternatives determined by the firm. The optional component model means that the customer is free to choose between certain ranges of standardized parts which are not mandatory for the product. The product becomes adjusted to the customer needs by adding functions to the basic product. In the enumerable spectrum model the customer can choose between ranges of pre-determined standardized modular settings. The numerical interval model implies that the modules can change their attribute between intervals, e.g. the geometrical dimension. During the configuration process the customer specifies the desirable values. Table 4:7 summarizes the main ideas of different product structure models.

Table 4:7 Summary of different generic product structure models. Based on Hvam et al., (2008), Leckner and Lacher (2003), and Ulrich (1995).

| Structure type | Description |
|---|---|
| *Integral-product-structure* (IPS) | The structure includes all components, which are directly related to each other, necessary to create the final functional features of the product offer. The product cannot be configured, i.e. only one setting is possible. |
| *Standard-modular-product-structure* (SMPS) | The product structure includes some common standardized components and modules for the entire product family. These can be combined in different ways and numbers to meet predetermined and additional customer functional requirements, e.g. car stereo, sun roof, car paint, motor strengths, and tank volume. |
| *Parametrical-modular-product-structure* (PMPS) | The product model consists of standardized components and generic modules common to the entire product family. The generic module can alter the features based on rules, e.g. geometrical dimensions. Each customer needs are met through a determination of the modules dimension within the given interval. This drives the exact type and number of components the specific configuration consists of. A product example is some industrial produced houses (see case B). |
| *New-product-development* (NPD) | New product development implies that the firm develops and engineers an integral product structure that fulfills each customer's specific needs per order, i.e. the firm offer customer specific product solutions. Thus, it is very similar to IPS-model, the major difference is the number of identical products that will be produced. |

## 4.7 Information processing and production of different product types

All product structures contain information about what to be produced, and it is based on an understanding of the needs of the market and the customers. Depending on the firms' customization strategy the product structures can be either strategically developed before the product order enters the industrial firm; or be developed in conjunction with the project order, as in conventional construction firms. Further, processes pre-CODP heavily relies on stored information to be executed, but to manage the processes after the CODP information must be processed. This explains why the more upstream the CODP is placed, the more information must be processed per order.

In the former case, for industrial firms, the product structure is generic and stores information for repeatable use when realizing numerous products. This information reduces the tactical and operational information processing need for realizing each product, even though additional information processing is required the more configurable the product structure is. In the latter case, for ETO-firms, the development of the product is the first step in the order specific product realization process, i.e. very little information has been stored to reduce the order information processing. The limited amount of information that has been stored is configured, but a large amount of new information is developed for each order. This production topology often also relies on highly skilled craftsmen to interpret "*uncertain* or *equivocal*" instructions to realize the products. In fact, this actually implies that in ETO-firms the managers or staffs do not need to process similar amount of information as the they do in the industrial topologies (see figure 4:9).

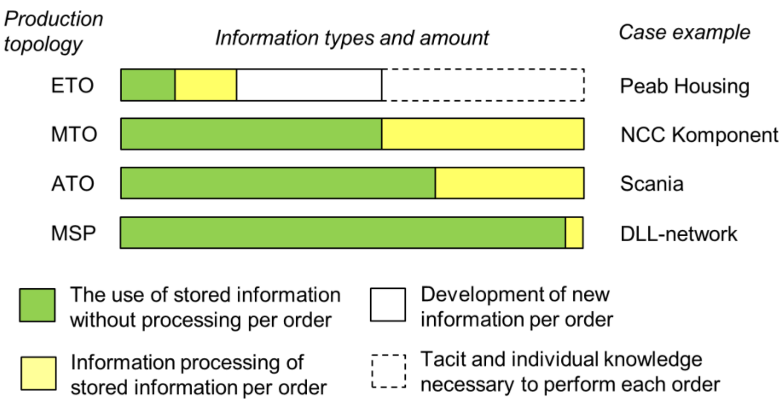


Figure 4:9 A principle illustration regarding how the common production topologies use different amount of information types per order. Note that each topology's information types is relative meaning that comparisons between the topologies could be deceptive.

Reconnecting to the earlier sections of production systems, it is obvious that depending on a firm's production system topology and to what extent the products are customized, it will impact the production steering mechanisms. In production research the focus is typically on controlling the active resources of the product realization process. It relies on the inactive organizational infrastructure to accomplish the product orders. The academic field of organization design considers this resource coordinating dimension. As mentioned in the introduction chapter, in competitive firms the production system and the organization design must be integrated support each other. Therefore, the presented theories of production systems must be complemented with organization insights if predictions on how the change of production topology will impact the organization design.

# 5 ORGANIZATION DESIGN

*This chapter explains what organizations are and how each major constituent dimensions can be related to the parts of the cybernetic control mechanism. The dimension organization structure is further described; its parts are interconnected to the different information types and their contribution to information storage and information processing. A summary of relevant organization configurations are presented to indicate appropriate organizational differences between the four common production topologies.*

## 5.1 What is organization?

The word *organization* can be derived from the Greek word "*organon*", which means instrument or tool necessary to achieve some kind of performance (Morgan, 1997; Anderson, 1994). The original meaning was related to biology, i.e. an organ in a living being (Maturana,1978), which has evolved to denote an instrumental view of an organization as an social engineered artifact designed to accomplish one or more objectives (Strati, 2000). Today, the term organization often is defined in the following ways:

> *Organizations have purposes, attract participants, acquire and allocate resources to accomplish goals, use some form of structure to divide and coordinate activities, and rely on certain members to lead or manage others.* Shafritz and Ott (1996, p. 2).
>
> *Organization is formal structure of planned coordination, involving two or more people who share a common purpose. It's characterized by formal roles that define and shape the behavior of its members.* Robbins (2000, p. 2).

Based on these two definitions organizations can be seen as a mechanism for management and coordination of the resources that perform the operative work (Mintzberg, 1979), in order to achieve the strategic tasks of the business (Kates and Galbraith, 2007). Similarly, Perrow (1967) and Woodward (1965) emphasize that an organization is a mean to get the operational work done, i.e. the management and coordination of the production function of the firm (Adam, 1983). These perceptions of organization indicate that if social behavior aspects are not included the organization solely become an instrument or infrastructure for direction and control of its members' behavior (cf. Marcus and Jacobson, 2008; Ahrne and Brunsson, 2004; Schein, 1996).

In comparison to the production system theory organization research focus on management and coordination of the resources towards the work and the production theory on the (technology) control of the production processes. For example, an efficient production system uses information and resources from all necessary parts of the organization to control the processes (Sohlenius, 2005). Therefore, the organization structure must support this coordination and information processing activity in order for the production system to become a high-performer. This acknowledges that a change of the production topology impacts the design of the organization.

## 5.2 Generic elements of the organization design

A common conception is that organization should be framed by five generic elements: (1) strategy, (2) structure, (3) process, (4) metrics and rewards, and (5) culture and people (cf. Zheng et al., 2010; Anand and Daft, 2007; Galbraith, 2002b). The strategy gives the firm its direction of what to accomplish and how to do it. The structure determines the location of decision-making and division of work, the process includes management of the operations, based on regulation of the information flow and collaboration. Metrics and rewards describe how the operations and members of the organization should be controlled and rewarded in order to motivate the prescribed behavior. The element of culture and people includes the necessary skills, social behavior and corporate beliefs of the organization (see figure 5:1). This is classical organizational view of what parts that constitutes a business firm, even though the focus varies among the researchers (e.g. Hunter, 2002; Gibson et al., 2003; Waterman et al., 1980; Gulick, 1937).

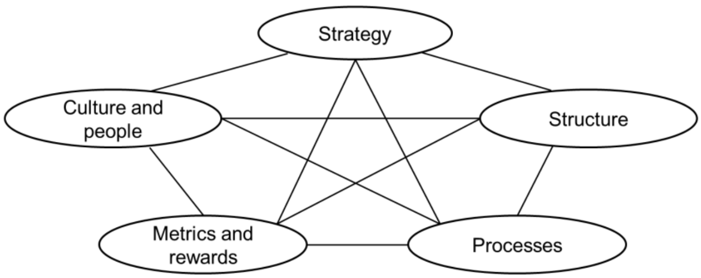


Figure 5:1 The five common dimensions that construct the organization arranged into a star, also known as the star model (from Kates and Galbraith, 2007).

The variations of organizations are often reflections (but not exclusively) of their adaption to the environment and their history (Anand and Daft, 2007). In high performance corporations, the organization design is optimized through the interactions of these elements – it is through the interaction the synergies are created (Marcheridis and Knutsson, 2007). Similar, Kates and Galbraith (2007) assert that it is only when strategy, structure, processes, rewards and the culture are aligned that the true potential of the firm will appear.

### 5.2.1 Strategy

All organizations have an objective or a reason to exist. The vision and strategy of a business firm determines the direction (Galbraith, 2002b). According to Robbins (2000) the vision and the business idea is the ideal representation of the firm's mission, how it should be achieved and what the performances will be. Based on this the business strategy is formulated. The business strategy describes, according to Porter (1991), how the organization will differentiate themselves from its competitors in order to gain a competitive advantage. According to Porter (1996) strategy is the creation of a unique and valuable market position, which clearly differentiate the firm from its competitors.

Based on the strategic objectives, which should consider the market offer's competitiveness from product quality, cost, flexibility, and delivery perception, functional strategies can be created (Krajewski and Ritzman, 2000). In general the strategies for firms' different function are denoted functional, e.g. market, product, finance, and production strategies. Therefore, Riis et al. (2007), Hill (1997) and Skinner (1969) asserted that the strategy is also about focus and development of the firm's operational capabilities so that the performances will be in conjunction with the chosen position and the objectives. The goal is to create the best possible offer to the customers and simultaneously achieve the best possible return for the stakeholders (cf. Dangayach and Deshmuhkh, 2001).

In the context of production strategy, it is in general the line mangers' duty to communicate and implement the company's strategy. It is their job to make appropriate decisions so the resources are performing the operations in line with the objectives (e.g. Day, 2006; Porter, 1996). However, in the strict sense it is only people who can have goals; employees' individual goals are often contradictory, both the individuals themselves and in relation to the company's (Mullins, 1999). In order to minimize these goals differences, strategy implementation should be supported by the structure, process, culture and reward systems (Zheng et al., 2010; Day, 2006).

### 5.2.2 Structure

The term organization structure is often misunderstood as the organizational chart, which only describe the division of the work into specialized groups or geographical specialization units (Mintzberg and van der Heyden, 1999). Further, numerous organizational structures have been identified; e.g. Weir (1995) found six different forms, and Hunter (2002) found twelve. At the same time, it is acknowledged that there is no general best organizational design – the structure is always situation dependent (e.g. Anand and Daft, 2007; Drucker, 2006; Mintzberg, 1981).

The objectives with organizational structure are to divide and group the employees around the work processes, and dedicate the members to determined tasks in order to increase necessary collaboration and skills. Another duty of the structure is to create coordination of the divided work, so that the overall work can be accomplish as efficiently possible (Child, 1972). Thereby, the structure determines the location of authority and decision making within the organization (Kates and Galbraith, 2007; Pugh et al., 1968). In general the following key factors are argued to form the structure: specialization or division of labor, departmentalization, chain of command, span of control, formalization, and centralization or decentralization (cf. Alajloni et al., 2010; Smith and Boyns, 2005; Robbins, 2000). However, according to Mintzberg (1980) these are only one category of the factors that need to be considered in order to understand the behavior of organizations. As indicated above it is not valuable or even interesting to discuss the structure separated from the working process.

### 5.2.3 Process

A process normally is described as a series of connected activities that transforms input to output (Linderman et al., 2010). Processes require goals, information flows, decision making, resource allocation and resources that performs operations or is consumed (e.g. Heizer and Render, 2011; Sohlenius, 2005). In order to execute the operational processes most functions within an organization contribute to any of these process dimensions (cf. Kumar and Suresh, 2008; Sacket et al. 1997; Mintzberg, 1979).

According to Roy et al. (2005) formal processes facilitate information sharing, collaborative decision and operations execution. Processes are a necessary complement to formal structures, because structures have a tendency to create “work silos” within the organization (Galbraith, 2002a). Processes, however, may cross the organizational boundaries and force the organizational units to interact, both vertically and laterally. Vertical directed processes, at strategic or tactical levels, allocate the appropriate amount of resources, e.g. funds and human skills, among the different functions and departments through budgets, business and production plans. The sequences of these processes are directed through the organizational structure (see section 5.4) and increase the vertical control as well as the lateral connections between departments, groups and individuals (Kates and Galbraith, 2007). The need for decisions and information flow, i.e. input and output of information, towards the resources that perform the processes, interconnects both the vertical and lateral processes (Hunter, 2002; Burke, 2003).

However, depending on the strategy the necessity of interactions is different. Generally, it is assumed that the more dynamic the market situation is the greater is the need of integration (Anand and Daft, 2007; Galbraith, 2002b). In highly dynamic situations the managerial information flow should be supported by comprehensive lateral connections that enable uncertain and equivocal information processing (Daft and Lengel, 1986). Thereby, the processes' design and the structural requirements to make them work a have major impact on the organizational characteristic and performances (Kates and Galbraith, 2007). For example, a conventional house builder and the truck manufacturer have fundamental different production processes due the very different circumstances (see case study A and D in chapter 7).

### 5.2.4 Metrics and rewards

Metrics and rewards are important mechanisms to align the individuals' behavior with the organization's goal (Kates and Galbraith, 2007). Metrics are used to evaluate the performances of departments, groups, individuals and machines. Reward systems are ways to encourage predefined behavior and steer the employees work performances towards the goal of the firm (Galbraith, 2002a). The basic idea is that conducted tasks with outputs in accordance with the strategic objectives should be rewarded; if the work performances are not they should be performed in different ways (Schuster and Kesler, 2012). This clearly supports the idea of cybernetic control with feedback and regulation of actions (cf. Elg and Kollberg, 2009).

The prerequisite for this kind of management procedure is that the tasks can be measured and that the strategic objectives have been translated and communicated in an appropriate way for each single process and activity (e.g. Kaplan and Norton, 2007; Tangen, 2005). As the information and control chapter concluded, information of the current operational performances is crucial for management of the organization processes. Organizational research tends to focus on strategic and tactical metrics (e.g. Kaplan and Norton, 2007) or employee reward systems (Schuster and Kesler, 2012), while the production discipline focus on planning and performance measurements on operational processes (e.g. Olhager, 2000). However, metrics and reward systems are only effective when they are designed and congruent with the other four organizational dimensions (cf. Kates and Galbraith, 2007; Liker, 2004; Imai, 1997).

### 5.2.5 Culture and people

This dimension is about policies, norms, and beliefs which are important aspects that impact the organization members' behavior (e.g. Mintzberg, 1989; Schein, 19996). According to Galbraith (2002b) it is about creation of talent, skills, appropriate group dynamics, and mind-set of the employees required to realize the strategy. Common methods to accomplish this are e.g. recruiting the right people, development and training of the employees' skills, leadership training, and the promotion of suitable leaders.

Schein (2004) would have denoted this element as organization culture, which he defines as ideas or assumptions that are shared or held common by a group of people. These will affect how employee perceives the business environment, and thereby impact their working behavior and performance (Chandon and Nadler, 2000). According to Mullins (1999) the corporate culture is based on the company's history, the ability to create a sense of belonging, participation and experience sharing. The culture is reinforced by rituals, communication patterns, the informal connections between the members, and by the expectation the organization exerts on each individual. Through culture, the individual can receive support, motivation and a sense of their work (Martin, 2002).

In summary, the organization culture creates a frame of reference for the interpretation of the work situations (Schein, 2004). Gibson et al. (2003) argue that only when employees share the same values and have similar attitudes and expectations the company can be a high performer. The corporate culture may support decision-making, coordination and control by the shared understanding, between the supervisor and employee, and motivate the employee to follow the order. Therefore, the culture can be considered as a subtle control element (cf. Potocan and Mulej, 2009). This makes it obvious that different production strategies, structures, and processes require different culture to create appropriate organizational talent and skills (cf. Martin, 2002). For example, a “tayloristic” mass producer needs employees who follow detailed instructions in systematic ways (McDuffie, 1995; Berggren, 1990). Project based organizations wants members who are creative, takes initiative and are self-organizing (Keegan et al., 2011; Huemann et al., 2007). In summary, these two types of organizations require fundamental different leadership, which according to Schein (2004) is one side of the coin – the other is culture.

On the other hand, Abrahamsson and Andersen (2005) claim that the theory of organization in general has undervalued the aspect of organization structure considering how to lead and shape the behavior of the employees, and thereby its performances. They assert that the scope of culture and sociological features of the organization are too emphasized on the expense of the structure intent. Marcheridis and Knutsson (2007) and Sine et al. (2006) argues that, explicitly integration of organization is created by three dimension; structure, process, and strategy. Therefore, this thesis focuses on the tangible parts of the organization, why it will deepen the description of the structure and processes as coordinating concepts towards strategic objectives.

### 5.2.6 The organizational dimensions correlated to information control

Each dimension of the organization represents a part of the generic control mechanism. The strategy creates the goals of the firm and the working processes. The performances of the processes is monitored and regulated through the use of people, rewards and metrics. In a sense, the organization structure is the pattern that describes how every part is placed in relation to the others, i.e. it is the infrastructure of the controlled system (see figure 5:2 and compare it with 3:1, p. 18). The culture provides the framework for the organization members to interpret the emergent situations in similar manner.

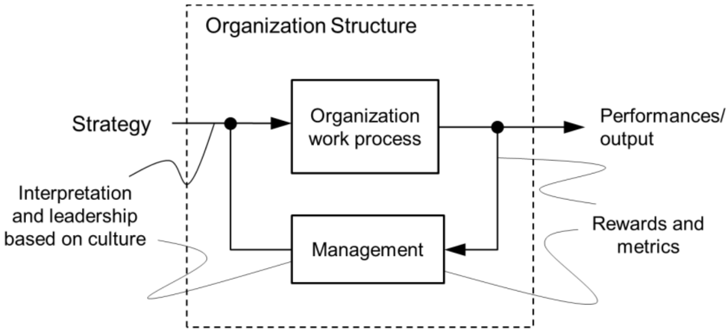


Figure 5:2 The organizational dimensions related to the generic parts of the cybernetic control mechanism (compare with figure 3:1, p. 18).

These dimensions are socially engineered concepts and pervasive for the entire organization. Each dimension will have a specific configuration and contribute to the organization as a controlling mechanism for realizing products. They are created in advance and consist of stored information for efficient use when accomplishing tactical and operational activities.

These generic organizational dimensions are, however, little too general to be able to explain why a firm has a specific design. They only give an explanation for which major parts of an organization that interact. Henry Mintzberg is one of the most influential scientists of *"modern organization structure theory"* (e.g. Ott et al., 2011; Lunenburg, 2011; Matheson, 2009; Pourezzat and Attar, 2009; Unger et al., 2000). Mintzberg's theory explains why the organizations may have different designs and also predicts different general configurations based on the firms' strategies.

## 5.3 The structure of organizations

The most important factor for steering the employees' working behavior towards a certain goal in a specific situation is the organizational structure (cf. Hunter, 2002). According to Abrahamson and Andersen (2005) and Mintzberg (1979) every firm's specific structural configuration is dependent on its contingency or situation. This affects how the work is divided and which the appropriate coordination mechanisms are. Depending on the work design and the favored coordination mechanism, a specific organization part will dominate and severely impact the overall organization configuration (see figure 5:3).


Figure 5:3 The evolution of organization configurations (adapted from Mintzberg, 1979).

These five elements offer a more tangible approach to analyze organizations than the star model by primary focusing on the infrastructure. However, in his later work (Mintzberg, 1989) he included culture as pervasive “force” that affects all other tangible constituents simultaneously. The following section will explore how the designs of these elements create several organization configurations. In each configuration one of the five generic functional parts will dominate and influence the decision making of the firm.

### 5.3.1 The generic parts of the organization

All the tasks an organization normally has to perform to work, are executed by five different generic organization parts or functions: the strategic apex (top management), middle line management, operation core, technical structure, and supporting staff (Mintzberg, 1979). Their relation to each other is illustrated in figure 5:4 on p. 70.

***The strategic apex***

The strategic apex level is occupied with the overall responsibility to develop strategies and manage the firm in accordance with its mission and norms (Unger et al., 2000). Another obligation is to monitor the external environment and communicate the performances of the firm with its market. A major responsibility is to develop, align and manage the corporation when stakeholders and market requirement changes (Anand and Daft, 2007). The work is normally characterized by a minimum of repetition, discretion and long decision cycles, i.e. it deals with highly equivocal information.

***The middle line***

The middle line is the intermediate line of managers that connects top managers with the operating core, i.e. it is the line of authority or chain of command (Alajloni et al., 2010). These managers have direct authority of the operational work and a major duty is to ensure congruence between all the other parts (Gratton, 2011; Unger et al, 2000). In most cases middle line managers are supported by staff units for deciding on resources allocation to sub-unities, and often exert direct supervision of subordinates, i.e. monitor the performances and regulate the processes when it is needed. The span of control varies between the managerial position's organizational levels and the nature of the managed work (Wren et al, 2002).

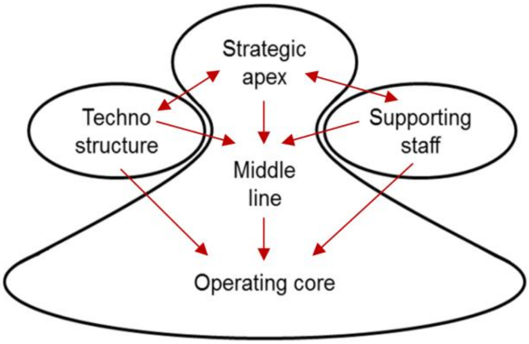


Figure 5:4 The generic parts of organization and their major relation to each other. The arrows illustrate the typical influence pattern the different parts exert on each other (from Mintzberg (1989)).

***The operating core***

The operating core is the part of the organization that is performing the basic work of product realization process, except tasks such as development and planning (Lunenburg, 2011). The operating core is the heart of every company, since it produces the output which creates the income of the business (cf. Skinner, 1969). Employees located here perform duties such as: purchase raw materials; machining, assembly, craftsmanship; maintenance, sales and distribute the products. The nature of the operating core differs depending on the strategy of the firm (Mintzberg, 1979).

***The techno structure***

The techno structure is a clerical staff function placed outside the line of authority and performs work that affects the work of others. The main objectives are to translate the strategy into operational activities, formalize and plan the product realization process. Other duties are often to ensure that the firms' members have necessary skills to accomplish their business objectives, i.e. typical head office duties (cf. Collis et al., 2007; Ono, 2003). The part also design, improve, support and maintain the organizational infrastructure with the intention to align the business with the changing environment requirement (Alajloni et al., 2010). Employees here process equivocal information into more certain information for easier use by the managers and operative core, e.g. by formalization of processes, developing working methods, production plans and schedules (cf. Linderman et al., 2010).

***The support staff***

The support staff part performs necessary but indirect support to the rest of the firm, e.g. administrative work including prizing, billing, and accounting (Matheson, 2009). In larger corporations, duties as legal counsel, human relation specialists, marketing, communication, PR, and management of long term R&D-projects are also common. Many of these tasks require highly specialized and skilled employees (Collis et al., 2007; Wren et al., 2002). The work has a character of being supportive for preparation or completion of the operative work when problems have emerged.

Note that in business practice not every firm organize or cluster similar tasks into explicit departments; but still, each different task can be placed within one of these organizational parts. This means that an employee that performs different tasks can execute operations that belong to several of these different parts; but in general, specific roles are dedicated to accomplish tasks within the same part (see table 5:1).

Table 5:1 The major organization parts' focus and examples of roles. Source Mintzberg (1979:33).

| Organization part | Work focus | Example of typical roles |
|---|---|---|
| Strategic apex | Leading towards the strategic goal through control over the decision-making in the line. | Board of directors, president, executive committee, president's staff |
| Operating Core | Personal optimization of knowledge and skills. | Purchasers, machine operators, assemblers, salesmen, carpenters, consultancies |
| Middle line management | Optimizing of the functional business unit's performance by concentration of the decisions to unit's dedicated processes. | Geographical divisions managers, functional divisional managers, plant managers, line managers, regional sales managers, district sales managers, purchasing managers |
| Techno structure | Rationalization through standardization of formal systems and processes, planning control, and adjustment of the processes managed by the middle line. | Strategic planning, controller, accounting, personal training, production and work scheduling, operations control and improvements |
| Supporting staff | Collaborate and supportive focus to integrate with all the other parts of the organization. | Legal counsel, public relations, human relations, research and development, pricing, payments, reception, mail etc. |

In summary, the generic parts of the organization describe different types of work and make theoretical categorization of this. However, it does not embrace how the work is managed or why it should be accomplished in that way.

### 5.3.2 Contingency factors

In order to be competitive firms must have an organization that is aligned with the situation on their chosen market and the internal conditions (Nissen and Burtoon, 2011; Goold and Campbell, 2002). According to Mintzberg (1979) four contingency factors should be considered when choosing to improve their competitiveness: age and size, market environment, power structures, and technical system (cf. Kates and Galbraith, 2007). A major change of any of these should imply a development of the design parameters, change of the coordinating mechanisms, and thereby reconfigure the organization structure.

***Age and size***

The age and size of an organization are both important factors of the structure design. In general, the older an enterprise is the more formalized it is; the larger the firm is, the more complex the coordination become (Collis et al., 2007), which usually increases the formalization (Smith and Boyns, 2005). Further, according to Mintzberg (1981) does history and previous performances also affect the organization norms and power structures, thus it will favor certain parts of the organization and specific behavior.

The NCC Komponent-case, for example, was a young organization under development, which implies that it should not be as formalized as an older construction company (cf. Stinchcombe, 1959). In comparison to conventional craft-based construction the industrialization require much more standardization and formalization, which severely impacted the power structure of the company. Hence, the differences between industrialized and craft-based businesses, i.e. the standardization and formalization degree, cannot solely be related to age and size.

***Market and business environment***

All business organizations act in a market and business environment. When the environment is dynamic the requirements on the market continuously change, e.g. constant variations in the customer needs, governance regulation, market economic conditions, competition etc. Dynamic environments are uncertain and unpredictable, which makes it risky or inappropriate for firms to manage the work through excessive job specialization or standardization (Dissanayake and Takahasi, 2006; Daft, 2009).

A firm’s market is complex if it requires the organization to manage and coordinate deep knowledge from many different areas to realize the product offer, e.g. products, material, suppliers, subcontractors, governance regulations, customers, and sustainability (Dellart and Stremersh 2005). The more complex the market environment is, the more difficulty it is for the central management to comprehend and manage the organization effectively (Blecker and Abdelkafi, 2006a). By dividing the firm’s market offer into smaller and more self-managed units the complexity is reduced – i.e. the decision authority is decentralized (cf. Anand and Daft, 2007).

The market of a firm can range from integrated to diversified. The more diversified the market is, the broader the range of customer or geographical areas the firm offer products on. Market diversity affects the organization structure by requiring division of the product realization process, which favors a decentralized and a divisionalized organization form. Construction firms are traditionally geographically oriented, which explains why contracts managers are responsible for managing project portfolios within the local area, e.g. a couple of municipalities. Integrated markets often drive the organization in the opposite direction, i.e. centralized management and functional/process specialization (Dissanayake and Takahasi, 2006).

***Power structures***

Power structures consider how the enterprise is controlled by external forces and is managed internally. In general, comprehensive external control e.g. through powerful shareholders drives the firm to be centralized and formalized. The reason is that external controllers, such as owners, often hold the chief executive officer responsible for the firm's actions and performances (Mintzberg, 1989). The evaluation of the firm's performances, from an outside approach, is to translate the objectives to tangible measurements (output standardization) and correlate this to formalized working procedures (cf. Schuster and Kesler, 2012). Further, Matheson (2009) asserts that organizational goals often shifts as a consequences of power struggles, i.e. if the pervasive power structure remains the major goal-changes are not likely.

All members of an organization normally want power, maybe not to control others but to control decisions that affect their own work. The personal power needs does not always corresponds to formal distribution of decision authority, which often create informal communications ways. Mintzberg does not leave any good explanation on how this affect the structure, just that it is an important factor of consideration. However, it seems to have more impact on the decision process regarding the organization design process than performing the actual work. Galbraith (2002b), for instance, suggests that reward systems and culture are means to deal with these potential problems and to align the organization towards the strategy.

***Technical system***

In organization research it is common to denote technology as mechanisms and tools that influence the execution of work operations or the coordination of these (e.g. Robbins, 2000; Child, 1972). If the technical system regulates the manufacturing process performed by the operators, it creates behavior formalization and a bureaucratic coordination of the operating core become necessary (cf. Stinchcombe, 1959). Increased sophistication or complexity of the technical systems makes it more difficult to comprehend and manage. Thereby, it drives collaboration of the staff functions and a selective decentralization to the support staff (e.g. Galbraith, 200b; Anderson et al., 2006).

Automation of the production process drives, according to Mintzberg (1979), the bureaucratic coordination towards a more organic one[3]. The reason is that in highly automated manufacturing plants, e.g. paper mills, the operators are not actually performing the activities. Their job has been reduced to: setup the machines, monitor the process, and fix simple problems that are not affecting the output quality, i.e. the operators have very little influence over the performance of operations. Changes within the manufacturing process to achieve manufacturing plans and objectives or to respond to major problems require support by professional technicians. This requires highly developed liaisons devices and selected decision authority; thus, the operating core must have the authority to call in the specialists. In fact, this means that the workers decided when to use the staff members' expertise.

However, with a production technology approach it can be questioned if the technical system factor really is a contingency factor. When the other contingency factors generate information needs that the organization must process on a strategic level, the technical system respond to a specific and a certain information processing need that is accomplished on a tactical and operational level. In this sense, the technical system is very much similar to the coordination mechanism or a job design parameter. Further, the other contingency factors are external or emergent factors of the firm; the technical system is a factor that is based on strategic choices and can clearly be steered (cf. Lindström and Winroth, 2010; Gorlach and Wessel, 2008).

### 5.3.3 The coordinating mechanism

The coordination mechanism describes how the firm steers and regulates the work. It is the fundamental principle for synchronization of different parts of the organization, i.e. making the organizational system manageable (cf. Arshinder et al., 2008). According to Mintzberg (1980) there are five different mechanisms of coordination (see table 5:2, p. 75); each requires a specific design of the other elements of the organization (see figure 5:3, p.68) and will favor a particular organizational configuration.

[3] Compare to higher levels of technology in table 4:3, p. 42 and figure 4:4, p. 44.

Depending on the market situation, strategy and nature of the firm one of the coordination mechanisms will dominate the organization. It is easy to comprehend that each organization part (see section 5.3.1) will favor one of these mechanisms. Thereby, the dominated coordinating mechanism will automatically give the part that favors this one a more influential and prominent role in the firm.

Table 5:2 The different coordinating mechanisms for producing firms (Mintzberg, 1979).

| Coordination mechanism | Favored organization part | Description |
|---|---|---|
| Standardization of work process | Techno structure | The contents of the work are specified, formalized and programmed and steer how to conduct the work, the quality of the output and how to control the output. The coordination of the work is done on the drawing board by the techno structure. |
| Direct supervision | Strategic apex | A manager is responsible for the all work performed by others, and thereby all give orders, monitor the actions and regulates them. This coordination is informal and often verbal communicated, with minimal support of other functions or mechanisms. |
| Standardization of outputs | Middle line managers | Standardization of outputs implies it is just the results of the work that is specified. Therefore, the interfaces between the major processes are predefined, which facilitate planning, control and evaluation. |
| Standardization of skills | Operating core/ support staff | The necessary skills to perform the work are specified. A skilled individual is supposed know how to perform the tasks suggested by the supervisor. The employees often need to have comprehensive training to be trusted a membership of the operating roles. |
| Mutual adjustments | Support staff/ operating core | Coordination of the work through informal, verbal and immediate communication over the functions boundaries. , Therefore, no one can be absolute sure on what needs to be done. The success mutual adjustment depends primarily on the skills of the individuals and their ability to adapt to each other. |

However, note that each organization part may use another coordinating mechanism than the dominating one that the firm uses from an overall approach. For example, a manager of staff unit will probably coordinate his subordinate in different way than a middle line manager of the operating core.

In summary, the contingency factors determine the strategy, which affects how the firm will compete and design the work. The coordinating mechanism that corresponds to the prominent organization part becomes dominant. Together these heavily impact the organization design configuration.

### 5.3.4 Organization design parameters

In Mintzberg's theory of organization structure there are eight design parameters of the firm: job specialization, behavior formalization, training and indoctrination, unit grouping, spans of control, planning and control systems, liaison devices, and (de)centralization. It is these design parameters that span the organization structure. Each organization design parameter can be configured in different ways to correspond to the contingency of the firm and the favored coordination mechanism. Further, it is the configuration of each device that gives rise to different organizational structure configurations (see e.g. Lunenburg, 2011; Pourezzat and Attar, 2009; Matheson, 2009). Therefore, it is these devices that should be changed when aligning the firm with its strategy.

***Job specialization***

Job specialization refers to the numbers of task a certain job position control over. It is probably the most generic principle of division of work and organizational design (cf. Taylor, 1967, Gulick, 1937; Wren et al., 2002). A job is horizontally specialized if it includes few clearly defined tasks at the same level of the working process or working area. Vertically specialized jobs mean that the performer lacks the control over the task, i.e. the worker is just a performer of the specified operation and cannot change the setup of the operation, monitor the output, or regulate the input to operation. Naturally a job can be a mix of both, see figure 5.5 and table 5:3.

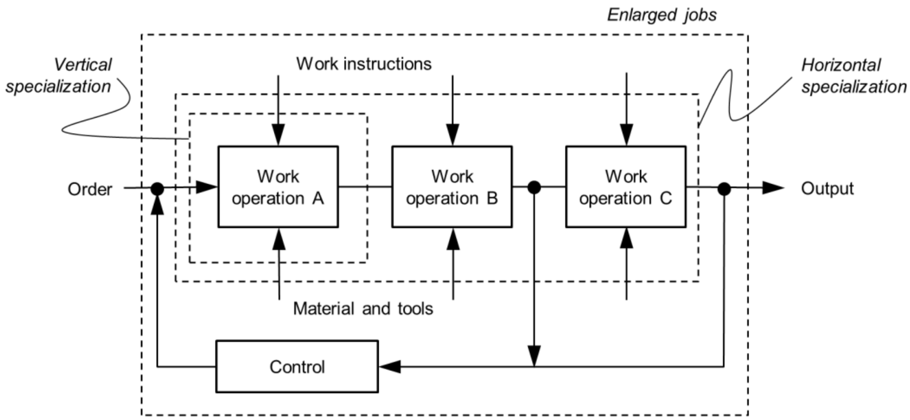


Figure 5:5 An illustration of the different job specialization types considering the work content. Compare this illustration with figure 3:1 *"The cybernetic feedback loop"* on p. 18 to see the similarities between organization structure devices and control.

Traditionally, mass production systems have been seen to rely on vertical specialization (e.g. Jovane et al., 2003; Taylor, 1967; Ford, 1927), but the current trend is to enrich the work through horizontally specialization (Johansen and Riis, 2005). In general, is the work of craftsmen of "enlarged job" type (Dai et al., 2007), while professional jobs, e.g. managers, staff members, and consultancies, have often rather specialized jobs horizontally but not often vertically (Pourezzat and Attar, 2009; Giertz, 1996).

Table 5:3 The three types of job specialization (from Mintzberg, 1979), see also figure 5:5.

| Specialization type | Description |
|---|---|
| Vertical specialization | The job task is separated from the administration and the control of it. |
| Horizontally specialization | Employees are performing a wide variety of tasks, sometimes for different products or processes, but not necessarily the control of the job. |
| Enlarged vertical and horizontally job | All activities of a task are included in the job, e.g. decision making, performance, control and rework/change of process. |

***Behavior formalization***

Behavior formalization means standardization of the work processes and implementation of operations instructions, job descriptions, rules and regulations for use when performing the work (Alajloni et al., 2011; Robbins, 2000). When formalization is achieved through operation instructions the instructions are connected to the activities of the standardized process. Job descriptions mean that there are instructions and rules for the dedicated roles for the work process. Formalization through rules and regulations implies that similar jobs can be performed according to specified rules (cf. Linderman et al., 2010; Sine et al., 2006; Brunsson and Jacobsson, 1998).

In practice firms often use more behavior formalization when the processes are stable and repetitive, which also implies that different parts of the organization are formalized in different extent (cf. Kates and Galbraith, 2007). Organizations formalize the work behavior in order to reduce process variability regarding speed and quality, and ultimately predict and control the process. Further, formalization also increases the capability for productivity improvements (Ford, 2004; Taylor, 1967) and organizational learning (Claver-Cortes et al., 2007).

I principle all organizations have some degree of formalization of their product realization process, even if the detailed level severely vary (Abrahamsson and Andersen, 2005; Poksinska, 2007). It is the amount of information an organization should store in advance and must process per order that drives the level of details. Further, all the work accomplished by different roles within a firm are not formalized in same way; it depends in which organizational part the work is executed.

***Training and indoctrination***

Training and indoctrination implies that organizations rely on formal training or apprentice programs to standardize the skills, knowledge and norms of the employees for specific roles. Training is a key to achieve skilled and professional people and high performers (e.g.

Javidan, 1998), and could be accomplished outside the company e.g. at schools. Indoctrination is way for organizations to socialize its members and create norms for how to accomplish the work and what is an appropriate quality standard (cf. Schein, 2004), e.g. through apprentice program of craftsmen (see chapter 4.5.2, p. 43).

Highly skilled workers are, according to Mintzberg (1979), basically a substitute to the formalized behavior. Through training and indoctrination, which affects the skills and norms, the output of the work become equivalent; in formalized standardization impose a normalization of the work process output – the result are more or less the same.

However, this can be questioned: if a firm relies heavily on training and indoctrination, such as in conventional construction (Dai et al., 2007), the managers are lacking the knowledge on how the work operations are executed (Jergeas and Van der Put, 2001). Instead there seems to be an assumption that craftsmen have enough know-how to be able to solve the operational problems that appears with minimal support of managers and staff (Gann, 1996). Therefore, the managers will have major problems to plan, monitor, regulate and improve the work performances (cf. Gerth, 2013; Love et al., 2010; Taylor, 1967). No one can be sure that the performance of the work is as the intended output. However, if a business environment for every product order is highly uncertain or equivocal, the use of highly skilled workers will reduce the information processing needed for e.g. planning and controlling the operative work for the managers (cf. Galbraith, 1974; Daft and Lengel, 1986).

***Unit grouping or departmentalization***

This design parameter is about how to group functions, processes and job positions together, i.e. putting these under the common supervision performed based on the same coordinating mechanism (Robbins, 2000). Within a group or unit the employees share common resources, contribute to same goals and should allocate updated information simultaneously. In general there are four types of grouping organizations in order to correspond to the market and environment requirements: functional, product, client, and geography (e.g. Schaufelber, 2009; Ahmad et al., 2009; Kates and Galbraith, 2007).

A functional organized firm is arranged around the major processes the company executes, e.g. finance, human resources, marketing and sales, product development and engineering, production, logistics and purchasing. This organization type promotes standardization and specialization of the employee to specific tasks, reduce duplication and create economic of scales (Kates and Galbraith, 2007).

In corporations that produce several product lines may use the organizational form product organization (or divisionalized form). In this form, an organization that includes all necessary organizational functions is created to manage the product line more or less self-dependent with minimal support of the rest of the corporation. The employees and resources here are dedicated to work with the product line (Mintzberg, 1981). Market or geographic structures appear when corporations acting on a geographically diverse market and have arranged the local employees and resources into self-managing organizations. This structure type is appropriate when the market needs differ among the geography, when the transportation cost is high or require services locally (Ahmad et al., 2009). Customer or client departmentalization has similarities with the geographic structure, but with the difference of that the sub-organizations are dedicated to certain customer segments or clients. Thereby, these departments will have the resources to fulfill the specific needs and service of the customer segments. For example, typical construction corporations have a mix of the geographic and clients organization. It is common with separated project-based-organized divisions for e.g. civil engineering buildings and private houses. Both product types can be located within the same region but the customer segments are fundamentally different (cf. Schaufelber, 2009; Fryer, 2006).

***Spans of control***

The parameter spans of control describes the number of position or units that are grouped together in a single unit or function (e.g. Ahmad et al, 2009). This was a hot research topic until 1950s, but has eroded because there is no general best way for organizing corporations (Ott et al., 2011; Collis et al., 2007). Usually there is a strong correlation between unit size and standardization of the work: the greater the reliance is on standardization of the work, the larger the unit size is. According to Mintzberg (1979) this is valid for all types of work. However, Collis et al. (2007) has shown that the opposite is the case for staff and headquarters, which are highly involved within the operative business, e.g. in adhocracy organizations. This also seems to be the case for the spans of control of operating personnel in craft-based firms; there the autonomous groups can be rather large per manager.

***Planning and control systems***

Planning and control systems are managerial ways to realize the determined output of the work. It emphasizes what is important for a specific period of time for the organizational members, and provides a way to steer the work towards a specific goal (Schuster and Kesler, 2012). In principle, there are two types: *action-planning-systems* (APS), and *performance-control-systems* (PCS) (Mintzberg, 1979). APS specifies the output of each operation before they are accomplished for immediate control and correction, e.g. drilling holes with specific diameters or the placement of a door. PCS specifies the result of many operations and processes. The result, e.g. sales growth of the year or the final product quality, is controlled after a given period of time, i.e. after the work has been accomplished. For example, typically conventional housing is using planning methods like the *critical-path-method* (CPM) which is a PCS (cf. Galloway, 2006).

However, PCS based planning methods have been criticized for not considering production rates, balancing of the crews and repetitive actions (e.g. Kenley, 2005; Arditi et al., 2002). These issues are considered by APS-methods, but often require different formalization behavior than an organization that often uses PCS-methods can offer. For that reason Ahmad et al. (2009) separate the planning systems based on the frequency that they will be used. For instance, in a PBO each project will have an individual plan for realizing the product once. The input to the plan is highly dependent on the project objectives, which often is of novel character. Therefore, PBOs will favor PCS based planning methods. In industrial firms a production plans can be "standing", i.e. frequently used to manufacture many products or perform repeatable actions. Thereby, the input for the standing plan is based on predetermined, standardized and stored information.

Reconnecting to the postponement theory, APS will dominate the pre-CODP processes and the PCS in post-CODP processes (cf. Olhager and Rudberg, 2002). The implication is that the APSs are suitable for certain and centrally driven organizations, and PCSs appropriate for equivocal or uncertain working situations. Thereby, industrial firms can have both systems, while PCS will dominate in ETO-firms.

***Liaison devices***

Liaison devices refer to all the devices and tools used to facilitate mutual adjustments within and among organizational units (Mintzberg, 1980). Examples of these are specific coordinating positions which have daily connections with many other units and positions, task forces, standing committees for work areas which require involvement of many departments e.g. sustainability and quality, and matrix organizations (cf. Daft and Lengel, 1986, Galbraith, 2002a). The more volatile or dynamic the situation is, more comprehensive the lateral interaction among groups and individual has to be (Daft, 2009) and the more organic the coordination of the work becomes. Thereby, this parameter clearly corresponds to the information processing theory of certain, uncertain and equivocal situations (see chapter 3).

Mintzberg (1989) asserts that firms acting in highly uncertain environments uses multiple liaison devices and has designed their structures for collaboration in the organization configuration adhocracy. Interesting to note is that Hansen (2009, p. 2) asserts that "*the greater the collaboration, the worse the results were*" (considering winning contracts). The reason was that collaboration challenged the management of the work and the power structures and often tended to hamper organizational learning.

***Centralization versus decentralization***

Centralization and decentralization embrace the extent of decision making, i.e. whether decisions are executed at the top or bottom. This parameter considers who starts and stops the working processes, and who executes and controls the actions. When the decision power is concentrated to the top it is called centralization; if it is delegated to managers down the middle line (the scalar chain) it is called vertical decentralization. Mintzberg (1979) expands the decentralization concept, and claims that it also should include who is influencing the decision without having the formal decision authority to be understandable. Horizontal decentralization describes the extent to which non-managers and people at staff functions influence and control the working processes. Decentralization can vary to only concern specific types of decisions or working processes, and differ between the parts of the organization. Thereby five types of decision power modes appear (see table 5:4).

Table 5:4 The five types of decision power mandate structures (adapted from Mintzberg, 1981).

| Decision power type | Description |
|---|---|
| Vertical and horizontal centralization | The strategic apex, top managers, has all the decision power over all the processes within the organization. |
| Selective horizontal decentralization | The decision power is shared between the strategic apex, the techno structure, and/or support staff, mainly for development, planning, controlling and improving the operative processes, i.e. the staff function gives the middle line managers strategic and operative objectives. |
| Parallel vertical decentralization | The power for making decisions is delegated to the middle line managers, often divided into parallel functional or geographical areas, to decide how to execute their working units, i.e. the organization have been divided into divisions. |
| Limited vertical and horizontal decentralization | The decision power is spread out among key positions at different parts of the organization, but in selective manner, e.g. matrix-organizations of project offices for product development. |
| Vertical and horizontal decentralization | The operating core has the power and control the production process. This can be found in craft-based organization such as conventional construction companies. |

For example, industrial firms, like industrialized construction companies, typically use selective horizontal decentralization regardless if they are of mass production or customization type. Without this decision pattern it would be hard to develop the product models, the production systems, plan and configure production processes and convince the middle line managers of this way to steer and accomplish the work. In conventional housing firms, many different roles placed at various locations in the organization influence the decisions for each project. Therefore, the decentralization mode is of vertical and horizontal type.

### 5.3.5 Organization structure from an information and control approach

This chapter has shown how a firm's contingency situation affects the coordination mechanisms and the organization design parameters. Depending on the organization configuration one of the organizational parts becomes dominating in the firm. However, by analyzing the constructs of the organization from information storage and processing approach; it should indicate why and how different organization structure configurations are appropriate for different business strategies.

***The firm's contingency and information processing need***

The external situation of a firm clearly has impact on the information management need. If the market is volatile, dynamic, or complex the information processing need is high. Depending on to what degree the company will offer customized products it will affect the information storage in advance and processing per order in different ways.

The purpose of the research was to clarify why and how a change of the production topology impacts the organization structure; therefore the contingency factors: age, size and power structure, are left out. These merely impact the perception of the environment and decision making regarding implementation of new strategies. Further, in this thesis the technical system is considered as a job design parameter because it has comprehensive impact on the organization structure and must be correlated to the design parameters. As indicted by the technology level in section 4.5.2 (p. 41) the technical system severely impacts the control, the information processing and storage dimensions.

Table 5:5 The generic organization parts, their information processing type, what specific type of stored information the parts manage. The parentheses indicate characteristics for ETO-firms.

| Organization part | Information of type | Task and control level | Use information about[1] |
|---|---|---|---|
| Strategic apex | Equivocal | Strategic | Objectives |
| Middle line management | Uncertain/certain | Tactical | Planning and control system |
| Operating Core | Certain/(Uncertain) | Operational | Skills and process instructions |
| Techno structure | Equivocal/Uncertain | Strategic to tactical | Standardized processes/products |
| Supporting staff | Equivocal/Uncertain | Strategic to tactical | Standardization of skills |

[1] The information types are correlated to the cybernetic control loop parts (see figure 5:2, p. 68).

***The organizational parts and their ability to control***

Figure 5:4, p. 70 and table 5:1, p. 71 together with figure 3:2, on p. 20 indicate that the different organization parts manage different types of information depending on their diverse nature of work (see table 5:5). Interesting to note, is that even if firms have different configurations the focus and type of information processing for respectively part is about the same. Thereby, the organizational part that is dominating within the organization impacts the firm's general ability to store and process information.

***The coordination mechanism***

The coordination mechanisms are approaches to manage different information situations which has emerged based on the firm's contingency. Each coordination mechanism favors information of certain type and requires information stored in different constituents of the organization (see table 5:6).

Table 5:6 The coordination mechanisms correlated to the information type that these mechanisms manage and use, and where this information is located and stored.

| Coordination mechanism | Manage typically information of type | Required information storage in[1] |
|---|---|---|
| Mutual adjustment | Equivocal/uncertain | Individuals, group |
| Direct supervision | Certain | Structure, rules |
| Standardization of processes | Uncertain to certain | Structure, processes, operations |
| Standardization of outputs | Uncertain to certain | Objectives, structure, processes |
| Standardization of skills | Equivocal to uncertain | Individuals, objectives |

[1] The location of the information is similar to the cybernetic control parts (see figure and 3:1, p.18).

Further, if the cybernetic control theory, with its three orders (see chapter 3), is added to this discussion it shows that:

- The coordination mechanism mutual adjustment and the standardization of skills will have problem to feedback information. From a controlling approach it is not clear how the process is accomplished, who monitor the output and how it will be analyzed.
- The mechanisms of direct supervision, standardization of processes and outputs completely corresponds to the cybernetic mechanism, they are distinguished on their different focus.

***Organization design parameters***

The organization design parameters are devices to direct, specialize, and steer the resources so the firms' strategic objectives can be met. In other words, the design parameters correspond to the parts of the cybernetic control system, which require stored information to work. Similarly, each parameter can store and/or contribute to information processing in different degree depending on the need. In table 5:7 the design parameters are listed and related to different information dimensions and types.

Table 5:7 The design parameters and the relation to information storage, processing and control.

| Design parameters | Focus area of the stored information | Contribution to information processing | Manage information of type | Appropriate in market situations of type |
|---|---|---|---|---|
| Vertical job specialization | Process | Minor | Certain | Stable |
| Horizontal job specialization | Process | Minor/medium | Certain/uncertain | Stable/dynamic |
| Enlarged job | Individual | Major | Equivocal | Dynamic/volatile |
| Operational instructions | Process | Minor | Certain | Stable/ |
| Job descriptions | Process | Vary | Equivocal to uncertain | All[1] |
| Rules and regulations | Process/output | Major | Equivocal to uncertain | Stable/dynamic |
| Training | Individual | Major | Equivocal | Volatile |
| Indoctrination | Individual | Vary | All | All |
| Functional/product grouping | Process[2] | Vary (minor)[2] | Certain/uncertain[2] | Stable/dynamic[2] |
| Market/client grouping | Output[2] | Vary (major)[2] | Dynamic/volatile[2] | Dynamic/volatile[2] |
| Spans of control | System/process | Vary | Vary | All |
| Action planning systems | Process | Minor/medium | Certain to uncertain | Stable/dynamic |
| Performance control system | Output | Major | Uncertain and equivocal | Dynamic/volatile |
| Liaison devices | Individual | Major | Equivocal/dynamic | Dynamic/volatile |
| Centralized decision structure | Process | Minor | Certain | Stable |
| Selective/limited decentralized decision structure | Process/output | Minor/medium | Certain to uncertain | Stable/dynamic |
| Decentralized decision structure | Output | Major | Equivocal | Volatile |
| Craftsmanship and hand tools | Individual | Major[2] | Equivocal | Volatile |
| Manual work and machines | Process (instruction) | Medium | Certain/uncertain | Stable/dynamic |
| Machines and robotics | Process (machine) | Minor/medium[3] | Certain/uncertain | Stable/dynamic |
| Automated lines | Process (machines) | Minor[3] | Certain | Stable |

[1] It is a tendency that the more enlarged the job is, the more general is the description.
[2] The characteristics are based on the comparison between the parameters of other configurations.
[3] Craftsmen increase the ability to process information by reducing the amount for staff/managers.

The design parameters that focus on infrastructural parts, i.e. structure, process, and system, contained stored information in advance, even though additional processing may be needed to accomplish the work. If the parameters focus on the individual, it is the employees that possess the tacit information or knowledge, limited amount of information is stored within the organization. The table also shows what type of information each design parameter usually manages and for which market environments it is appropriate. The technical system is divided into the sub-factors described in table 4:4 on page 44. The decision structure is reduced to only consider the centralized and decentralized type; these will be further discussed in the following chapter. Based on this table an appropriate organization configuration for the firm's chosen business strategy can be predicted and developed.

## 5.4 Organizational configurations

This thesis is limited to consider large companies that produce discrete physical products with different degree of customization. Therefore, only three generic types of organizational configurations are described here. Burns and Stalker (1961) describe two polar extremes of organization archetypes based on their ability to respond to market and customer changes, i.e. the mechanistic and organic organization systems. According to Claver-Cortes et al. (2007) these correspond quite well with Mintzberg's machine bureaucracy and adhocracy. The mechanistic mass producing firm as one extreme, the organic project based organization as the other, and the organization type that allows mass customizations in the middle. In the forthcoming pages the previously described organization mechanisms and factors will be used to characterize these organization design configurations.

### 5.4.1 Mechanistic and bureaucratic organizations

The mechanistic organization, or machine bureaucracy, is based on the principles of scientific management (cf. Ott et al., 2011) and is appropriate in stable environments (Mintzberg, 1979; Burns and Stalker, 1961). This organizational form relies heavily on division of work and specialization in order to create highly productive manufacturing. The goal is to produce standardized products in high volume offered on the mass market. The intellectual part of the work, e.g. strategy, product development, production planning and control, is clearly separated from the practical part of production operations. In many cases the manual work has been replaced by automated machines or robots (cf. Frohm, 2008, Womack et al., 1990). Therefore, the mechanistic organization is often denoted as centralized and bureaucratic (Stinchcombe, 1959).

It has often been misunderstood that managers are the key figures, but in fact it is the staff units that have the most influence over the work (Mintzberg, 1989). Giertz (1999) even call the middle line managers as puppets, because the staff more or less order the managers what to do, by providing them with process descriptions, plans and control of the performances (see also table 5:8). The main idea with this management system is to create specialists or very skilled employees for each activity, through repetition and learning (cf. Marcheridis and Knutsson, 2007; Jensen, 2005; Gann, 1996). It is interesting to note, that most literature about learning and organizational learning assert that the centralization has to be replaced by decentralization in order to increase learning capability (e.g. Galbraith, 2002a; Senge, 1995, Burns and Stalker, 1961). But, the next section will show why the decentralized organization has major problems to realize a learning organization (cf. Pathirage et al., 2007; Sine et al., 2006; Santos et al., 2002b).

The mechanistic management approach is based on comprehensive information processing in advance, which is stored within the organization for reuse when producing the products. The information processing need for each product is set to a minimum; thereby the explicit information can continuously be improved and reused when performing the work. In fact, when an improvement is made and has been implemented it is valid for all upcoming operations and products (cf. Womack and Jones, 2003, Liker, 2004). The entire organization is specialized for producing a specific product and to accomplish the major strategic objectives of cost efficiency. The consequence is that a change of the product offer may require major organizational and production system developments. However, today the market conditions tend to strive towards customization of products, which favors responsiveness capabilities (Wadwa et al., 2009; Siggelkow and Rivkin, 2005).

### 5.4.2 Organic and innovative organizations

The organic or innovative organization configuration has the ability to produce customized products and is therefore suitable for highly dynamic markets and (cf. Melkonian and Picq, 2011; Pine, 1993; Burns and Stalker, 1961). The utopia is an extreme flexible firm that can produce almost everything that each specific customer wants. This requires highly flexible organization structures, processes and competences. In theory there is no need to prepare the organization for the future by formalizing how to manage the work, because the firms do not know what to produce tomorrow (cf. Burns and Stalker, 1961). Thereby, this utopia of the organic organization is assumed to be manifested by PBOs, like conventional construction firms. However, the reality is different – all organizations have some degree of formalization and some dedication, in other case there would be no business firms at all (e.g. Maskendahl, 2010; Claver-Cortes et al., 2007).

Firms that possess this flexibility often have a loosely coupled organization (Dubois and Gadde, 2001; Orton and Weick, 1990), i.e. groups and individuals that are working together in temporary teams for a certain project or job (Kadefors, 1995). Mintzberg denote this business type adhocracy organization, because it coordinate and use employees from all levels and parts of the organization to realize each single project order. It is also common that the individuals have to work with different duties for each job (Burns and Stalker, 1961). The implication is that even major corporations are only able to hold employees with a rather general competence in order to perform many different duties (cf. Keegan et al., 2011; Laslo, 2010). Specialized competences are procured when there is a specific project need. These characteristics are typical for conventional construction firms (Maskendahl, 2010; Dainty et al., 2006; Winch, 2003). Table 5:8 summaries the major differences between the mechanistic mass production firm and the organic or adhocracy company.

Table 5:8 Typical organizational differences between mechanistic and organic organization systems. Sources Mintzberg (1979) and Burns and Stalker (1961).

| Organization mechanism | The mechanistic or machine bureaucracy configuration | The organic or adhocracy form configuration |
|---|---|---|
| Typical market environment | Stable and not to complex | Dynamic and often highly complex |
| Key focus area | Standardization and formalization to create effectiveness | Individual expertise and collaboration to create agility |
| Key coordinating mechanism | Standardization of work | Mutual adjustment |
| Key part of the organization | Techno structure | Support staff with operating core |
| Type of decentralization | Limited or selected horizontal decentralization | Vertical and horizontal decentralization |
| Vertical job specialization | Typical | Unusual |
| Horizontal job specialization | Common | Unusual |
| Enlarged vertical and horizontally job | Unusual | Typical |
| Operational instructions | Detailed | Wide |
| Job descriptions | Deep | General |
| Rules and regulations | Not common | Not common |
| Training and indoctrination | Some is required | Comprehensive and required |
| Grouping (area of supervision) | Functional/product structure | Market/client structure |
| Spans of control | Narrow in top and wide in operating core | Wide in top and narrow in bottom |
| Planning and control systems | Extensive with focus on APS | Limited, but favor of PCS |
| Liaison devices | Few | Many |
| Work regulating technology | Comprehensive | Unusual |
| Complex technology | Possible | Not possible |
| Automated production | Possible | Not possible |

From an information processing approach, have organic or adhocracy firms very little information stored in the organization structure. Instead, the organization relies on individual and tacit knowledge to realize the products. When an order arrives the employees have to collaborate in order to clarify what to produce and how to do it. If the employee does not possess the necessary knowledge it is procured from consultancies or sub-contractors. Thereby, extensive information processing is required for each new order and will in most cases result in new knowledge (cf. Engström 2012; Brun et al, 2009). However, because it is very uncertain if this particular project will be produced again the knowledge is not formalized and stored for future use. This is a major obstacle for organizational learning (Jensen, 2005; Yeo, 2005), but it is highly developing for the individuals (Argyris and Schön, 1996). In fact, Sin et al., (2006) concluded that highly flexible firms cannot become more strategically competitive through increasing its organic capability. The reason was that this type of firms hampered their organization learning ability.

In summary, organic organizations are structured for extreme flexibility and customization of products. However, it happens at the expense of control and system improvements capability. Therefore, flexible organizations for mass customization of products can be an alternative to join the best of these two extremes.

### 5.4.3 Flexible organizations for mass customization production

Today, the dynamic market requirements of customized products produced with a cost efficiency close to mass production, speaks for a mix of the two extremes presented earlier (cf. Piller, 2004). However, many authors discuss mass customization from a mass production perspective (Trentin et al., 2011; Duray, 2002) and emphasizes the need for making the functional organization structure more flexible (e.g. Galbraith, 2002b). Therefore, common suggestions are e.g.: increased decentralization (Kates and Galbraith, 2007; Senge, 1995); creation of hollow and modular structures (Anand and Daft, 2007); the reinforcement of the integration of different parts of the organization (Marcheridis and Knutsson, 2007); and the development of virtual or network based organizations (Wadwa et al., 2009). However, these propositions are seldom elaborated in the same detail level as the dominating theories of the "mass production paradigm" have been. In the beginning of the 20th century the research focus was on how to make the transition from craft to mass production. Today, the dominating focus is on how to re-configure the mass producing organizations to be the mass customizers (cf. Trentin and Forza, 2010; Nambiar, 2009; Jovane et al., 2003). This approach, should be complemented with opposite direction, i.e. how to transform highly flexible and organic organizations to be mass customizers (Gosling and Naim, 2009; Haug et al., 2009).

Based on the literature it is easy to misunderstand that flexible organizations for mass customization strategies as a mix of the mechanistic and organic organization structures – that is not the case. For example, Gerth (2008) asserts that industrial house builders with a mass customization strategy corresponding to the MTO-topology have more in common with MSP-topologies, i.e. mechanistic mass producers, than with conventional house builders, i.e. organic organizations with an ETO-topology. By applying an information approach, with the two dimensions of information storage and processing, the dissimilarities between the different organizational types can be clarified.

***Information* storage *and processing in mass customization organizations***

Mass customization is according to Piller (2004) and Pine (1993) the capacity to adjust the product offer to each single customer's specific needs and manufacture this product with mass production efficiency. In order to accomplish this, the total product offer must be limited, prepared in advance, and correlated to the production system (Pine and Gilmore, 2000). Thus, each part of the product, production system and organization is pre-developed, standardized, and formalized but can be configured according to specific configuration rules (Blecker and Abdelkafi, 2006b; Brown and Bessant, 2003).

From an information approach this indicates that a large amount of information is stored within the organization in order to be processed when the customer order is configured. In order to transform a mass producer to be a mass customizer, the organization must be changed in such a way that it can process information for each order. The organic adhocracy firm, on the other hand, should be developed in such way that it can both store and process more information. The reason for increasing the ability to process more information is because craft-based organizations rely heavily on tacit knowledge and has delegate much of the processing actions to the individual level. This way of managing information cannot proceed, but must become explicit and systemized to realize the mass customization objectives. Therefore, firms with a mass customization strategy should have more similarities with mass producing firms than with organic firms.

In conclusions, flexible organizations for mass customization manufacturing must be able to store information within the organization structure, process information for each order, and rely on the cybernetic control mechanism for effectively management and improvement. A flexible organization must be based on standardization and formalization of information storage, but decentralized enough for order initiated information processing at different levels. The forthcoming chapter presents a conceptualized model which predicts how the organization structure should differ between producing firms with different production topologies.

# 6 CONCEPTUALIZATION OF THE PTO-MODEL

*In this chapter is the developed "Production-Topology- Organization-model" (PTO-model) presented. From an information approach it clarifies why and how the change of production topology will impact the organization structure. The model is a conceptualization of the previous reviewed theories in chapter 3 to 5.*

## 6.1 Informational differences between production topologies

All business firms stores and processes information in order to realize the products which are offered on a specific market. The chosen market, the product type, the customization degree and the production complexity determine how much information that must be managed. The more volatile an equivocal the business market is, the more information must be processed per order in order to clarify the product and how to produce it. More stable and certain business situations imply that information can be strategically processed and stored for repeatable use when producing the products (see figure 6:1).

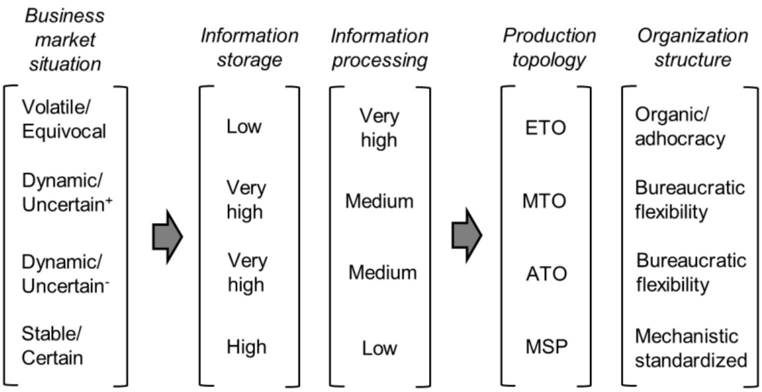


Figure 6:1 The relation between different market situations and their information requirements related to the appropriate production topology and organization structure types to manage the information.

The more information that a firm can store in advance and reuse repeatedly, the less information processing is needed per order. The consumed resources, to develop and store the information in advance, can thereby be spread out among many products. This corresponds to the existence of a trade-off between the degree of customize products and the production productivity (da Silveira and Slack, 2001; Squire et al., 2006; Luu et al., 2008), based on the fact that information processing consumes resources (e.g. Galbraith, 1974).

### 6.1.1 Strategy, information and organization design

When a business firm determines to change their business strategy, which implies a change of the production topology, it induces development of the organization and the production system. It is the change of product customization degree and the production flexibility that changes the CODP placement within the product realization process (see figure 4:7, p. 52). In turn, this induces a re-design of the organization in order to realize the new objectives on both the process and the overall level (see figure 6:2). Upstream and downstream processes of the CODP manage information differently, and these new requirements must be met by the organizational structure. It is the organization structure that creates the different abilities to store information and process information.

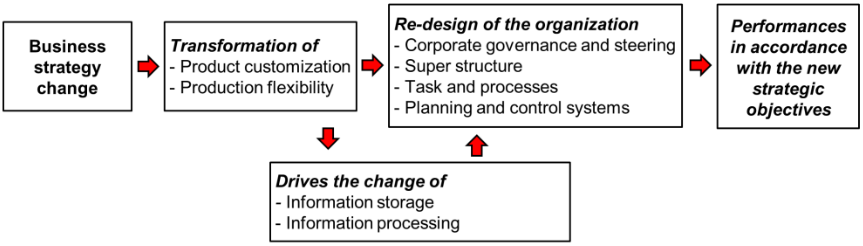


Figure 6:2 Visualization of the business organization development process; from strategy change, i.e. transformation of the product customization and production flexibility, to development of the organization structure, which results in performances in accordance with objectives. The lower box indicates why the organization must change.

### 6.1.2 Information processing and control levels

The total information management process can be divided into three categories: strategic, tactic and operational information processing. Strategically, firms must process information to develop, dedicate and prepare the organization and production system for its chosen strategy. Every enterprise needs to develop structures, systems, procedures and procure appropriate resources to coordinate the work. Information is processed in advance for storage within the organization infrastructure and for reuse when conducting the work. This strategic information processing is a mix of 3$^{rd}$ and 2$^{nd}$-order cybernetic with the goal to transform equivocal to uncertain information into more usable information on tactical and operational managerial level (see figure 6:3, p. 92).

Tactical information processing is about management, planning and improvements of the operational level. The goal is to translate uncertain information into a more explicit and certain type, in a similar manner as the 2$^{nd}$-order cybernetics. Typical information processing activities at this level are: forecasting, scheduling of dedicated resources, and process improvements. The information processing activities are the respond to the dynamic market conditions and the changing customer requirements.

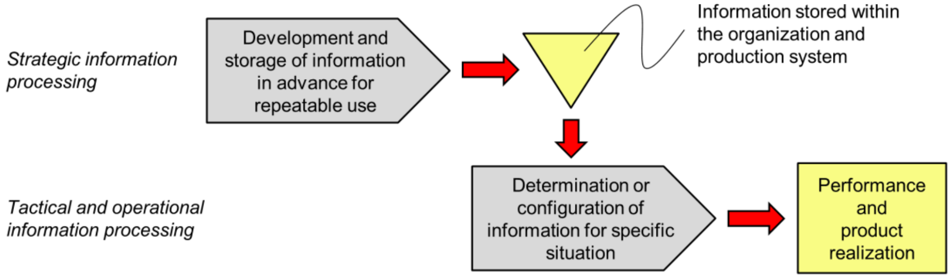


Figure 6:3 Illustration of the strategic, tactic and operational information processing. The strategic information processing results in stored information that is used by the other two processing levels to accomplish the work and the products.

At the operational level information is processed to perform the tasks, i.e. the 1st-order of cybernetic control. The goal is to make the information as explicit and certain as possible, i.e. it should clarify what to do and how to do it. Typical actions are preparation and regulation of the machine/operation settings, and control of the output of the task. All information that has been processed prior to the arrival of the order can be spread out among the products that share that information. The specific information for each individual order requires additional processing. In most cases stored information is of certain or uncertain type.

For example, if a business situation is perceived as equivocal the firm must transform it to be certain information when realizing the products; such the case is for ETO-companies. This implies that very little stored information can be used to clarify what to do and how to do it. Thereby, most information that will be used for realizing a product must be processed for each order. If a business market is certain and stable the corporation, e.g. mass producing firms with a MSP-topology, probably has stored information within the system for repeatable use when producing the products, i.e. less information needs to be processed per order (see also figure 6:4, p. 93).

| Production topology | | Strategically stored information | Tactical information processing | Operational information processing |
|---|---|---|---|---|
| ETO | ⇨ | Low | Low | Very high |
| MTO | ⇨ | Very high | High | Medium$^{+}$ |
| ATO | ⇨ | Very high | High | Medium$^{-}$ |
| MSP | ⇨ | High | High | Low |

Figure 6:4 Illustration of how the four common production topologies correspond to the three levels of information processing and storage.

### 6.1.3 Information requirements and organizations structure types

Organization structure directs the resources towards the more or less wide tasks, which impacts the resources ability to specialize and the need of information processing per order and task. The more information the organization infrastructure contains, the lesser work knowledge the operative employees' need to possess in order to accomplish the work tasks. This indicates the relation between the information requirements, the topologies and different organization structure types (see figure 6:1, p. 90).

## 6.2 Generic constituents of the organization and production system

All producing firms possess the generic organizational elements: business strategy, corporate governance and steering, super structure, tasks and processes, and plan and control systems. It is the design of these that makes the firms different. Figure 6:5 on p. 94 illustrates how the generic infrastructural constituents of a producing firm can be categorized. Each of these major elements corresponds to one of the parts in the cybernetic system control mechanism: the business strategy is similar to the goal; the corporate governance and steering describe the principles of how to control the system; the super structure directs the system's resources towards the controlled processes; the tasks and processes matches the cybernetic work process; and planning and control systems defines how the regulating system is accomplished and transferred. Developments of any of these elements induce new relations, which drives a need for a re-configuration of the organization in order to realize the potential.

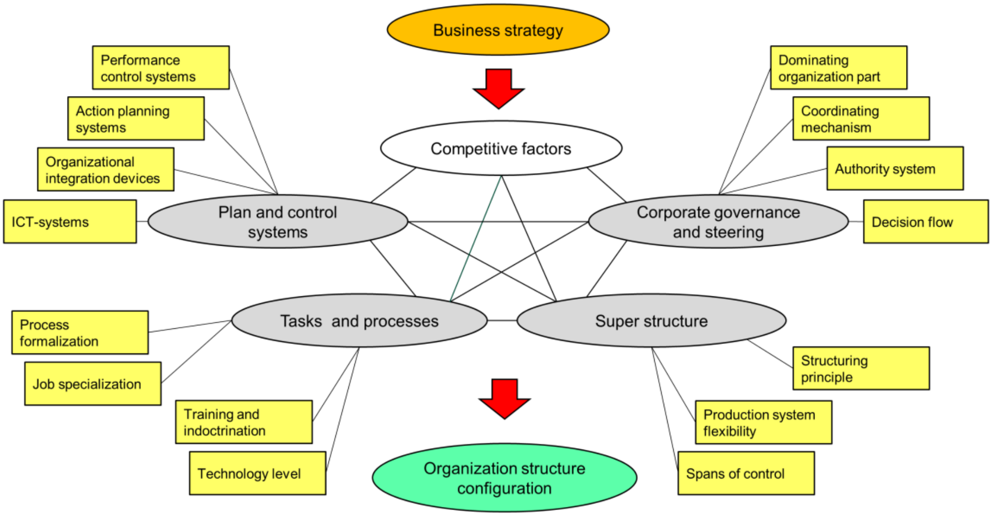


Figure 6:5 The illustration of structure PTO-model's major elements (grey ellipses) and their constituent factors (yellow boxes). The design of respectively element corresponds to the different information dimensions and creates specific organization configurations for each production topology.

The PTO-model suggests what control mechanisms that are suitable for which business situation and production topology (see table 6:13, p. 112 and table 6:13, p 114). Yet, in practice the suggestions must be further developed to fit the exact conditions of the firm.

### 6.2.1 The business strategy's competitive factors and the enablers

The business strategy priorities the competitive factors; product customization degree, production cost, and delivery time. These are closely related to the enablers; product configuration strategy, product structure type, and the production system flexibility (see figure 6:5). The product customization strategy corresponds to the uncertainty regarding the customer needs. The product structure contains information on what to accomplish, and it precedes the design of processes, dedication and specialization of production resources to the product realization process. The production system possesses information on how to manufacture every component in the product structure. However, if a firm changes its strategy, i.e. changes the customization degree, the product structure and the production flexibility must also be developed. Figure 6:6, the trade-off box, illustrates how the change of the business strategy impacts the competitive factors, which in turn affects the strategy enablers (compare it with table 6:13, p. 112).

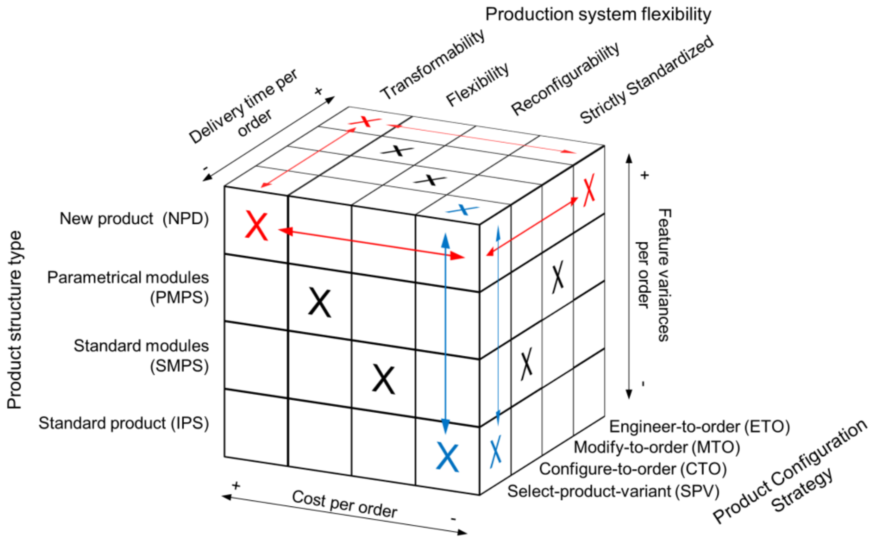


Figure 6:6 The trade-off box illustrates the relation between product customization strategy, product structure type, the production system flexibility, and their relations to cost, product features and order delivery time. The red and blue X:s and arrows exemplify how the conventional house builder (red color) and a mass producer (blue color) should interconnect these dimensions.

The trade-box should be interpreted as the following example. Conventional housing firms, which put unique products on the market, uses an ETO-customization strategy; thus, develops a new product structure for every project (NPD) and therefore uses an extremely flexible production system (transformability). Follow the red arrows which connect the X:s to see how the customization degree, product structure and production system correlates. Because housing firms' develop every building from scratch in each project the production cost is high per order and takes a long time to produce.

If the housing firm determines to implement industrialization strategy and only produce standardized products with no customization at all (SPV), the product structure must change to be of IPS-type and the production system to be of standardized type (see blue X and blue arrows). Thereby, the firm can reduce the product cost and the delivery time per order, but on the expense of the ability to offer different product features for each product order.

***From business strategy to production topology***

The trade-off box characterizes the four common production topologies: *engineer-to-order* (ETO), *manufacture-to-order* (MTO), *assembly-to-order* (ATO), and *make-standard-products* (MSP). Note that these four production topologies require different capacity regarding information storage and processing (compare to figure 6:1, p. 90). The different information capacity requirements can be explained by the three dimensions of the trade-off box. The customization degree drives information processing, while the product structure and the production system can store information. The ETO-topology is an exception from this, due to the customization degree is too comprehensive. The individual product orders are so dissimilar that the chance to apply pre-developed information in other projects is scarce. Thereby, it is not worthwhile to develop information for storage from overall company perspective. Figure 6:7 clarifies the characteristics in accordance with figure 6:6.

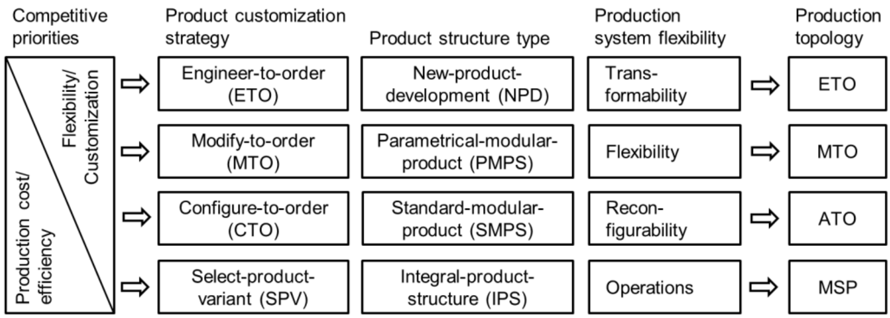


Figure 6:7 Summary of the four common production topologies' characteristic strategy enablers.

### 6.2.2 Corporate governance and steering

This major element considers how the information is used within the decision process and flows among different parts of the organization with diverse authority, e.g. for development, preparation and execution of the work processes. Depending on the design of these flows, different coordinating mechanisms of the organization become dominate. The part is constituted by four factors; the coordinating mechanisms, the authority system, the favored organizational part(s), and the decision flow.

The *coordination mechanism* describes a firm's major way of steering and regulating the work, i.e. through standardization of work and mutual adjustment. Standardization of work implies that the contents of the work are specified, formalized and steer the employees in how to conduct the work, the quality of the output and how to control the output. Work coordination is accomplished on the drawing board by the techno structure, i.e. all the necessary information to perform the work had been developed in advance. In the case of mass customization additional information processing must be required for specifying the exact job tasks of a particular customized order. Coordination based on mutual adjustments is often informal and verbally communicated regarding what to do and how to do it. It is appropriate in highly uncertain or equivocal environments when very little information can be processed and formalized before the order is initiated. The success of mutual adjustment depends primarily on the skills of the individuals and their ability to collaborate and adapt to each other. Therefore, conventional housing firms which uses this coordination mechanism relies on highly skilled craftsmen. The information characteristics of the coordination mechanisms are summarized in figure 6:8.

| Coordination mechanism | | Information type | Information storage | Information processing |
|---|---|---|---|---|
| Mutual adjustment | ⇨ | Equivocal/ uncertain | Low | Very high |
| Standardization of work | ⇨ | Certain/ uncertain | High | Low/medium |

Figure 6:8 Relevant coordination mechanisms and their capacity to deal with the information aspects.

The *authority system* is the formal system of making decisions and how to communicate these, i.e. who report what to whom. Two appropriate streamlines for producing firms are identified; limited horizontal decentralization and selective decentralization. Further, the dominating coordination mechanism also influences how persistent the *decision flow* is: if the decision flow is different for each order, it is organic; if it is the same, it is bureaucratic standardized. The continuity of the decision flow depends on how much information that must be processed per work tasks and the individuals who influences the decision process.

Together these steering mechanisms will favor an *organizational part*. A specific part becomes dominating when it continuously has major impact on how other parts are performing the work. Standardization of work relies on the work of the techno structure for developing plans and standards. These are then used by the other organization parts when performing their work. When firms rely on mutual adjustment and organic decision flows, most parts are involved and collaborate for each order, i.e. no part is dominating the others. Further, if the information storage is comprehensive, as it is in all types of industrial firms, it will favor the techno structure. If the information processing per order dominates, as it does in conventional construction firms, no particular part will dominate the other. Figure 6:9 (p. 98) correlates the sub-factors of the "corporate governance and steering" element.

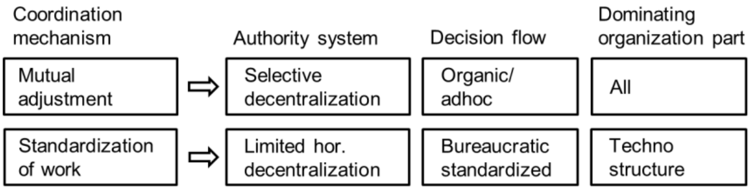


Figure 6:9 The coordination mechanisms, the appropriate steering principles and favored dominating organizational part.

The nature of each production topology will favor a specific coordination mechanism, authority system, decisions flow and the part that is dominating in the organization (see figure 6:10). The reason for this is that each of the steering mechanisms supports the information storage and processing in different ways.

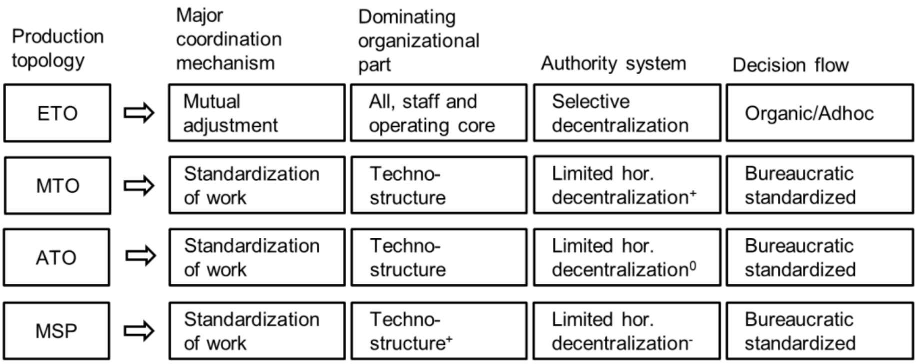


Figure 6:10 The different “corporate governance and steering” aspects for the production topologies.

### 6.2.3 Super structure

The “super structure” explains how the firm is mapped and organized. It directs the organization’s resources towards certain processes or working areas in order to achieve specialization and/or flexibility. Thereby, it directs the decision and information flow and indicates how the performing resources are arranged and interconnected. The super structure consists of the structuring principle, the production system flexibility, and the spans of control.

The *structuring principle* describes how individuals and groups are linked together and coordinated by a common supervisor. Typical jobs within the same unit strive towards a common goal, and are controlled in similar ways, share the same resources, and encourage knowledge sharing. This is often illustrated as organization charts and thereby describes how resources are dedicated to certain areas in the firm. Two major organization structuring principles are division based on functional/process or market/product location[4]. These two corresponds to the production layout types rather well (see section 4:5). The functional/ process division means that functions and groups are organized around major processes, in order to achieve efficiency through specialization. It relies heavily on information storage even if information can be processed when it is necessary. Market organized firms is designed to perform all the work where the product is sold and produced. The locations of the necessary resources are the dominating organizing principle rather than the working procedure. This principle allows firm to be more flexible and responsive to external and internal changes than functional organized firms. The reason is that some authority is decentralized to the manager of the working area in order to be more free to meet the local market's specific needs (see figure 6:11).

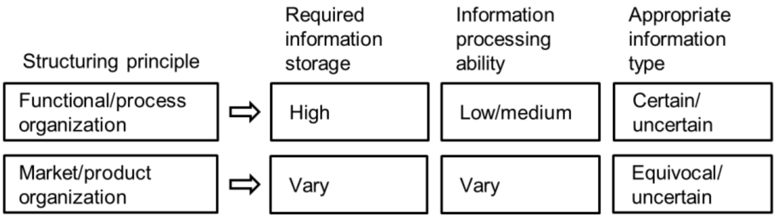


Figure 6:11 The information characteristics of the two *structuring principles* of organizations from a top-down approach.

From a top-down approach the functional/process divided organization implies that corporate managers and staff must process a lot of information in order to maintain the interaction between the parts and implement changes of the work. In organizations with a market location division the information processing is decentralized down the organization hierarchy. Thereby, the corporate manager and staff levels does not need to process similar amount of information, which creates responsiveness to the local business environment. Each single local unit may store or process large amount of information per order, which explains why the information aspects can vary.

The *production system flexibility* demonstrates how the pervasive the flexibility is. The higher up in the system structure the changes occur, the more comprehensive the system transformation that must take place becomes. The implications is that if the production system is of transformable type the subordinate levels should be flexible and reconfigurable,

[4] Sometimes these four types are separated, but because of the similarities they are categorized into two in this thesis.

i.e. if the top level change it may induce configuration of the lower levels as well (see figure 6:12 and compare it with figure 4:2, p. 37).

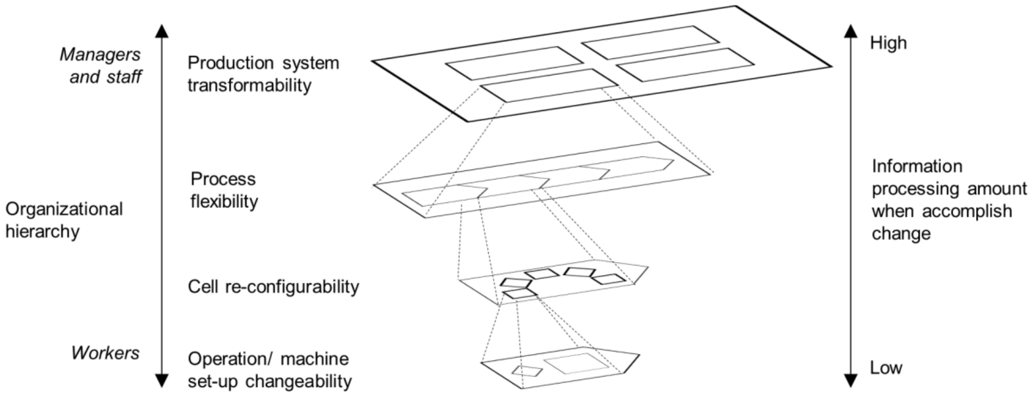


Figure 6:12 The levels of flexibility of the production system hierarchy. The closer to the top the system structure is transformable the more information must be processed to make the working processes and operations clear and ready for action.

Since every change require information processing it is obvious that the more comprehensive the change is, the more information must be processed. The processing work often relies on stored information in the tasks and processes, but it does not necessarily mean that a highly flexible system structure contains more information. In the extreme flexible structures, e.g. the ones in conventional construction firms, the super structure contain less information; instead these firms' develops the subsequent levels for each project. By using highly skilled craftsmen, that can interpret construction blue-prints and determine how the task should be accomplished, the managerial levels do not need to develop the subsequent levels, e.g. the operation and cell levels.

The close relationship between structure and processes implies that the product realization process also must correspond to the flexibility requirement. The flexibility differences are considered by the production topology that describes how the work flow, the processes types are designed and corresponds to appropriate production layouts. The work flow describes how the business firm should be organized and dedicates its resources (see also chapter 4.3.5). It indicates how information flows within a production system in order to realize the products. For example, if an organization has a work flow that supports flexibility, the dedicated resources must possess the ability to deal with the particular information processing need for each order. Firms with a work flow that supports standardization and specialization should have resources that have the capability to use stored information with a minimum of additional information processing (see figure 6:13).

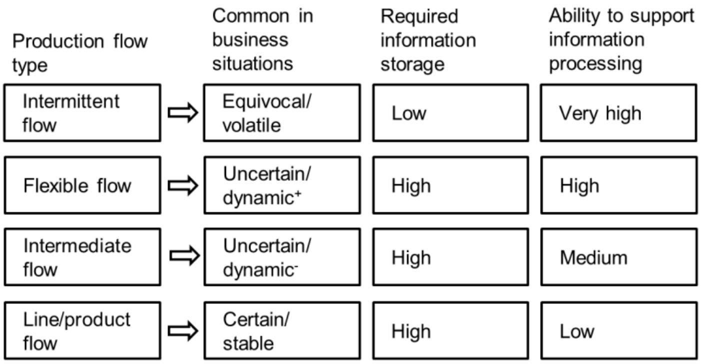


Figure 6:13 The information characteristics for relevant production flows.

The process types; project, job, batch, and line differentiates between processes depending on their ability to generate product variants and product volumes. In practice there seems to be a trade-off here; the more flexible a process type is, the more information must be processed per order and vice versa. The production layout describes the physical flow of resources and materials within the processes to realize the products. It will differ depending on the product characteristic and the producing volume of particular products.

The more individual each order is, the more flexible must the physical transportation of the resources and materials be in order to accomplish the particular product order. High volumes of a particular product, module or item make it possible to standardize the physical layout, i.e. information can be stored within the system and be reusable for multiple orders. In table 6:1 the process mechanisms of discrete product manufacturing are summarized and related to different aspects of information.

Table 6:1 The process types' and production layouts' information characteristics.

| Topology mechanism | Required information storage in advance | Necessary information processing per order |
|---|---|---|
| Project process | Low | Very high |
| Job process | Medium | High |
| Batch process | High | Medium |
| Line process | Very high | Low |
| Fixed position layout | Low | Very high |
| Process layout | High | High |
| Cell layout | High | Medium |
| Product layout | Very High | Low |

The flexibility of sub-processes within the product realization process is related to the placement of the *customer-order-decoupling-point* CODP. The CODP is the point there the product configuration (PC) can be accomplished, which imply that the greater the configuration degree is the more information must be processed per order both regarding product structure and the production process. For example, in conventional housing is the CODP placed at the design phase. An entirely new product is engineered from scratch for each project, which also requires that the production organization, the process and the project resources must be developed or procured for each order. The characteristics of the generic production topologies are summarized in table 6:2.

Table 6:2 Characteristics of the common production topology regarding the super structure.

| Mechanism | ETO | MTO | ATO | MSP |
|---|---|---|---|---|
| Structuring principles | Product market location | Functional | Functional | Functional |
| Production system flexibility level | Manufacturing transformability | Process flexibility level | Cell re-configurability | Operation/ machine set-up |
| Overall production layout | Entirely fixed position layout | Process/cell (fixed position layout) | Cell and product (fixed position layout) | Product (fixed position layout) |
| Typical work flow | Intermittent | Flexible | Intermediate | Line/mass production |
| General process type | Project | Flexible | Batch | Line |
| CODP/PC placement | Design/ engineering[1] | Manufacturing | Assembly | Delivery/stock |
| Pre-CODP process type | - | - | Line | Line |
| Post-CODP process type | - | Flexible/job | Flexible/job | - |

[1]The order initiation is in the design and engineering phase.

Pre-CODP are the processes standardized and typically designed as line or batch processes that can be accomplished based on forecasts. Post-CODP processes are flexible and initiated by a specific order. These processes rely on stored information and additional information must be processed on order for re-configuration of the production processes. Table 6:3 summaries the information characteristics and typical process aspects pre- and post-CODP.

Table 6:3 The process types and production layout information characteristics.

| Topology mechanism | Processes pre-CODP | Processes post-CODP |
|---|---|---|
| Information storage | High | High (except in ETOs) |
| Information processing | Low | High |
| Information situation type | Certain | Uncertain |
| Work flow | Product | Flexible |
| Process type | Line/batch | Batch/job |
| Production layout | Product/cell | Process/cell |

In industrial production systems more standardized jobs allow wider *span of control* than more flexible jobs. The reason is that the standards, used technology and instructions control regulate the employees work behavior and thereby the performances. This implies that the supervisors do not need to spend as much time on monitoring and controlling the output as if the process was less standardized and the job more horizontally specialized. Within a unit the supervision principle is the same and depends on the job specialization, the coordinating mechanism and the control principle; between the units the supervision principles can differ.

Craft-based production system is different, due to it is relying on highly skilled craftsmen that have very enlarged job types and often work in autonomous teams. This means that each single craftsman process a lot of information during the work, e.g. reading and interpret the blue prints, determine which type of tools, material and activities to use for execution of the specific task. When the work is done the craftsman control his own work. A substantial amount of the managerial work is thereby decentralized to the worker through the enlarged jobs. The supervisors do not need to process as much information as in industrial systems with horizontal job specializations, which allow the craft-based production system to use a wider span of control. Therefore, it is not possible to give a general suggestion of an appropriate number of subordinates to a supervisor role. Rather it should be seen as suggestion that if the production topology changes the unit sizes may also be changed.

### 6.2.4 Tasks and processes

The major element "tasks and processes" is about how work processes are designed, predetermined and executed. It also indicates which part of the organization that processes the information in advance and per order. The element is constituted by the factors: process formalization, job specialization, training and indoctrination, and technology level. The design of these constructs corresponds to the amount of the necessary information to manage and conduct the work operations and where it is stored.

The factor *process formalization* describes the standardization of work through formal descriptions and instruction on how to perform the processes and jobs. In fact, this is one of the major factors for storage information within the organization and is an important way of controlling the work. Four general principles are identified;

- *Process formalization/standardization*
  Detailed description and visual presentation of the processes, including inputs, outputs, rules and support, and information needed for each activity within the process. A standard process requires instructions for each included activity.

- *Operations instructions*
  Formal information for a given task(s), written and illustrated, supplied to an operator that specifies method, tools, machines to be used, and the output quality of the job.
- *Rules and regulations*
  Formalization through institutionalized rules and regulations implies that similar jobs have to be performed in resembling ways but not necessary identical.
- *Function and role descriptions*
  Role descriptions are written statement of the essential tasks, working conditions, purpose, rules, limitations, duties, responsibilities and authority of a specific job.

In principle all organizations have some formalization, but the detail levels vary because of the necessary information processing degree and the chosen mechanisms to control the work (see table 6:4).

Table 6:4 The "tasks and process" devices regarding information storage, control mode and their appropriateness in different process types.

| Task and process mechanism | Type of stored information | Impacts control level | Appropriate in process type | Comment |
|---|---|---|---|---|
| Working process formalization | Certain to uncertain | Tactical $2^{nd}$-order | All types | Detail level vary, purpose is to processes explicit or certain info. |
| Operations instructions | Certain | Operation $1^{st}$-order | Standardized and flexible | The foundation of industrial work |
| Rules and regulations | Uncertain | Tactical $2^{nd}$-order | Flexible | Scope and detail degree vary due to the flexibility level |
| Role and function description | Equivocal to uncertain | Operation $1^{st}/2^{nd}$-order | All types | Scope and detail degree vary depending on its organization part and production topology inherency |

*Job specialization* refers to the number of tasks a worker is responsible for and in what degree the performer is instructed on how to perform the task. Three important categories describe the differences within this factor; vertical, horizontal job specialization and enlarged job. Vertical specialization induce that the job task is separate from the administration and the control of it. If the job is of horizontal type the workers are performing a wide variety of tasks, sometimes for different products or processes, but it does not necessarily includes the control of the job. Enlarged job is when most activities of a job is included and determined by the performer, e.g. decision making, operation set-up, execution and control of the accomplished work. Clearly, the major differences between these are how much information that had been processed by the techno structure in advance and how much information a supervisor and worker must process to accomplish their duties. Table 6:5 summaries the major differences of the job specialization categories regarding the information aspects.

Table 6:5 Characteristics of the *job specialization* devices regarding information storage, control mode, managers' work and for what situations the job-types are appropriate.

| Job specialization | Required information storage | Managers information processing per task | Appropriate information situation/type |
|---|---|---|---|
| Vertical specialization | High | Low[1] | Stable/certain |
| Horizontal specialization | High | Medium | Dynamic/ uncertain |
| Enlarged job | Low[2] | Low | Volatile/ equivocal |

[1]Valid when the tasks are not changed

[2]See also education. The employee has the skills perform the job without detailed instructions.

Traditionally mass production has relied on vertical specialization, but the trend is to enrich the work mainly through horizontally specialization. In general, the work of craftsmen is of "enlarged job" type and can be found in conventional housing (see also the examples in spans of control on p. 102).

The job specialization differentiation is closely related to the need of *training and indoctrination*. The factor of training and indoctrination is about securing that the employees have the necessary knowledge and skills for accomplish the tasks without comprehensive formalization of the work. According to Mintzberg (1979) the more enriched and enlarged a job is the more important the individual knowledge and skills become. Today even the traditionally simple manufacturing tasks require fundamentally understanding of processes. Therefore, most producing firms require high school education of its blue collar workers and some socialization of company specific norms. In craft-based production, e.g. in construction, this is not enough which explain why apprentice programs are used to secure the necessary working knowledge and skills. Table 6:6 shows how the job specialization categories are related to the different sub-factors of training and indoctrination and typical production paradigms.

Table 6:6 Typical *training and indoctrination* aspects of the job specialization types.

| Job specialization | Education | Apprentice programs | Socialization of norms | Typical production paradigm |
|---|---|---|---|---|
| Vertical specialization | Common | No | Preferred | Standardized mass production |
| Horizontal specialization | Common/ necessary | No | Preferred | Flexible production |
| Enlarged job | Necessary | Usually | Preferred | Craft-based production |

The factor *production technology* describes the dominating technology level and artifacts used to transform inputs to outputs. It considers the operating core working activities and the use of tools, equipment and machines, which impacts on how to perform and control the operations. Four categories of different technology levels are identified: craft-based technology, manual operated machines, cells and advanced machines, and automated lines and robots. The different levels require different skills, formal instructions and control modes (cf. Frohm, 2008). In craft-based production systems, the craftsmen use relatively simple tools based on their pre-understanding of the situations and their implicit skills. When a production system uses manually operated machines, labors are using machines necessary to perform the operations, but they need instructions for how to use the machine and what to produce (see table 6:7).

Table 6:7 The manufacturing *technology levels*' requirements in relation to the other factors of the element "tasks and process" and their commonality in different process types.

| Technology level | Process formalization (detail level) | Appropriate level of training and indoctrination | Typical job specialization | Common process types |
|---|---|---|---|---|
| Craft-based technology | Low | Very high | Enlarged job | Project, job or conventional housing. |
| Manual operated machines | High | Medium | Horizontally specialization | Flexible and assembly processes |
| Cells and advanced machines | High | Medium | Horizontally specialization | Reconfigurable assembly/ manufacturing processes |
| Automated lines and robots | High | Low | Vertical specialization* | Continuous line processes in mass production |

When the technology level of cell and advanced machines type is used, advanced machines or static machines are grouped in such a way that the work content for the laborers are reduced. A production system consisting of process that is highly automated lines implies that the human worker had been replaced by self-regulating machines and robots. This implies that the technology had reduced the operators' work by monitoring the process, turn on/off, and load the machines with inputs and to solve simple problems. Advance problems often require specialists' involvement, e.g. people from the staff departments.

In summary, the different technology levels contain various degrees of stored information on how to execute the tasks. It is also obvious that the more advanced the manufacturing technology is, the more information have to be processed strategically and stored within the system (see table 6:8). Furthermore, in industrial production systems the more flexible the technology is, the more information must be considered in the development process; due to that the technology must be prepared for each possible configuration.

Table 6:8 Information and control characteristics of the different the *production technology levels*.

| Production technology level | Information storage requirements | Ability of information processing[1] | Impacts control level[2] | Suitable in information/ environment type |
|---|---|---|---|---|
| Craft-based technology | Minimal | High | 1st / 2nd-order | Equivocal/ volatile |
| Manual operated machines | High | Medium | 1st -order | Uncertain/ dynamic+ |
| Cells and advanced machines | High | Low | 1st -order | (Un)certain/ dynamic- |
| Automated lines and robots | Maximal | Low | 2nd-order | Certain/stable |

[1] Considers the information that is processed on blue-color or machine/operations level.
[2] The control is executed by managers, staff or workers depending on the job specialization.

Note that the technology level for a specific process not necessarily is the same for the entire product realization process. The level is often different depending on if the particular process is placed pre- or post-CODP.

### 6.2.5 Planning and control system

In contrast to the more latent “corporate governance and steering”, which described the principles of how firms’ operative processes should be managed; the “planning and control system” considers the design of the active control mechanisms. These are vital for steering of the organizations’ work flow from both a preparation and execution approach. However, the design of these control systems depends on the firms’ ability to: predict the external environments, translate this information into forecasts, prepare the organization for operation execution, and regulation of the production when necessary. The variations are founded on firms’ ability to store information in the infrastructure and processing it when conducting detailed plans and regulating the operations. It is obvious that when considering the whole control process: from forecasts development, production scheduling, and operation regulation, it involves all the major parts of the organization (see figure 5:4, p. 70) and integrates the three cybernetic orders (see figure 3:2, p. 20).

Four types of areas are identified to construct this element: performance and action based control systems, integration devices and ICT-systems. Scholars have argued that ICT-systems are a kind of integration devices, but the use of explicit information in ICT-systems is very different from other organizational integration devices (see figure 6:14, p. 110). Table 6:9 shows the major differences between the planning and control modes.

Table 6:9 Summary of the different planning and control system modes from an information approach, the major control level, and the main users.

| Organizational control mechanism | Deals with information type | Information storage requirements | Capacity of feedback information | Impacts control mode | Main user |
|---|---|---|---|---|---|
| Performance control system | Equivocal/ uncertain | Low | Low | 1st / 2nd-order | Techno structure/ middle management |
| Action planning systems | Uncertain/ certain | High | High | 1st -order | Techno structure/ middle management |
| Organizational integration devices | Equivocal/ uncertain | Low | Low | 1st -order | All parts |
| ICT-systems | Uncertain/ certain | High | High | 1st / 2nd -order | Techno structure/ middle management |

*Performance-control-systems* (PCS) are concerned with the result of a range of operations or processes in general terms and often in comparison with targets or earlier performance, e.g. budgets or percent improvements. It is about standardization of outputs or setting a target for implementation during a period of time. The result of a number of operations and processes are lumped together and monitored after they have been performed. Thereby, it will be hard to correct the current output if it is not meeting the objectives, because there is no direct link between the objectives and the activities. Instead the PCS impacts the interface between the strategic and tactical control level (2nd-order of cybernetic). Generally it is used when there is little interdependent between units. Instead, each unit is responsible for their own action planning, i.e. the middle-line managers are relatively free to manage and control their own unit. However, in most cases there is a direction on aggregate level rather than detail level determined by the higher-level managers. Draw-backs are the emerging loose couplings between long-term and short-terms goals, which make the integration and synchronization between units hard to achieve. Typical examples of methods within the PCS area are long range planning, aggregate planning, forecasting, budgeting, project planning etc.

*Action-planning-systems* (APS) specify the result of a specific action, e.g. the diameter of holes that should be drilled, before it is taken and when it should be performed – thus, it is mainly about process standardization. The output of each operation can be monitored and compared with its objective, i.e. APS makes plans on tactical levels for control on operational level (1st and 2nd-order cybernetic). If necessary a specific operation's set-up can be adjusted and regulated so that subsequent workload achieves the objectives. APS are often used for planning and controlling specialized units in e.g. process structured organizations. The control mode mainly considers routine activities that have been formalized and standardized; for example scheduling and routing, line balancing, cycle time planning, inventory and resource slack/buffers. The APS requires PCS to make the centralized companywide control mode possible. All of these actions are performed in advance, before the production of the order starts, by the techno structure. Specific objectives and plans are authorized by top managers and middle line managers. The major differences between the PCS and APS are showed in 6:10.

Table 6:10 Major differences between performance and action planning systems.

| Aspect | Performance control systems | Action planning systems |
|---|---|---|
| Purpose | Direct and prepare the organization, answers the question what to achieve for a period of time. | Plan and regulate operations and jobs, answers what, how, where and when to act. |
| Information requirements | Standardized output/objectives | Behavior standardization, formalized actions and performance objectives. |
| Measurement technic | General unit and process objectives for comparison: e.g. plan or budget | Detailed operations metrics and instructions for regulation |
| Feedback | Loosely coupled, i.e. no direct link between goals and operations. | Tightly coupled, every part is defined and interrelated. |
| Information processing level | Managerial and staff level, cybernetic of $2^{nd}$ and $3^{rd}$-order | Staff and management levels, cybernetic of $1^{st}$ and $2^{nd}$-order |
| Appropriate environments | Equivocal and uncertain situations | Uncertain and certain situations |
| Dominates in organization types | Market or output divided organizations | Functionally and product divided organizations |
| Common in production system | Craft-based and industrial-based | Industrial-based |

*Integration devices* and *ICT-systems* are all kinds of methods, tools and IT-systems that increase lateral and vertical communication between different processes and functions of the firm. The device considers both implicit and explicit information and experiences. In most companies information is kept in different parts of the organization, e.g. product and process descriptions, specialists' competences, operations and machines performances. The more individual products the firm can produce, the more integrated the organization must be in order to facilitate the necessary information flow between the parts (Daft, 2009). Integration means in this context communication and collaboration between separated organizational units and individuals in order to align their working efforts. Integration devices mainly consider implicit information that is communicated through e.g. face to face meetings, workshops, group meetings, and specialists' guidance. ICT-systems, on the contrary, mainly store and transfer explicit information between different organization members and units. When IT-systems are used it normally has required comprehensive work from the staff and managerial personnel to process and store the information in the systems. The integration devices are typically used by the employees when necessary to accomplish the work tasks without orders or involvement from managers. Thereby, the integration devices reduce the managerial information processing by decentralized it to the subordinates (see table 6:11 for examples of integration devices).

Table 6:11 Examples of different integrating devices.

| Formalization factor | Description |
|---|---|
| ICT-systems | Channels for communication and systems storing formal and explicit information and data. |
| Multifunctional group meetings | Regular meetings with members from different functions within the organization to consider multiple areas of expertise. |
| Liaison roles/procedures | Supporting roles and specialists that on a regular basis are interacting with other processes/departments. It can also be temporary and problem solving groups consisting of members from different places of the firm. |
| Autonomous groups | Self-regulating groups which are responsible for planning, execution, and controlling the work by themselves. |

A difference between craft-based and industrial production system can be expected: the craft-based production is designed to manage equivocal information, and the industrial production for uncertain and explicit information. This should imply that craft-based production system use more implicit integrating devices on a regular basis than industrial firms. ICT-systems are designed for dealing with explicit and certain information, which should imply that ICT-tools are used in lesser extent on construction sites than in factories (see figure 6:14).

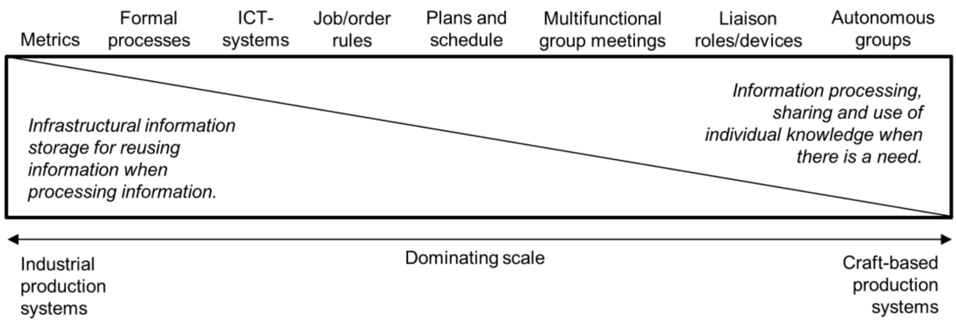


Figure 6:14 Examples of devices that increases the organizational integration both laterally and vertically. Devices to the left will be more common in industrial production systems, than in craft-based production systems, and vice versa.

## 6.3 Theoretical conclusions

In summary, a firm's business strategy determines the prioritization of the competitive factors of product customization degree, production cost and delivery time, which determines the information type (equivocal, uncertain or certain) that the organization must be designed to manage. This severely impacts the organization structure's and the production system's necessary ability to store and process information. These abilities together with the dominating information type affect the appropriate control mechanisms the organization should possess. Every mechanism and device that has been reviewed on the previous pages contributes to the specific needs of information storage, processing or control requirements in a certain way. This implies that a specific business strategy will favor specific organizational configurations.

Interesting to note is that firms dealing with equivocal information, e.g. conventional construction firms, differ significantly from the companies managing uncertain and certain information, e.g. mass customizers and mass producers. The reason is that equivocal market situations make it hard for firms to predict and prepare the organizations both regarding long-term and short-terms market conditions. In a stable or on a dynamic market the situation is certain or uncertain which makes accurate forecast and predictions possible (see table 6:12 for summary).

Table 6:12 Summary of perceived business market situations related to the appropriate information storage and processing degrees, typical production systems and dominating control modes.

| Business situation | Stored information | Information processing | Typical production systems | Dominating control mechanism |
|---|---|---|---|---|
| Volatile/ equivocal | Low | Very high | Craft-based production systems, e.g. typical house contracting | Decentralization and informal modes increases the ability to deal with new challenges. |
| Dynamic/ uncertain | Very high | Medium | Mass Customizers, e.g. flexible industrial house builders | Standardized flexibility improves the ability to respond to predictable and pre-determined changes. |
| Stable/ Certain | High | Low | Mass producers, e.g. many industrial small-house producers | Standardization favors productivity by spreading out the information processing among many products. |

In firms that perceive its market as equivocal very little information can be processed in advanced, stored and reused for producing several product orders. Instead large amount information must be developed for each order, both considering what, how and when to produce. In most cases this is a too comprehensive process for the management and staff levels to accomplish by themselves in each project. Therefore, it is common to decentralize some of the information processing activities to the operative employees in order to increase the efficiency of each order. This requires highly skilled individuals working together in informal and autonomous teams. The result is that the organization becomes more manageable and productive than if similar amount of formal information had been processed as in industrial systems for each product. Nevertheless, it happens on the expense of formalization and detailed feedback of explicit information, which is a key for organizational learning and improvements.

In a firm acting in dynamic and uncertain market the future is relatively predictable even if the specification of the individual customer needs can be postponed until orders arrives. In other words, the firm can use a mass customization strategy and an MTO or ATO-topology. This allows the company to develop, store and process a large amount of information on what and how to produce and configure the products. Therefore, the firm will favor both infrastructural mechanisms for information storage and information processing.

For mass producers with an MSP-topology, i.e. for firms within stable and predictable environments, it is enough to focus on information storage devices. On this basis a high technology level and specialized work force can be used, which require a lot of development and planning work by the techno structure, but often with a minor degree of process change.

### 6.3.1 The four production topologies' organization configurations

The four common production topologies are mapped to appropriate market conditions and how these typically are met by the organizational enablers, i.e. the product configuration strategy, the product structure, and the production system flexibility in table 6:13.

Table 6:13 The characteristics of respectively production topology considering the information aspects and the major organizational enablers.

| Characteristic type | Engineer-to-order (ETO) | Manufacture-to-order (MTO) | Assembly-to-order (ATO) | Make-standard-products (MSP) |
|---|---|---|---|---|
| Perceptions of market environment | Volatile and equivocal | Dynamic and uncertain | Dynamic and uncertain | Stable and relatively certain |
| Customization strategy | ETO | MTO | CTO | SPV |
| Product structure | NPD | PMPS | SMPS | IPS |
| Production system flexibility | Transformable system structure (project) | Flexible at process level (production) | Re-configurable assembly (cell) process level | Setup changeability at operation level |
| Information processing per order | Very high of equivocal type | Medium of uncertain type | Medium of uncertain type | Low of certain type |
| Infrastructural information storage | Low | Very high | Very high | High |
| Cybernetic control level | $2^{nd}$ dominates | $2^{nd}$ and $1^{st}$ dominates | $2^{nd}$ and $1^{st}$ dominates | $1^{st}$ and $2^{nd}$ dominates |

The founding idea for the characteristics of table 6:13 are (see also figure 6:15, p. 113):

- In firms that are acting in volatile/equivocal market (ETO-firms) the dominating organizational control mechanisms facilitate information processing, and the one that supports use of stored information is not prominent.
- Industrial firms acting on dynamic/uncertain market and uses a mass customization strategy (MTO and ATO topologies) must be designed to possess both organization control mechanism that can store and process information.
- Corporations that produce standard products (MSP-topology) are organizational designed to mainly manage stored information on the expense of the information processing abilities.

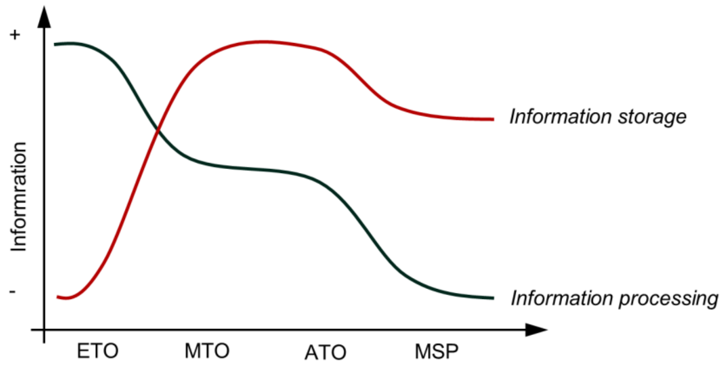


Figure 6:15 Illustration of the founding principles of information storage and information processing per order for each production topology. These different information requirements must be met by the mechanisms that construct the organization structure.

Table 6:14 on the following page summaries and predicts the organization design configuration of respectively production topology, which should be appropriate in order to manage the specific information requirements that appears due to the business strategy. The next chapter describes four case study organizations belonging to one of the production topologies. These are used to empirically test and validate the organization structure predictions in table 6:14.

Table 6:14 Concluding differentiating organizational configurations of the production topologies.

| Mechanism | Engineer-to-order (ETO) | Manufacture-to-order (MTO) | Assembly-to-order (ATO) | Manufacture-standard-products (MSP) |
|---|---|---|---|---|
| Coordination mechanism | Mutual adjustment | Standardization of work | Standardization of work | Standardization of work |
| Authority system | Selective decentralization | Limited horizontal decentralization | Limited horizontal decentralization | Limited horizontal decentralization |
| Decision flow | Organic/adhoc | Bureaucratic standardization | Bureaucratic standardization | Bureaucratic standardization |
| Dominating organization part | All | Techno structure | Techno structure | Techno structure |
| Structuring principle | Product market location | Functional | Functional | Functional |
| System structure flexibility | Transformable system structure | Process structure flexibility | Cell configurability | Operation level |
| Pre-CODP (Production) | - | - | Standardized process lines/cells | Standardized process lines/cells |
| OPP/PC-process | Design | Manufacturing | Assembly | Delivery |
| Post-CODP (Production) | Project/job process, intermittent flow | Flexible production processes/cells | Reconfigurable assembly process/cells. | - |
| Span of control | Wide | Narrow | Narrow | Wide |
| Process formalization | Low | Very high | Very high | High |
| Job specialization | Enlarged job specialization | Horizontal job specialization | Horizontal job specialization | Vertical/Horizontal specialization |
| Training and indoctrination | Education, apprentice program, socialization of norms | Education, socialization of norms | Education, socialization of norms | Socialization of norms |
| General technology level | Craft-based technology | Manual operated machines, cells and advance machines, | Manual operated machines, cells and advance machines, robot lines | Manual operated machines, cells and advance machines, robot lines |
| Performance control systems | High[1] | High[2] | High[2] | High[2] |
| Action planning systems | Low | High | High | High |
| ICT-systems | Low | Very high | Very high | High |
| Integration devices | Very high | High | Medium | Low |

[1] In ETO-systems PCS-tools are commonly used for managing projects on operational level.
[2] Industrial firms use PCS-tools for developing strategic and tactic plans, which are complemented with APS-plans at operational level.

# 7 THE CASE STUDY COMPANIES

*In this chapter the case studies organization are presented. Their differences and similarities are clarified in the light of the major organizational elements described in chapter 6.*

Note that the three construction cases were subsidiaries to major contractor corporations, which implied that these cases could use some resources and corporate wide systems for managing their business. The forth case study, the truck manufacturer, is broader described, because of its functional organization each major process is rather self-managed, but is highly integrated with the other processes. This means that in order to understand how this corporation function all processes must be considered, at least in general terms.

## 7.1 Case A – Peab, the conventional house builder

Peab housing division develops and executes mainly private housing projects for the consumer market. It is a subsidiary to Peab AB, one of the major contractors in Sweden, acting on the real estate development, construction and civil engineering markets. The housing division is a typical conventional entrepreneur and delivers “unique” products in every project. It relies heavily on craft-based production, about 1/3 are office employees and 2/3 craftsmen. In 2011 the firm had approximately 928 employees, had an annual turnover of 3 960 mSEK and developed and produced approximately 2000 apartments per year, 73% of the produced dwellings were sold.

### 7.1.1 The strategy and product realization system characteristics

The vision of the firm is to develop and produce “*homes that lasts”.* This imply that houses should be technical and functional sustainable over time to a reasonable cost. Therefore, the target market is not the premium market segment but the larger middle class segment. These customers want homes close to the cities, but not down town, with developed infrastructure, neighborhoods and often green surroundings. The division was geographical focused on the middle parts of Sweden and divided into four regions. In these regions the market needs were different regarding e.g. the architecture requirements of small and multistory houses. The local market orientation allowed the firm to decentralize the project development decision so new houses could be engineered and realized in every project. Thus, despite that the firm produces the projects on “speculations” the customers do not initiate the product realization process and have limited impact on the product design, every project is perceived as unique to fit the local conditions of the building.

The production organization is highly flexible because each project can be located in different places and generally involved different individuals every time, both regarding its own employees and sub-contractors. Therefore, every project is managed as a *new-product-development* (NPD) project with perceived minor degree of similarities between the other projects. The only way to accomplish this was to use craftsmen supported by appropriate production technology equipment when necessary, see figure 7:1 for examples.


Figure 7:1 Illustrations of the production technology equipment found on constructions sites; typical hand-tools of the craftsmen to left, and advanced machines (excavator) on-site to the right.

A typical housing project consisted of 40 to 70 dwellings and took about three to four years to accomplish from real estate investment, through project development, request for building permission, and production to occupancy. The differences, considering the time, were mainly caused when appealing against the building permissions for the projects, and problems to achieve the corporate requested pre-sell percentage of the prospected projects' dwellings. Therefore, this is interpreted as a volatile and equivocal market.

### 7.1.2 The super structure

The firm's organization was a typical *project-based-organization* (PBO) with a central part, divided into the head office and four local regional offices (see figure 7:2). In the interface between the regional office and the producing projects there were contract managers, which were responsible for development and realization of a portfolio of projects within a sub-domain (specific municipalities) of a region, i.e. the organization was clearly market divided with sub-units for a certain business region.

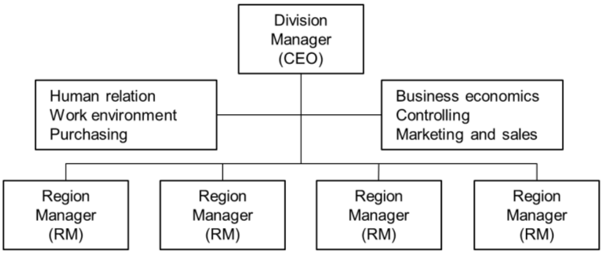


Figure 7:2 The organizational chart of the housing division with central staff functions and the market located regions. Within the regional units the projects were developed and accomplished.

The central and permanent organization included managers, administrative staff and operative staff with special competence who worked with adapting the corporate strategy to housing and the local situation of the regional business. On regional level, the techno structure or operative staff worked mainly with project support necessary for project realization, even if some development work occurred. The human relations manager (HRM) was another important role who coordinated the pool of craftsmen and allocated appropriate numbers of them to each project of the region. This resource allocation process was about scheduling and prioritization of each project within the region. The goal was to optimize the production flow of the entire regional project portfolio based on projects' progress. Figure 7:3 summaries the typical organization of a region.

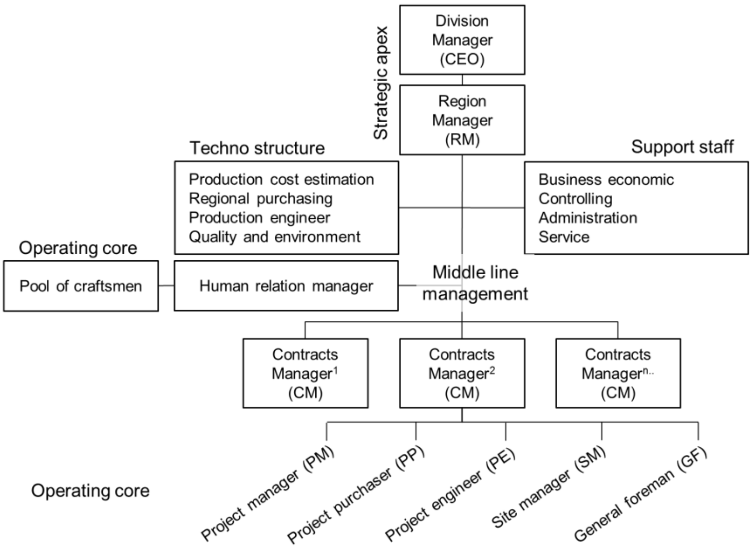


Figure 7:3 Typical regional organization with staff functions and contracts manager units. Note that there were differences among the roles and numbers of roles within the regions and the sub-groups.

The contracts managers (CM) were highly independent and had decentralized authority to organize the employees as they wanted. Most of the interview respondents stated that the CM was a really free role as long as profit was delivered. The more profits they made the more freedom they got sanctioned form the regional manager – a CM said;

> *"We [the CMs] have a very free role. As long as I deliver high performances [projects with high margins] I can do what I want – if I deliver better than expected I got more freedom".*

Each CM headed a group of white-collar workers, engaged in designing, planning and coordination of the projects. Each position within the CM-group has different working areas, usually dedicated to specific project processes (see table 7:1). Further, in general the CM-group had eight projects in progress in their portfolio, and each position worked with different numbers of projects at the same time.

Table 7:1 Description of a typical contracts manager organization and the respectively role's duties.

| Position | Main duties | Project process phases |
|---|---|---|
| Contracts Manager (CM) | Preparation of investment decisions, management of the CM-group, organizing the projects etc. | Pre-concept, preparation of investment decisions |
| Project Manager (PM) | Concept development, design, approval for building permission, advertising and selling | Concept development, design, marketing and selling |
| Project Engineer (PE) | Production control management, production planning, quality inspection | Production on-site |
| Project Purchaser (PP) | Project specific purchasing, delivery planning | Purchase, product cost, planning |
| Site Manager (SM) | Production management on-site | Production on-site |
| General Foreman (GF) | Production supervision, quality inspections | Production on-site |

On the construction site each project had its own organization; there the site manager (SM) was responsible for the on-site building activities and the operative personnel, both CM-staff and craftsmen. The craftsmen were, thereby, matrix organized to the site of each project, but formally belonged to a centrally pool of craftsmen (see figure 7:3). In similar manner the CM-group's PE and GF was dedicated to a project by the CM and supervised on-site by the SM.

### 7.1.3 Corporate governance and formalization

The case company had a general business system that follows the guidelines of the ISO-standard, but the process descriptions are wide in comparison to the industrial cases. The processes are also almost entirely focused on how to produce one single project, independent and intermittent from other projects. Further, most of the routines were also optional which confirms the extensive decentralization of authority to project level.

What further indicates the low formality of the firm is that, except for the financial liability, the exact content of the CM position was not very well articulated. Instead the role of the CM was based on traditions of the trade, rather than on formal job descriptions stipulated by the company. As one of the interviewed CM expressed it:

> *"The roles are not so explicit… but, roughly I know how the other [contract managers] works, and I continue on the same track. Somehow you know what you are responsible for, and then it is up to you to ensure it happens – but it can be done in different ways".*

The vague and optional routines and the CM's authority to organize their units as they wanted based on the current situation favor mutual adjustment and verbal communication within the group. This has led to very different ways of organizing the units and how they were working. For example one CM-group had developed his group by focusing a lot on marketing and selling, another had focused as long as possible on using prefabricated wall modules. The work structure within the groups also varied from project to project. A consequence of this was that the employees were saying that they knew what they were responsible for in the particular project, but they didn't know what their colleges were working with. Thus, these white-collar workers had very enlarged jobs, which indicate broad but not specialized skills.

Interesting to note is that within Peab the position at middle management and staff levels were not possessed by employees with academic degree in the same extent as the competitors and the other case study companies. Instead the firm promoted employees which comprehensive experiences from different positions, especially from the operative line. For example, surprisingly many middle managers, project portfolio managers, have started as a craftsman or a foreman and then climbed up the hierarchical ladder.

### 7.1.4 The project – an order in the extremely flexible production system

A housing project starts when information about an estate for sale is captured by one of the employees in the CM-group. The CM assigns one of his PMs, for the working out the pre-trial of what kind of dwellings and architectural ideas suitable for that specific location, often supported by an external architect. The production costs were estimated, the earnings forecasted and project risks were evaluated. When the resulting prospect was ready the RM or CM requested for a meeting with the "investment group" who made the decisions regarding the investment of the real estate.

Every housing project must pass through investment group at corporate level for a financial risk analyze and formal approval for continuation. The group consisted of people from the top management level above the housing division (Peab AB), e.g. corporate financial manager, corporate controller and division manager. Two major gate-decisions which were executed; the first one was about whether the division should investment in the real estate, and the second about the approval of start of the production on-site.

After approval of investment in the real estate, the CM often let the dedicated PM to continue the project development. Supported by architects the PM developed the project idea and the detailed design of the project. In most cases, staff (techno structure) services at regional (see figure 7:3, p. 117), was called off for e.g. production cost estimation and project purchasing preparation. The CM-groups' purchaser was working out project specific purchasing plans together with the regional purchaser. Annual contracts were reviewed and new suppliers were contracted. Therefore, building materials could not be stored between the projects; instead most projects have some degree of inventory on-site. The PM, often together with the CM, developed the plan and the design of the estate in discussion with the municipality. When project plans and design was completed they requested for building permission, which was approved by the municipality. Both the architecture and the building placement at the estate must fit the special conditions of location (see figure 7:4, p. 121).

Based on the approved project design and documents the resource needs, production time schedule, bills of quantities, and current prices of the materials and suggested subcontractors were decided. In most cases it was the PM who controlled the project specific data, but it was monitored and approved by the CM. The SM was encourage to detail the production plans including on-site layout, the need of machines and craftsmen per week etc., supported and controlled by PM or CM. However, despite that each project design and its production site design were perceived as highly dependent no special methods or routines for design the production layout on-site existed. The only recommendations how to think about on-site layouts and material flows were aspects to consider, e.g. the placement of site-office cabins, goods storage in consideration to the work place and placement of tower-cranes. Although that the fixed position layout force the production layout to be dynamic, i.e. it changes in accordance with the production progress, this was not a major matter of concern. Instead the company trusted the PM or the site-manager to manage this based on their own experiences.
Figure 7:4 shows a construction site there big trees must be preserved, which severely impacts the building design and production site-layout.


Figure 7:4 An example of a production site there the layout emerged in accordance with the project's location and work conditions.

During these early phases of the project the PM also develops marketing and sales materials, and starts the selling process of the dwellings. The second decision meeting with investment group was requested, and the CM or PM prepared the basis for the decision documents. To get the permission to start the production on-site, the internal regulation required 60% presales of the dwellings, approved building permission and required profits and risk taking. In this forced formal routines you can read;

> *"Every project must be preceded by an investment request. Decisions regarding project investment are executed at investment meetings by a corporate management group of Peab… The investment team, which are delegated the decision mandate from the corporate executive group and the CEO, makes the decision on project investments matters… In the investment team the following project investment matters are managed; decision regarding investment of real estates, and decision regarding permission to start production on-site".*

The authority system is of selective decentralization art, in the sense that different areas of decision are decentralized to different roles depending on the CM-group. The decision flow is organic for each project, i.e. the work to develop decision preparations are conducted by different individuals with different competences for each project. Which these persons are depends on the project's conditions, informal "gate-keepers" and the personal relations. Further, coordination was often verbal communicated which increase arguments for the organic and mutual adjustment steering mechanisms. Thereby, production organization structure becomes highly flexible, with the ability to combine different persons from several places in the firm and organize them in project specific configurations. Further, no specific organizational part is continuously dominating how the work by others is accomplished. Figure 7:5 illustrates how the projects are accomplished in an extremely flexible production system and that the decision flow is highly organic often influenced by many different roles from project to project.

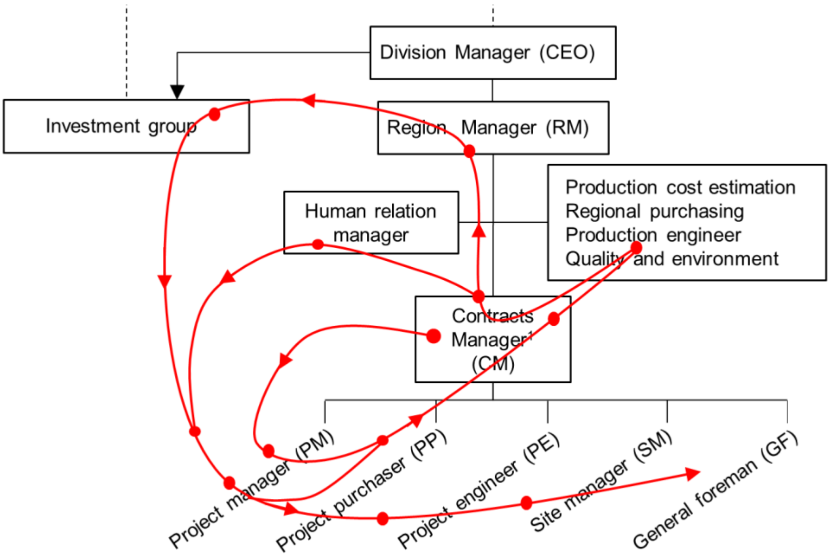


Figure 7:5 Illustration of the iterative single project decision flow. Note that same person/roles could contribute to the information flow in different ways depending on the each project's condition. The dots indicate an activity in the decision flow.

### 7.1.5 The production site steering

The site manager was responsible for the management, coordination and controlling the operations and the personal on-site. This included monitoring and controlling the production progress in accordance with the project schedule and budget. Regulation was accomplished through meetings and verbal communications of both craftsmen and subcontractor. Most of the material supplies were planned and accomplished for the specific project, thereby the total number of the suppliers the firm used was very high, and the contracts were generally only valid for a specific project. This implies that new collaboration partners and new communication routines needs to be accomplished for each project.

On-site, the main operative supports were the project engineer (PE) and the general foreman (GF), there the PE usually worked with the production cost control and scheduling. The GF was usually working on the field with quality engineering, coordinating craftsmen, and site-logistics. But their duties often varied between the projects. Traditionally the craftsmen were conducting the enlarged job in autonomous work-groups, it was mostly the overall output performance features that were controlled. For example, progress of work per room or apartment, moisture content in the walls when construction had been accomplished in rain. The overall control of the project progress was in most cases monitored by the CM through telephone or face-to-face meetings. However, when problem was serious, e.g. when workplace accident or contracts issue with suppliers or subcontractors emerged, the CM was informed immediately.

During the production stage the dwellings were customized, which mean the customer could choose e.g. the color or the wallpapers, floor types, and the white goods from a pre-specified list. This work was in most cases done by the PM and administrated by the PE, the site manager, or by a sales person in some CM-groups. When the house contract is signed and the payment completed the customer can move in to their new home.

### 7.1.6 The planning and control mechanisms

As indicated earlier, the case study company favored performance control mechanisms and only in minor degree used action based control systems. For example, the corporate and division strategy and the long range plan identified the financial objectives, market directions and the volume of housing needs. These were used to procure real estates in appropriate locations and to develop the employees' competences. The goal was to prepare the production system for future demands. The division directed its regions through business plans with individual objectives and focus areas for each region. However, most of the CMs indicated that these plans have no influence on how the projects were accomplished. They said the business plan included too superficial goals; e.g. profit per project, number of projects, number of dwellings, number of projects in different phases etc. On the other hand, the projects become affected by the strategy through the general financial goals and its direction on which location of real estates that were interesting to invest in. Remember that each project was analyzed and approved by the investment group based these on factors among others.

The operational planning and control mechanism, on regional and project level, were a mix of performance and action planning, e.g. the Gant-based scheduling methods for the regions' resource allocation plans and the individual project schedules. These plans specify what resources to use under a specific time period; thus, the behavior of the resources to accomplish the goals are not considered.

The resource allocation was accomplished during the regional management meetings and involved the regional, the RM, HRM and CMs. Before the meetings all the CMs' analyzed the current status of their projects and forecasted the need for craftsmen three years ahead. They reported this to the HRM who presented a project resource allocation schedule for the entire region during the regional meetings. Project assignments of the centrally placed specialists were also planned during the region meetings. This procedure makes the schedule very complete for the forthcoming six month – but quite reactive. Delays of both production starts and production end-dates, and the need for more resources or for a longer period in on-going projects were quite normal. Therefore, it was rather common for projects keeping craftsmen longer than necessary, especially the high performers, to utilize them in forthcoming projects in the CM-group. In the end it created a competitive culture between the projects, due to that the projects were competing for the same resources.

When planning each project a central database with records of standard times for all production activities (craft level) and what the different types of material costs based on annual contracts. The information considering the operations time within this database was purchased from an external company and used by all regions and divisions in the corporation. The material costs were updated with the prices from the firm's annual contracts and project specific procurement. This resulted in overall production time schedule, resource needs, bills of quantities, and current prices of the materials and suggested subcontractors for the specific project.

### 7.1.7 ICT-systems and integration devices

The firm Peab is using ICT-systems for most levels and roles, except for craft work on-site. Many of the ICT-systems were, however, not integrated and could not be easily used by all project participants. In fact, the information regarding product design, bill of material, product cost structure, and production plans could not be interchanged interactively. Instead telephone and e-mail is often used to transfer information.

The firm is clearly structured for developing new projects, i.e. development of new information, and the coordination and of the organization members' individual experiences. Therefore, the information processing is accomplish through knowledge sharing based on verbal communication supported by liaison roles, multifunctional meeting, organic and temporary groups etc., steered by a few formal rules. For example, the resource allocation meetings at regional levels can be classified as a multifunction group for collaboration and mutual adjustments of the resource allocation plan. The operative staff specialist roles placed within at regional level performing tasks for every project is a typical example of liaison functions. Further, the CM-groups in principle worked as self-governing teams, which configured their project organizations informally. In a similar manner the craftsmen acted in autonomous work groups.

## 7.2 Case B – NCC Komponent, the flexible industrial house producer

NCC Construction Sweden is one of the major contractors in Sweden, and develops and produces real estates, properties and other civil engineering projects. During the years 2002 to 2008 the corporation did extensive investments in industrialized housing and developed a division for industrialized housing. The main objective was to strengthen the business for the other conventional contractor divisions by supplying them with houses with higher quality produced to lower costs than conventional housing could achieve. However, even external clients within the private and rental market were targeted. The industrial housing division was divided in two departments: NCC Komponent and Small houses. NCC Komponent is the case study B and the product concept *Det-ljuva-livet* (DLL) managed by the small house department is the forthcoming case study C.

***NCC Komponent AB***

NCC Komponent was an industrial housing company which produced extremely configurable products in a highly industrialized factory. The products become realized in a developed mobile assemble process at the location where the product was going to be used. On-site, craftsmen where used only to produce the foundation of the building, the rest of the house was assembled with white gloves dressed assemblers supported by specialized tools and machines. During the empirical investigation period the company was under development and it was never finalized; the firm was started 2003 and terminated 2008. In the end of November 2007, when the decision to discontinue the endeavor was presented, there were 220 employees; 119 office workers, 101 laborers, and an additional 100 external consultants and labors from rental agencies were also involved. The objective of the development project was to design an organization and factory for the production of 1000 dwellings per year. Just before the termination decision the production rate was 600 dwellings per year, in accordance with the original development plan. On April the second 2008 the last module was assembled in the Beckomberga-project. During these five years the company produced 15,804 modules, assembled to 304 dwellings into 17 houses in eight business projects. The project was terminated due to the expected cost reduction was not assumed to be achieved without further investments.

### 7.2.1 The strategy and product realization system characteristics

The firm turned towards the entire Swedish market of private, rental and social housing. Therefore, the product offer was designed to meet most requirements that could be identified within the market for multistory houses of three to eight floors. The market requirements were perceived as dynamic and uncertain, why one of the top managers explained;

> *"The goal is to develop a product model with as much product flexibility as possible, closely to the conventional housing and to meet as many clients as possible".*

This required an extreme flexible product model that could be configured for each client's specific needs and the local condition of the estate. At the same time, the flexibility had to be balanced with the ability to produce these product variances to lower prices than conventional construction in order to sell the necessary product volumes. Therefore, the building system was developed as a standardized product structure based on generic and parametrical modules. This implied that the geometrical forms of most module types could change within certain interval and limits. For example, the modules of walls, floor joists and ceilings were configurable on millimeter level: hence, the firm used a product configuration strategy of *modify-to-order* (MTO) type.

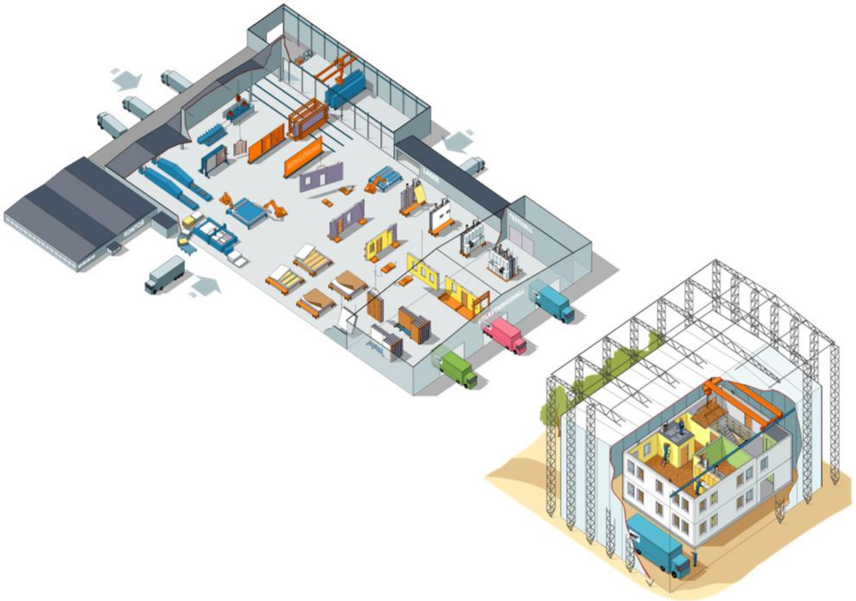

Figure 7:6 Illustration over the production system layout with the stationary factory and mobile assembly halls. In the late 2007 there were eight mobile assembly halls.

In order to be able to realize these numerous variances of modules for each product order efficiently, the production system was industrial and highly flexible. This indicated that the production topology was of *manufacture-to-order* (MTO) type, i.e. nothing was produced until the product order was configured and contracted; or as the product development manager said;

> *"Each house is defined in every detail level and we know exactly what the building system consists of. There is no need for any craft-based ad hoc solutions on-site, due to that the reality didn't corresponded with the architect blue-*prints. *The client always got exactly what the specification describes".*

Further, the factory could also produce modules for eight houses concurrently – the numbers of mobile assembly halls were in autumn 2007 the bottle neck. Note, the final assembly had to be accomplished at the location there the house is used, why the firm developed mobile assembly halls very similar to factory assembly units. In conclusion the production system was highly flexible on process level. Figure 7:6 on p.126 illustrates how firms overall production layout, with the stationary factory and the mobile assembly halls.

### 7.2.2 Super structure and corporate governance

The firm was, as expected, organized based on the functional principles; each major process had its own dedicated and specialized organizational unit. The following functions could be identified; top management including supporting and administrative staff, market and project development, product development, purchasing, production with logistics, factory manufacturing and on-site assembly units (see figure 7:7 for summary).

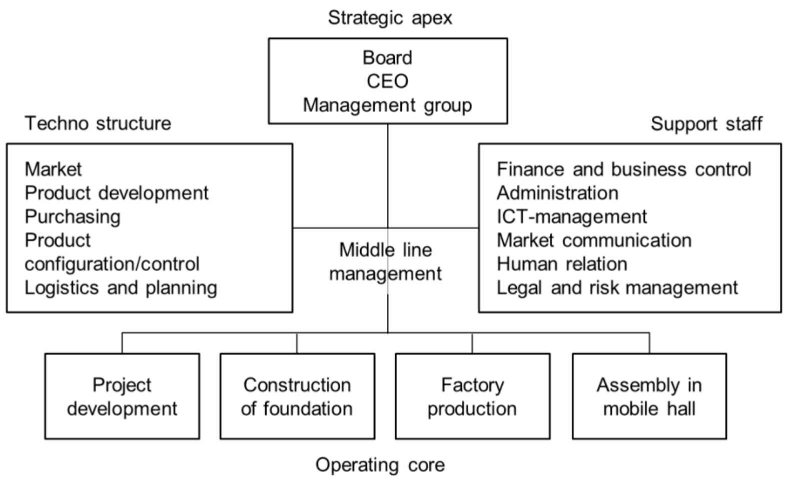


Figure 7:7 The major organization parts (departments and processes) of the case study firm.

Even if the firm was under development the roles and processes of each unit become more and more formalized. In beginning the management roles were possessed by the people from the construction sector and the processes was developed based on their experiences. After a while they realized that different competences were needed, due to that similar roles in construction and manufacturing is very different. The production manager which earlier had been a production manager at an automotive company, explained;

> *"In an industrial organization, purchase work more with supplier development and control than in the traditional construction… that is something our purchasers have experienced. It is also a big difference between engineering in the construction and the automotive sector. I think it is because within construction, there are craftsmen who are trained to find the solutions on-site... it will not work on an assembly line. In our production process there must be an exact instruction and a drawing on how to perform each operation. There's no time [for an assembler] to call the designing engineer and ask how it should be done. Although it only takes a couple of minutes, it could have enormous consequences [i.e. disturbances] of production flow".*

NCC Komponent relied on the principles of industrial production why the coordination mechanism was the standardization of work. The authority system was clearly a limited horizontal decentralization, there the market and project development unit forecasted the production volumes on an annual basis, prioritized the forthcoming project orders in the project portfolio ready for production. Further, the product development department designed the product in collaboration with the production system developers, which severely impacted the operative laborers' working situation. Even if the workers were encouraged to give improvement suggestions, it was always the specialists that were developing and implementing the improvements solutions; hence, the techno structure was the dominating organization part.

### 7.2.3 The product configuration process

Each project order was customized and specific according to the clients. The configuration process started when one of project coordinators at NCC Komponent together with the client and his architect investigated the proposed real estate and the project ideas. Thereafter, the architect used a special CAD-solution, provided by NCC Komponent, which allowed him to draw the house. The rules of the program moved the drawn lines automatically to the closest allowed place. When the house was drawn and specified, controlled by the NCC and approved by the client the configuration process was finished.

This product configuration model required a lot of information processing for realizing the product, both regarding controlling the modules and specifying the production instructions.

The company was implementing and integrating the product configurator software with the PDM and ERP-systems. These systems included information about the building system, the production system and these should be steered and configured to generate the customized building. Further, the ICT-systems allowed that every part, module, component and material had a generic ID-number. After the configuration process every component and module that was used within a project had a project specific ID-number, which significantly increased production plan and control process.

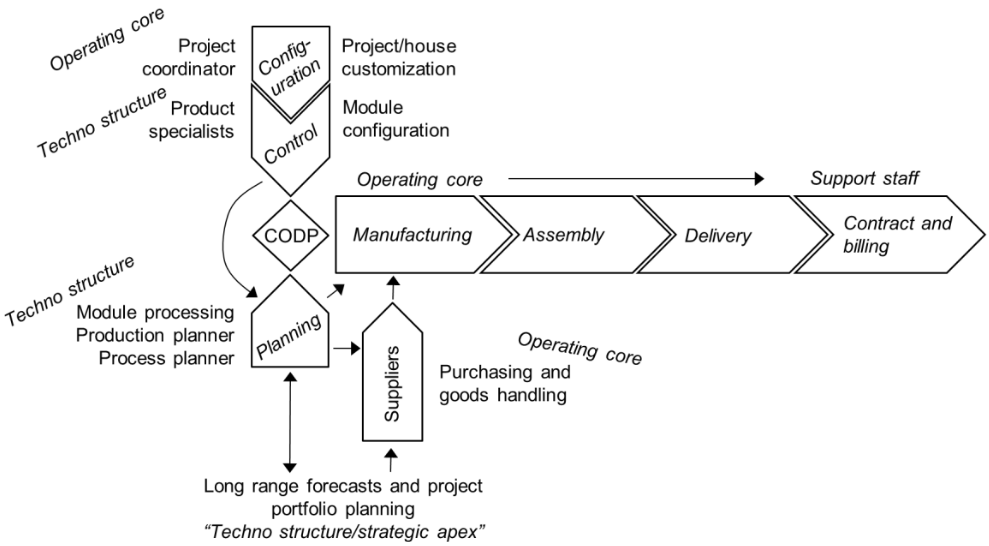


Figure 7:8 The product configuration process and its initiation of production management. Note that the major process step is related to a function and major parts of the organization. It is obvious that the techno structure dominates the managerial steering.

When a project was contracted and all the modules were specified the production plan process started by the logistic and production plan units. The optimal assembly order on-site, directed the transport plan and the production schedule, because of every module was geometrically unique for each floor. Each specified module also got an individual process plan, including instruction of geometrics and machining; the photographs in figure 7:9 (p. 130) shows modules with different features and their specific assembly sequences.

The operators then produced the modules; the modules were transported to the site where a team of operators performed the final assembly. The production of the foundation was accomplished by special trained groups within the NCC Construction contractor divisions. The process to realize a project was standardized and every function and position was specialized to conduct a piece of that process in same way for each order; therefore, the decision flows was naturally bureaucratic standardized.

Figure 7:9 Two different assembly lines within the factory that illustrates how each module can have different content and features. To the right the manual work to assemble the kitchen model is showed.

### 7.2.4 The production system

The production system of the firm consisted of a factory in Hallstahammar and eight mobile assembly halls. The factory flow was flexible both in terms of handling different production volumes, interchangeable components in some of the module types, and the geometrical variations of the modules. This implied that the production could only start, or even be planned after that the product order was contracted; or as a process planner expressed it;

> *"We don't produce anything, neither components nor modules, on forecasts – everything is produced in exact numbers for each project order".*

The process was equipped with robots, machines, fixtures, and other supporting tools. Every operating task was directed by accurate instructions, which also was a prerequisite though each task needed a change of the operation settings. Each module's process steps were about the same, but some operations could be added or removed depending on the modules content. For example, some walls included windows, doors, electric components etc., in others these were not built-in (see figure 7:9). The production process was thereby flexible at process and cell level. The photographs in figure 7:10 (p. 131) show how the different technology solutions were used within the factory.

The finished modules were transported to the mobile assembly halls on special developed trailers. The mobile assembly halls were established there the final product will be located. The foundation of the building had been built before the assembly hall was established.

Each project required an assembly hall for finalization of the houses; therefore the number of halls regulated the total production system delivery flexibility. Prepared with overhead cranes, fixtures and support tools the assemblies of the modules were efficient – note that the largest wall modules were eight meters long and weight eight ton. The final assembly process was accomplished in a standardized way, it was only the sizes of the modules that were changing, and operation was supported by assembly instructions.

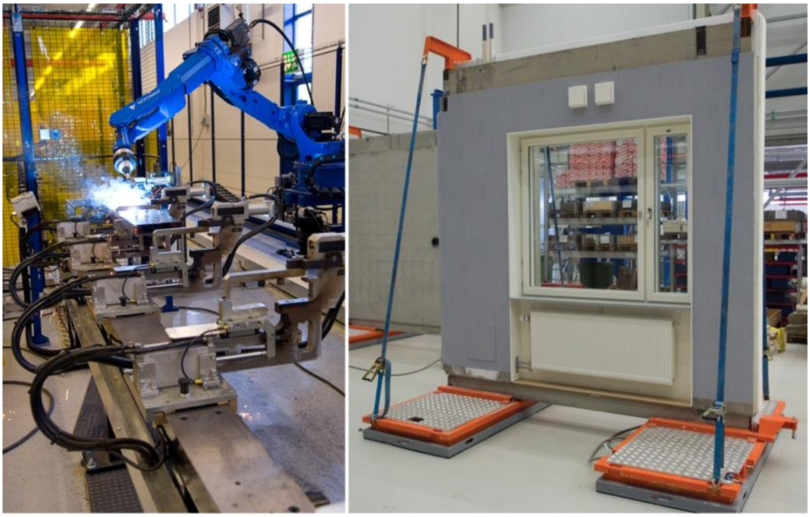

Figure 7:10 Examples of different production technology used within the factory; from robots to air-bags for manually move the up to eight ton heavy wall modules in the factory.

### 7.2.5 Production processes and tasks

The high technology level requires comprehensive process formalization on a deeply detailed level. Further, the product mix and concurrently production of modules to different projects induced extensive process planning, regarding the overall production system work load and the specific order operations. For the case study company, this information was stored in PDM, ERP and MSP-systems, ready for use during the configuration and planning of every order. This called for deep explicitly knowledge about the production process and the standardized operations, which further allowed the production unit to use visual steering boards and other lean-tools. More, for each assembly hall there was a dedicated container with equipment, tools and materials that was used during work. The contents amount were standardized and filled when necessary and always after a project was finalized.

The job specialization was horizontal; meaning even if some tasks were quite specialized, but job rotation made the work horizontally specialized. For example, the final assemble of the houses were conducted by rather autonomous teams, consisting on four assemblers and one manager. These groups were mixing factory work with assemble hall work iteratively. Interesting to note is that the workforce was not craftsmen, but industrial blue collar workers, many with earlier experiences from the manufacturing industry. Thereby they were working in accordance with industrial norms, even though corporate specific norms were under evolution. Figure 7:11 shows the manually assembly process “on-site”.

Figure 7:11 Final assembly process within the mobile assembly hall to left, and the half-way finished floor to the right. Note that the assemblers are working white gloves “*on-site*”.

On managerial and staff level the dominating experience background were construction and university except for the production unit, there most employees had industrial background. In the production unit most managers and specialists had university degree and the laborer high school education. Naturally, this affected the firm’s culture. The company had the ambition to reduce the influence of traditional construction values, e.g. project unique solutions, but this work was probably hampered by the fact that many top managers had long experiences from this sector. On the other hand, the transition had begun but was not completed or pervasive as one employee expressed it;

> *”it is very easy to let go of the industrial mindset when the external environment press and emphasis the traditional way of thinking”.*

### 7.2.6 The plan and control mechanisms

NCC Komponent’s performance based system was not completed, during the case study period regarding e.g. budgets and explicitly determined improvements goals for the running business. However, the development of the firm had clear objectives which directed the designing work e.g. the targeted production volume of 1000 apartments per year, and reduce the project time with 50% in comparison to conventional housing. Other objectives were, reducing the time on the construction site with 75%, and reduce the production cost with at least with 30% in comparison to conventional housing. Further, the development work was coordinated by a project schedule of Gant-type. In this every major work-package, or sub-project, necessary for completing the development of the organization and production system was placed and time framed.

When the firm entered the business phase and started to deliver real project to clients the action planning system was almost finished. There were enough operation data systemized in such way that the product could be customized and the production system re-configured for making forecasts, prioritizing project in the order portfolio, and schedule the delivery of product at specific time. Forecasts was mainly performed by the market function and determined by the LGM (top management group meetings). The priority of projects and information regarding project start decisions was prepared by the project coordinators but discussed and executed by the LGM during special meetings.

The major long-range plan included project prospects and contracted projects with a time frame of years was in place. It showed resource need for the different phases per month, start and delivery dates. This was complemented with specific project schedules, factory plans because the factory produced modules to different projects at the same time, and assembly plans due to that there were limited numbers of assembly halls. It was based on the forecasts so that the total production system balancing could be accomplished, but it was a complicated duty. The scheduling principle was based on the assembly order of each project; it regulated the manufacturing order of the individual modules.

In production the assembly hall called off modules in the correct order, which make the entire process pull-driven with a JIT orientation. Visual boards for showing e.g. tact times could be seen in the factory, and kanban-cards were used for regulation of the material flow within the factory and with the suppliers. This required that all necessary data, e.g. operations resource and time consumptions, was placed within the ICT-system to accomplish the planning on minute level and realizing the products. Interesting to note is that when the necessary information was in place or structured problems emerged, due to the development phase. A process planner said;

> *“The deliveries with standard modules and components from us and our suppliers are controlled by the kanban-cards – those we manage well. New modules, on the other hand, we don’t have the same control over, and these are often causing disturbances”.*

### 7.2.7 ICT-systems and integration devices

As indicated these *production planning and control systems* were, however, only possible to use because of the standardized production system and use of the integrated ICT-systems. Information about e.g. the product structure model, the configuration process, production process and operations, order specific production plans, have to be integrated. Figure 7:12 shows an example of how IT-tools were necessary to steer the machines on the production floor. In fact, all the functions and roles could not have contributed to the product realization if the information was not reachable, stored and presented in such a way that the employees had problems to use it.

Figure 7:12 ICT-tools were used on the operational level. In many cases it was necessary for re-configure the advanced machines' set-up for each module.

Therefore, the firm had created many multifunctional group and meetings to develop and maintain the necessary information interaction structure. In the factory there were also production specialists, improvement meetings for the operational personnel and other lean influenced tools which increased the interaction vertically and laterally. In overall the firm was highly integrated and used many of the suggested devices in theory. The most important and formalized cross sectional coordinating meetings is described in table 7:2.

Table 7:2 The cross sectional meetings for transfer of information.

| Meeting/group | Description |
|---|---|
| Top management (LGM) | Manager meetings considering strategy, organizational and human resources matters. |
| Project decision meetings (PBM) | Meetings for prioritization of projects within the order portfolio and determination of project starts. |
| Delivery plan meetings (LPM) | Meetings for securing the planning and delivery process of project orders. |
| Development coordination meetings (UKM) | The UKM was meetings for securing the quality and efficiency regarding the product and process improvements. |
| Production development group (PUG) | Sub-groups for productivity and product quality improvements of each line within production. |
| Product structure meeting (PRM) | These meeting considered the product structure and the product configuration possibilities offered to the market. |
| Project change group (PRG) | The PRG controlled the changes in the progressing projects. |

## 7.3 Case C – DLL, the standardized industrial housing endeavor

As mentioned in the former section, NCC Komponent formed together with a department for industrialized produced small houses the division of industrial housing within the major contractor NCC. The small house department was fundamentally different from NCC Komponent because it had no production resources, but worked in close relationships with external prefabricators. The formal mission was to develop, improve, administer, and coordinate the industrial projects/orders i.e. be the decoupling player between the in-house client and prefabricator. The product concepts were strictly regulated by contracts, e.g. the ownership, financially and how to improve and manage the long term business collaboration and accomplish projects. During the case study the department had one running product concept, the *Det-ljuva-livet* (DLL), with one supplier and another under development with a different prefabricator. Case study C considers DLL which were a very standardized product concept offered to the rental and private housing market through the conventional division of NCC; thus, the product was realized in some kind of business network.

### 7.3.1 The strategy and product realization system characteristic

The formal mission of the *Small-house-department* (SHD) was to develop, improve, and administer industrial product concept, and coordinate these projects/orders, i.e. be the decoupling player between the in-house client and prefabricator. The product concept DLL was developed for, as one of the project coordinator said; "*so that the tenants should have afford both a high quality home and enjoy the private life*". In order to accomplish this, the product was designed as a standardized product without any customization possibilities for standardized and efficiency factory based production (see figure 7:13, p. 136).

The origin of the product concept DLL was a competition arranged by the *Swedish-association-of-public-housing-companies* (SABO), which followed the *public-procurement-act* (LOU). NCC together with the prefabricator Finndomo developed a product concept in accordance with the specifications and participated and won in competition of 20 different challengers. The prize was that all the public housing companies could refer to this competition as an already performed LOU-act the forthcoming five years when buying the product concept. The gain for the clients was they did not need to perform the time and resource consuming LOU-process. Based on this term, the product concept owners interpreted this as a relatively stable and certain market segment, especially if the product could be used for private housing as well. The estimated production volume was 400 dwellings per year, which seemed to be a profitable volume for all parties and a strategic collaboration was formed. Before the collaboration organization is described the product strategy follows.

Figure 7:13 Two different projects which clearly shows how standardized the product concept was, the major different was the color of the façade.

The product concept was very standardized, and was not allowed to change if the public housing company was going to be able to refer to the SABO-competition. So, when the client initiated a project with DLL, the numbers of apartments were determined and their sizes. The client could choose between three sizes; two, three, or four bedroom apartment, the facades material (plastering or wood panel) and the color, and roof type; mono or double pitch roof. Despite these possible choices the product structure is interpreted as of *select-product-variant* (SPV) based on *integral-product-structures* (IPS), because in conventional construction this is an extreme standardization for professional clients. The organization of the network was dedicated to realize only one product type, i.e. its production topology should be denoted *make-standard-products* (MSP). The prefabricator's factory was, however, flexible enough to switch from the DLL concept to the producers own products and also used the same assembly sub-contractors for final assembly of the DLL-products. But, there is an explanation of this extreme production flexibility capacity on *operational level*, which not directly corresponds to the typical industrial production solutions.

### 7.3.2 Super structure and project development

The organization for realize DLL was a network consisting of two central and permanent parts and two project depended (temporary) parts (see figure 7:14).

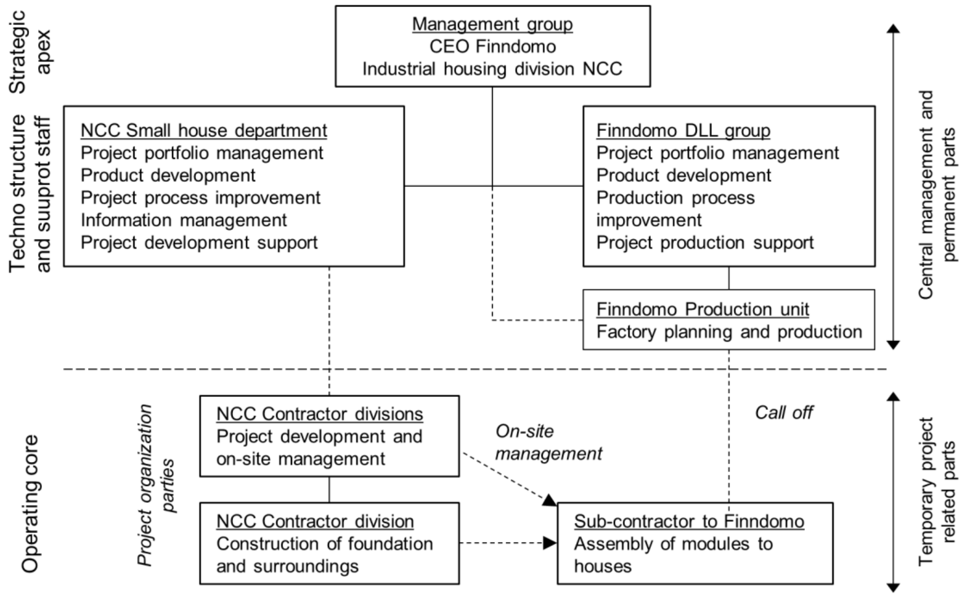


Figure 7:14 DLL's network organization with central and permanent management units and temporary project dependent work organizations.

The permanent parts were; NCC's SHD which worked with development and project portfolio management, and Finndomo, which worked with development and factory production. Each project was initiated by different project managers within NCC's conventional contractor divisions with experience of the local market conditions. The project manager was responsible for customer/client relations and for conducting the foundation of the building. Finndomo was responsible for the assembly of the building modules, but had different sub-contractors of doing this depending on where the projects were located. This network organization is interpreted as a mix of functional and market divided organization. Each function is responsible for a specific process, and the process structure is standardized to operations level; but, the structure is flexible enough to allow different temporary parties to conduct necessary sub-process depending on where the project is located.

The central and permanent organization of the network had developed and formalized the entire product offer and the project realization process. One duty of SHD's project coordinator (PC) was to guide the project managers through this standardized decision flow for it to become effective. So, when the NCC's project manager (PM) contacted SHD, the PC supported the PM through the project development phases and explains the differences in comparison to conventional projects. A project manager at NCC said;

> *"An advantage with DLL projects is that it becomes much less work for me (in comparison with conventional housing) due to the fact that almost everything already is developed and determined on forehand. Every instruction, process and blue print that we use in the projects is already developed and standardized".*

Some of the conventional construction process duties remained e.g. apply for building permission at the municipality and if necessary clarify the process with the client. In case when the private housing projects were accomplished the project passed through similar investment decision processes as the contractor in case study A. During the same time as the building permission was applied Finndomo's production planner was contacted in order to discuss and book production time in the factory. The production planner planned the order and determined when the project could be produced. Finndomo also prepared and called off the craft team for assembly houses when the time came. In figure 7:15 the project decision flow is illustrated.

Thereby, the network clearly had the techno structure as a dominating organizational part and authority system of limited horizontal decentralization type. As expected the decision flow was bureaucratic standardized, meaning all documents and the decision route was prepared, or as project manager at NCC asserted;

> *"The advantage is that the concept is designed and projected once, which mean that you don't need to invent the wheel again, you are supposed to reuse the building blueprints and process instructions in forthcoming projects".*

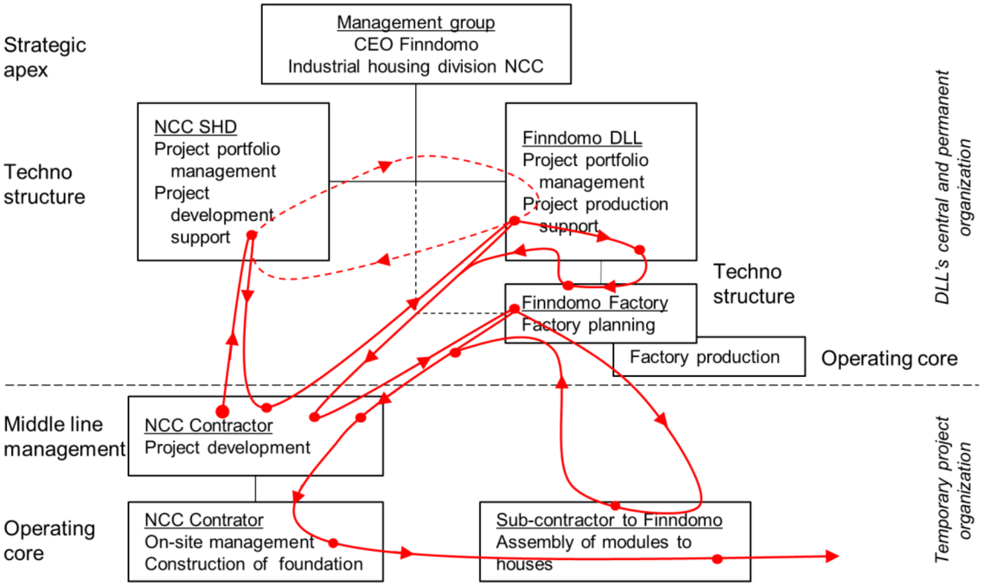


Figure 7:15 The project information and decision flow in the network of DLL.

Interesting to note is that the coordinating mechanism was a mix of both standardization of work and mutual adjustment. The reason is that the different parties belonged to different production paradigms; permanent parties belonged to the industrial production paradigm and the temporary participators to the craft-based production paradigm. A consequence was that the formal instructions on how to design, plan and manage the projects were not at an appropriate detail level.

For example, many project managers tried to change the product concept in accordance with the conventional way and got upset when they could not get the modules at the moment they wanted or be changed when the order was planned. They had hard time to understand that their projects were placed within a factory production scheduling, among many other orders, which not could be changed repeatable. Another project manager called Finndomo and asked for the documentation considering the whole product. In conventional construction projects he wanted every document that was possible. He did not know that in industrial processes everything is much more detailed and that even the production operations are also described. Finndomo answered that of course he get all the blue prints and documents, but it was many more than he was used to. The project development manager insisted and got every document, he said; *"..it was thousands, I will never ask for all of them again!"*. Despite this, the manager of SHD said;

*"if we had not documented the process, the other [NCC people outside permanent organization of the DLL-network] wouldn't know what to do and how the project management process is different from conventional projects".*

### 7.3.3 Production processes and tasks

Despite that DLL was an industrialized product concept produced in a factory environment the process formalization the process formalization was not as detailed as the other industrial cases (see case study B and D). The reason for this could be that the factory workforce did not consisted of industrial workers, but conventional construction craftsmen who belonged to different guilds, e.g. carpenters, painters, and plumbers. The instructions for the job tasks were rather wide, even if these were more detailed than in conventional construction. The job specialization degree was also of enlarged type, which was not expected for an industrial production of a standardized product. On the other hand, by using craftsmen Finndomo increased its flexibility on operational level – the highly skilled craftsmen could solve most of the tasks with minor of instructions. Figure 7:16 illustrates how craftsmen work in the factory.

Figure 7:16 Craftsmen are conducting the operations in the Finndomo's factory.

The technology level in the factory was more advanced and structured than conventional construction sites. The work was supported by jigs and other equipment dedicated to were the placement of operation in the production flow. Hence, the work was highly manual and few advanced machines were used, e.g. advanced nailing machines. The production manager said regarding the industrial technology level within the factory;

*"if you want to be harsh, you can say that we have a construction site under roof. We have a lot to do regarding developing the industrial thought further".*

Similarly, the operations on-site were also conducted by highly skilled craftsmen, and not by assemblers, working in autonomous teams, regardless if it was the construction of the foundation or assembly of the modules. Production technology on-site was conventional for construction, e.g. mobile cranes, excavators, and caterpillars. Thereby, most of the operative personnel had both the education, and undergone the apprentice program and possess the norms as conventional construction workers had.

A consequence of this could be seen in the finished product, there different detail solutions had been used to solve the same tasks. It did not affect the overall product feature, but the quality of the work varied and become difficult for the permanent organization to adjust. New instructions were not always implemented carefully, and when they were implemented they were not always read. Further, if they had been read it could also take long time, i.e. many projects, before they were read again, so improvements was occasionally missed.

### 7.3.4 The planning and control mechanisms

The performance control system was more developed for DLL than in conventional construction projects. The foundation was the forecasted production volume of 400 dwellings per year, on which both the contracted fixed price was calculated and specific numbers of productivity and quality improvement per year – these were formulated in the product's business strategy. However, no fact based market forecasts had been made for determination of the production volume, but as an ad hoc decision from the NCC's organization. The real market need was much lesser and only about 120 apartments were produced per year. This created some problems for Finndomo's production planning which got further aggravated by the ad hoc order income. It also increased the production costs for the concept. The permanent group was trying to improve the DLL-system and to reduce the production cost and developed routines developed for monitor, collecting and analyze these. Yet, it had problems to coordinate and implement the development work with their respectively operative organizations. This indicates that the performance control system, the product business plan, was not directly linked to the action planning system.

The delivery time of DLL-projects, was according to the contract, from order to delivery of modules to the construction site was twelve weeks. However, because of the low product volumes and the ad hoc income of project orders did not make the DLL-project prioritized, which often resulted in longer delivery times. Further, in comparison to the other 12-14 product models Finndomo produced, DLL was perceived as complex. A production planner said;

*"What makes DLL complex is that it is so many variants to arrange the different dwellings. It is same dwellings, but they are delivered to new locations every time; to keep this chain together is probably the most complex thing we work with".*

This indicates that the production system was not particular structured and heavily rely on craft-based production principles, and the production process was not specialized for the DLL product. The factory layout used standardized lines, i.e. the production of certain parts of the products was physically determined to specific locations within the plant. Figure 7:17 illustrates the production line of the 3D-modules that the final houses were consisting of.

Figure 7:17 The standardized factory line based on highly skilled craftsmen. Some facilitating mechanic tools can be seen to move the 3D-modules within the factory.

The operations to accomplish the product parts were highly flexible and interchangeable; the production manager explained;

*"In the production the bottleneck can appear anywhere in the process, it is fundamentally driven by which the product type it is. Therefore we are using craftsmen; the machine cannot be used for every product".*

Thereby, typical industrial management methods such as production leveling and line balancing were scarce. Because these methods are based on a deep production system understanding and formalization of e.g. material and resource flow, operation time consumption, quality measures etc. Correct scheduling data was lacking and the problems and obstacles were communicated verbally – typical for craft-based production. Further, for Finndomo's entire production system, including all product models, the relationship with the material suppliers varied, in most cases there were annual contracts and only a few were used per item. Nevertheless, for comprehensive orders, such as in case of DLL-orders, the company often did a project specific procurement to get a better price.

In overall the action planning and controlling systems were limited, even if an MSP system was under implementation to get control over the information flow. The production planning unit also asserted that in the future, on basis on the new MSP-system, there is a need for knowledge on how to plan and calculate optimized production flows.

### 7.3.5 ICT-systems and integration devices

Within the factory ICT-systems and visual production steering tools was scarce, probably because of the low operations understanding on management and staff level. However, considering the DLL-network, it required rather deep integration of information both regarding the collaboration and to manage the product realization process, i.e. on management levels. Therefore, all the necessary information was stored in information system, PDM-system, which all individual participating in DLL-network could reach. In order to manage the projects the project personnel were invited to access this database. This information was not virtually transferable by the IT-systems, but needed extensive manual work to transform and use the data from one process to another.

Further, each corporation had special educated roles to integrate and support the project and production process. NCC had "project coordinators" which supported the project developers with NCC, and Finndomo had "project managers" to support the site (mainly the subcontractor assembly team). Further, the development work of the product concept was completely based on collaboration, and had multifunctional meetings once to twice per month. Each finished project were also evaluated together to capture experiences on-site. A project manager at Finndomo said; *"It is a take-and-give collaboration, 50/50 collaboration, we work together to get ahead and be better".* A project coordinator from NCC asserted that both companies could and should learn from each other, and use this knowledge to improve the other businesses areas, not directly related to the DLL-network. In conclusion, the integration devices were surprisingly many almost at the same level as for conventional housing projects, but more centrally driven. The reason for this is probably the network organization and the mix of craft-based and industrial production paradigm despite that the product was highly standardized and did not allow any customization.

## 7.4 Case D – Scania, the flexible truck manufacturer

Scania is one of the major truck manufactures in the world and produces heavy trucks (≥16 ton), buses, and industrial/marine motors. For years the firm has outperformed its competitors, and the last time they had a year of economic loss was 1934, despite several financial crises during the years. Today, Scania is doing business in most countries in the world with sales and service offices in more than 100 countries, except for North America.

Production plants are located to Sweden (Södertälje, Luleå, Oskarshamn), France (Anger), Netherlands (Zwolle), Argentina (Tucumán), Brazil (São Paulo), and Poland (Stupsk); the head office is in Södertälje in Sweden. In 2011 the firm had 37,496 employees worldwide including sales and service, produced and sold 72,120 trucks, 7,988 buses, and 6,960 engines. The operating income was SEK 12,398 m SEK, and operating margin 14.1 %.

The firm Vabis was founded 1891 and Scania 1900 which were merged 1911 and created the Scania-Vabis AB, which together produced cars, trucks, buses, trains and motors. Around 1924 the company finished the production of trains and cars to focus on trucks, buses and motors, and located all the production to Södertälje. In 1938 the company started the serial industrial production of the remaining product types. Since then the corporate strategy had focused on concentration and profitable growth through organic expansion. Already in 1939 the modular system ideas were founded with interchangeable motor parts, which were further developed during the fifties to increase the synergic affects within the product types and production processes. The goal was to combine the customization with production cost efficiency. In middle of the 1990 the development and work with the so called, *Scania-production-system* (SPS) started with experience interchange with Toyota. Toyota offered knowledge about "lean" and Scania about the modular system. Today, SPS is fundamentally pervasive of the entire company: it influences the corporate culture, strategy, management, marketing, production of orders, and development of products.

### 7.4.1 The strategy and product realization system characteristic

The case study company perceived the market as dynamic and rather predictable, but each customer's specific need as uncertain. Therefore, in order to be competitive the firm has chosen a *configure-to-order (CTO)* strategy. This allowed each customer to choose exactly the attributes that they wanted from predetermined range of choices; in fact, no product was produced without being customized. In order to accomplish this, the firm had developed a generic product model consists of modules and components which could be configured in numerous of ways, i.e. it was of *standardized-module-product-structure* (SMPS)[5] type. The product structure included all parts that were necessary to generate the various product variants. Based on about 20,000 unique parts in the generic product structure and a configurator (IT-system) generated customized products consisting of about 3000 parts (approximately 8000 ID-numbers). For example, regardless of the three market segments all the products shares the same generic product structure, in fact the trucks and buses shares about the 85 % of the components and modules. It was also said that the firm produces 1,8

[5] Note that the firm says it is the interface that is standardized not the components or modules. This is the principle which allows the generic product model to be developable. However, at the moment a specific order is customized the product model consists of standardized parts configurable in accordance with specific rules.

trucks a year that were exactly identical. Figure 7:18 illustrates how a truck consists of interchangeable parts; different customer choices create certain product attributes.

Figure 7:18 An illustration of how the customized truck consists of specific parts, selected among many in the generic product model to generate the product feature that was required.

The product structure and configuration corresponds to the production system flexibility by divide product realization in two parts. Standardized manufacturing process pre-CODP and flexible assembly processes post-CODP, i.e. the final assembly processes were of re-configurable art.

### 7.4.2 Super structure and corporate governance

In order to produce and offer the customized trucks the firm was divided in two parts, the industrial system and the business system. The industrial system develops and realizes the physical products and includes; research and development, purchasing, production and logistics – these are cost units. The business system is a profit center and is divided into two sub-domains; sales and services management, which focus on the retailers and the service units, and franchise and factory sales, which are managing the internal business of components and service between the different organizational units. All the sub-divisions are kept together with top management and staff departments, e.g. human resources, finance and business control, legal and risk, market communication, and IT. These staff units facilitate the interaction between the sub-division and support the corporate wide management and control. For example, the market department identifies future market trends, often supported by the retailers, and is responsible for the overall market and production volume forecasts which are the basis for production preparation and leveling. See figure 7:19 for summary of the organization chart.

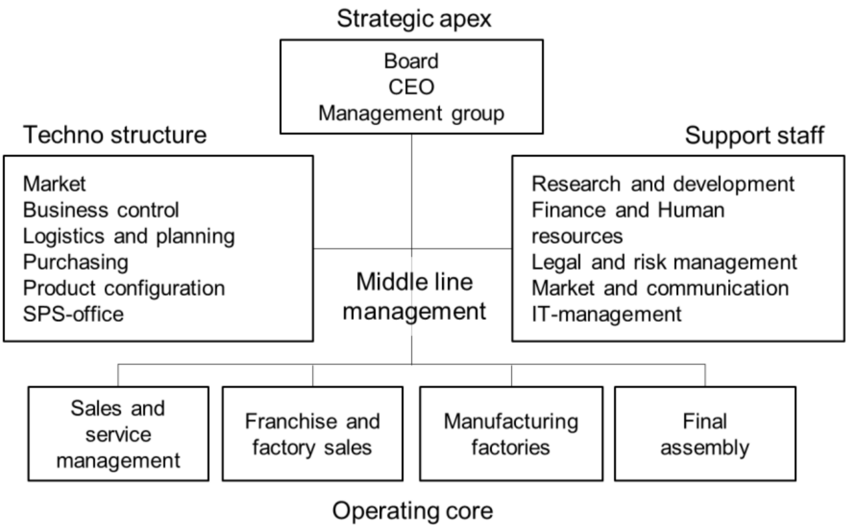


Figure 7:19 Scania's overall organization. Note that functions are structured in accordance with Mintzberg's framework and not directly based on Scania's own organization charts.

Clearly the organization is functional oriented, where each function concentrate on its processes. In the industrial system respectively process unit either manufacture the standardized items and parts on forecasts, or assembly the custom order specific modules into final trucks. The corporate management had delegated some authority to factory level, e.g. economic result responsibility and development. The high production volumes strengthen the feeling of independent factories for the employees, as one employee said;

> *"In the factories of components you don't see the modular thinking, it's only when you are considering the whole truck you can see it. Every production process doesn't need to bother if the firm is selling customized products, it is only the parts that is customer order driven that need to do that".*

Even though these production units were perceived as relatively self-managed, their authority only considered decisions that did not affected other factories or processes. For example, general production planning or development endeavors, necessary for making the entire production system integrated and efficient, were managed centrally but with input from the sub-units.

Further, the product order configuration and the separation of the product realization process in forecast and customer driven production, require comprehensive central production system coordination and planning. It was about leveling and balance respectively factory process performance, so the entire production system produces items, modules and final products intact. Therefore, most organizational structure, e.g. departments, groups, product structure, processes and steering methods, had been formalized, structured and aligned. In figure 7:20 it is illustrated how the major norms, management and steering mechanism are integrated into the *Scania-production-system* (SPS).

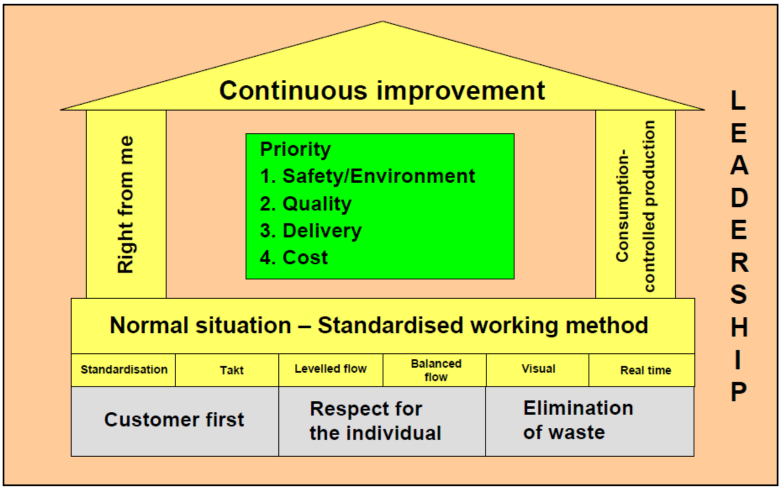


Figure 7:20 An illustration of how Scania's production system is consisting of different but integrated steering mechanisms. It considers both the production management and improvements aspects.

This integration is necessary in order to keep the production as efficiency as possible and manage the information processing work for each customized order. In other words, the firm was relying on the coordination mechanism standardization of work and the dominating part of the organization was the techno structure. However, in order to customize the products the salesmen, i.e. the operating core, have some decentralized mandate. In a sense, the salesman could influence the customer and thereby affect what the firm will produce. During the customization process the customer together with a retailer's salesman specify the product attributes by answer 55-70 multi-choice questions and generate millions of product variations. The specified choices were atomically controlled by another software program, after about 15 min the customer got his answer if it had been approved. The reason for the control was that the each possible product variant has not been controlled or tested in advance; although every part of the generic product structure had been individually tested and controlled from both a product quality and manufacturability approach. Further, even if the salesman actually initiated work for the product controlling and production planning roles, i.e. positions of techno structure type, it was the specialists that approved the order specification. During this process the product order is also placed within the MRP-system for production scheduling and delivery at a certain date (see also figure 7:21).

Further, the foundation of SPS encourages the blue-collar workers to identify and suggest improvement and even participate in the development work. Even if the staff specialists and managers have the decision power, it implies that the operating core could initiate the work of others. The decision flow was also very structured and bureaucratic standardized, and always performed in accordance with the same pattern. Hence, the firm had a limited horizontal decentralization with a hint of selective decentralization regarding certain questions.

### 7.4.3 The production topology and the processes

As indicated the production topology was of typical ATO-type, and figure 7:21 shows the major processes to realize a customized trucks and which part that was performing them.

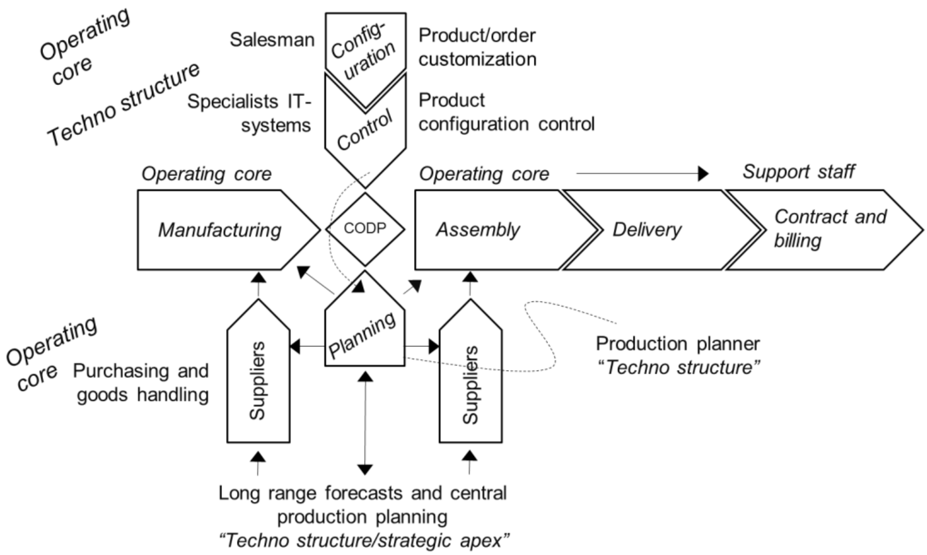


Figure 7:21 The overall production process of the customized product order, which part of the organization that was performing the respectively process and influence the work of others.

In the case study company the product realization process consists of, except from the product development, management and purchasing processes, of nine steps: (1) order specification process, (2) order specification control, (3) material planning, (4) suppliers transport and delivery to Scania, (5) component and module manufacturing, (6) final assembly, (7) product delivery, and (8) billing. Thus, before the product was configured the final assembly could not be completed. Processes pre-CODP were highly standardized and forecast driven, and the assembly processes post-CODP must be flexible enough to the change process/cell settings for each order.

The different nature of these processes also impacted the common production technology level. In component and module factories the technology level is robot lines and advanced machines; in the assembly processes the technology level is more manual supported by simple machines, jigs and hand tools, a senior manager explained (see also figure 7:22);

> *"The final assembly is dominating by manual work supported by jigs and hand tools. It is hard to automate the assembly with all the product variances which appears due to the modular program and the customization. Here robots can only be used for welding and component grabbing. Within the component factories which are demand driven or batch regulated it is much easier to use robots and automated machines".*

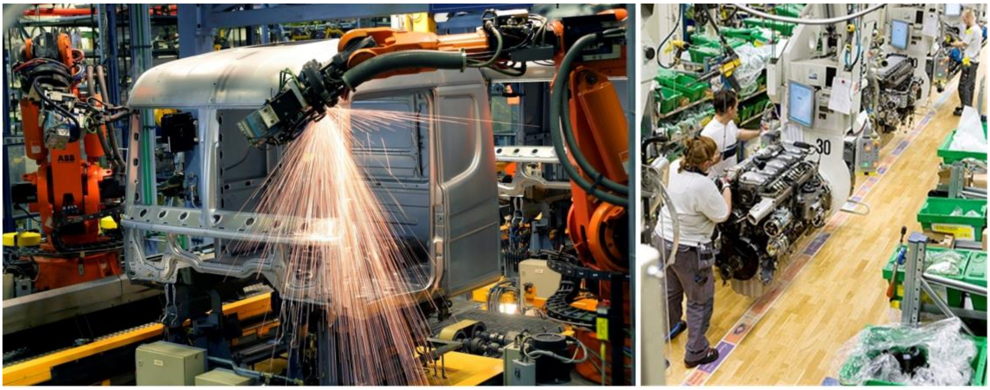

Figure 7:22 Two examples of technology levels. To the left a robot line welding a cabin, to the right manual work in the assembly line motors.

The use of robots and automated lines require comprehensive standardization and formalization of the processes. Even manually operations can, however, be better controlled and managed if the instructions are formalized. In comparison to the other case companies, these operation instructions are much more detailed with photographs and text instructions, see figure 7:23 on p. 150 for example. NCC Komponent would probably have reached a similar detail level in the operations instructions if the company had continued.

Further, Scania encourage employee to horizontal specialization through learning and exercise many different operations, and to participate within the improvement work groups. Well educated blue-collar workers are needed, why the firm has its own high school with focus on industrial production programs. At staff and managerial level the company favored recruiting highly educated persons at university level. Interesting to note is that Scania also seeks to rotate top managers and middle line manages between different units to increase the overall business understanding and the alignment of the corporation. For example, one production manager in Brazil had been promoted to be the head of a product development department in Sweden.

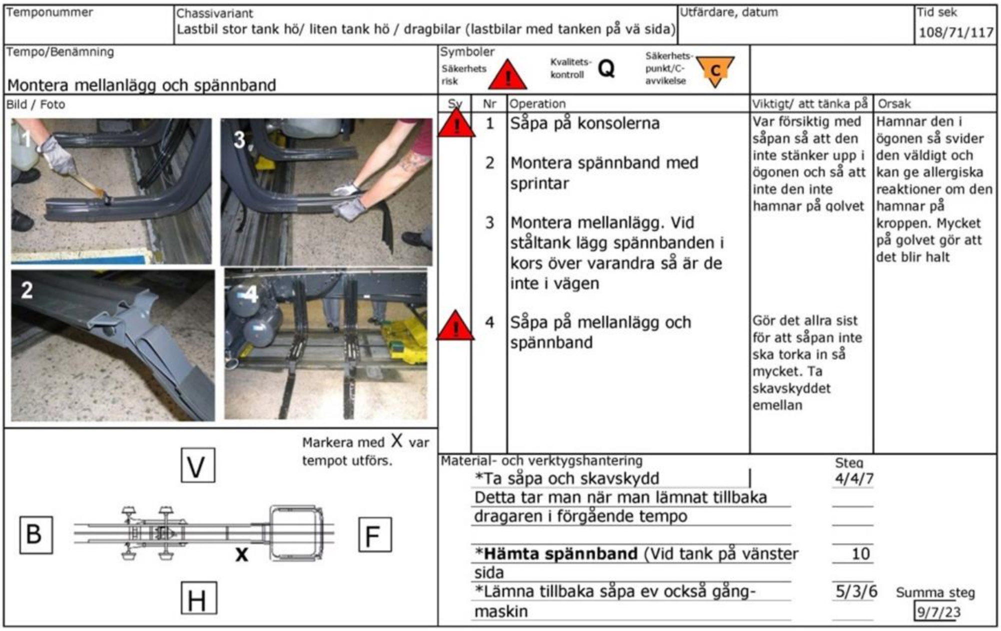

Figure 7:23 Example of an assembly operation instruction (in Swedish).

Another interesting aspect to note is that, in comparison to the other cases, Scania work very hard with the corporate culture, and really tried to make all the employees aware and work in accordance with the firm's norms. The foundation of SPS is the company specific norms and these are explicitly highlighted in many documents and often within the factories. This is a little surprising, due to that the theory indicate that the more flexible production become the more norm-based the steering should be – and Scania was not the most flexible company in this study.

### 7.4.4 The planning and control mechanisms

All production orders are performed within the same line regardless of the specification. Thereby, it is possible for the overall production system tact time to reflect the selling of customer orders. For the component factories, the corporate staff unit, i.e. the market department, forecasted the need for the next six month, which is communicated to the central production plan department. The plans were discussed and updated on monthly cross-functional meetings with representatives from market, financial and production units. The decision includes the production volume of the forthcoming six months, detailed month plans, and the tact times and determined by the CEO.

The tact time is based on the specific volume need for a certain time of period, and become the same for the entire company through this centralized planning process. Thereafter, the component factories translate the overall tact time to appropriate number on process and operation level. The final assembly line was excluded from these orders because it is fundamentally customer driven. Each customized order consists of different amount of work, which implies that the assembly work process must be sequenced and balanced. Therefore, the tact time is crucial for everyone that performs the operations; they need to know how long time the present task should take and how much time that is left. That is why most assembly processes had information boards showing the status in real time.

According to a top manager tact times and line balancing *"is about planning optimal use of the current resources, i.e. humans, machines and equipment",* and he continued *"…one of the worst factors of waste are unbalanced or unleveled workloads".* There are also many formal methods for managing the balancing and leveling within the company, both for preparations and controlling. Hence, this performance control system is a centralized way to align the performances among the production units. Based on this goal directed plans the production units could plan their production in detail, i.e. using *action planning system* for planning and steering their processes.

In summary, the information amount that must be considered when planning and reconfigure the production system is extensive if the firm is going to be competitive. It clearly shows that for industrial organizations the degree of customization is closely related to the required need of system control, or as one employee emphasized;

> *"The more customization choices that is allowed, the greater control you need to have over production, so the promised product features actually can be produce".*

### 7.4.5 ICT-systems and integration devices

In order to keep the entire organization system, including generic product structure, customization procedures, production system under control the firm heavily relied on integrated ICT-systems. It is most obvious in product specification process there the salesman could sit together with the customer in an office somewhere in the world, for example in Germany. The specified order was sent away digitally for control and within 15 minutes the order was controlled regarding, if it was possible to create that particular product feature. If it was producible and if there was a production window open and the necessary parts were available at the wanted date. Further, the steering of robots and the automated production flow through also require the use of IT-systems. Note that visual boards are communication tools for steering the production flow, but require deep production knowledge and formalized processes.

Despite that the theory suggests that the more standardized and formalized a producer is, the less integrating devices are needed. Scania used many integrating devices e.g. the multifunctional meeting procedures overall production planning. Within each factory there was integrating roles for support by technical specialists, e.g. production engineers and process planners, which also participated in product development projects managed from the central staff departments. Within the factories there were also improvements group, there are more than 1000 within Scania, there both roles within the operating core, technical staff and middle managers participated. Based on the norms and rules of the SPS the firm could decentralize certain issues to subordinate organizational levels, such as improvements of the operations. However, in comparison to the other cases the integration devices were not used in same amount for each single order. Instead these were used to coordinate the portfolio of orders or improve the businesses between orders.

## 7.5 Summary of the case studies

Table 7:13 Summary of each case strategic choices regarding the competitive factors product configuration corresponding product structure and production system flexibility level.

| Strategic choices | Case A<br>Peab | Case B<br>NCC Komponent | Case C<br>NCC DLL | Case D<br>Scania |
|---|---|---|---|---|
| Perceptions of market environment | Volatile and equivocal | Dynamic and uncertain | Stable and relatively certain | Dynamic and uncertain |
| Product configuration strategy | ETO | MTO | SPV | CTO |
| Product architecture | NPD | PMPS | IPS | SMPS |
| Production system flexibility | Transformable system structure (project) | Flexible at process level (production) | Setup changeability at operation level | Re-configurable assembly (cell) process level |

It is apparent from these four qualitative case descriptions that there are both similarities and differences in accordance with the predictions made by the PTO-model. Considering the strategic competitive choices regarding product customization, product structure and production flexibility level all the four cases are in line with the predictions in chapter 6:3 (see table 6:13, p. 112). In table 7:14 it is shown that three of the four case study companies corroborate with the predictions in table 6:14, p. 114. There are several reasons for this which will be further elaborate in the next chapter there the case studies will be discussed.

Table 7:14 Summary of the identified properties of the each case study. Deviations are marked in red.

| Mechanism | Case A<br>Peab | Case B<br>NCC Komponent | Case C<br>NCC DLL | Case D<br>Scania |
|---|---|---|---|---|
| Coordination mechanism | Mutual adjustment | Standardization of work | Standardization of work *and mutual adjustment* | Standardization of work |
| Authority system | Selective decentralization | Limited horizontal decentralization | Limited horizontal decentralization | Limited horizontal decentralization |
| Decision flow | Organic/adhoc | Bureaucratic standardization | Bureaucratic standardization | Bureaucratic standardization |
| Dominating organization part | All | Techno structure | Techno structure and *middle line management* | Techno structure |
| Structuring principle | Product market location | Functional | Functional | Functional |
| System structure flexibility | Transformable system structure | Production process structure flexibility | *Production process structure flexibility* and operation level | Assembly process (cell) configurability |
| Pre-CODP (Production) | - | - | *Changeable standardized processes* | Standardized process lines/cells |
| OPP/PC-process | Design | Manufacturing | Delivery | Assembly |
| Post-CODP (Production) | Project process, intermittent flow | Flexible production processes/cells | *Project process* | Reconfigurable assembly process/cells. |
| Span of control | Wide | Narrow | Wide | Narrow |
| Process formalization | Low | Very high | *Medium/low* | Very high |
| Job specialization | Enlarged job specialization | Horizontal job specialization | *Enlarged job specialization* | Horizontal job specialization |
| Training and indoctrination | Education, apprentice program, socialization of norms | Education, *socialization of norms* | *Education, apprentice program, socialization of norms* | Education, *socialization of norms* |
| Technology level | Craft-based technology | Manual operated machines, cells and advance machines | Craft-technology manual machines, advanced machine | Manual machines, advanced machines, robots |
| Performance based control systems | *Medium* | High | High | High |
| Action based control systems | Low | High | *Medium* | High |
| ICT-systems | Low | *High* | *Low* | Very high |
| Integration devices | Very high | High | *Some* | Medium |

# 8 ANALYSIS AND DISCUSSION

*In this chapter the empirical cases are analyzed based on the PTO-model and compared to previous research. The underlying relation of information storage and information processing to specific organizational and production system configurations are discussed.*

## 8.1 Research problem

The objective with the thesis is to explain why and how an industrialization of housing firms requires a change of the production topology and development of the organization structure. Two research questions have been articulated to capture the essence of these objectives.

- *What are the generic causes that explain the organization structure differences between firms with diverse production topologies?*
- *How does the change of a firm's production topology impact the design of the organization structure and the production system?*

## 8.2 Condensation of the PTO-model

The generic function of organization structure and production system is about steering, i.e. coordinating of resources and controlling the processes as efficiently as possible in relation to the firms' strategic objectives. Depending on the corporation's perceived market conditions and its chosen strategy to create competitiveness, the specific need for information storage in advance and information processing per order will be determined. These information requirements must be met by the organizational mechanisms that steers and controls the work. If a firm changes its strategy, i.e. changes the customization degree, the organization structure must be developed in such a way that it corresponds and possesses the appropriate information capability. Figure 8.1 illustrates the sequence and interaction between the strategy and organization structure design.

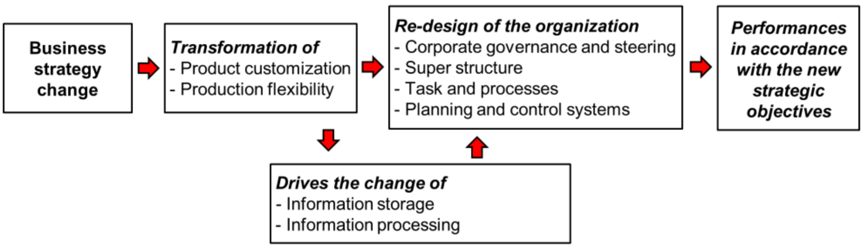


Figure 8:1 Visualization of the business organization development process; from strategy formulation to the change of the organization structure. The lower box indicates why the organization must change.

### 8.2.1 Different information types and information steering capacity

Depending on if the firm's market is volatile, dynamic or relatively stable it impacts the degree of product customization per order and in turn the production cost efficiency. What actually happens is that the more predictable the market is, the more the specific product order decision is postponed. This implies that prior to the decision point, the *customer-order-decoupling-point* (CODP), the information has been developed in advance and stored within the organization for repeatable use for producing the products. The CODP initiate information processing activities for developing or configuration of the stored information into useful instructions for the production of the specific product order. Thereby, the processes pre and post the CODP require different control mechanisms. Processes downstream the CODP may also be of different types depending on if the managed information is of equivocal or uncertain type (see figure 8:2).

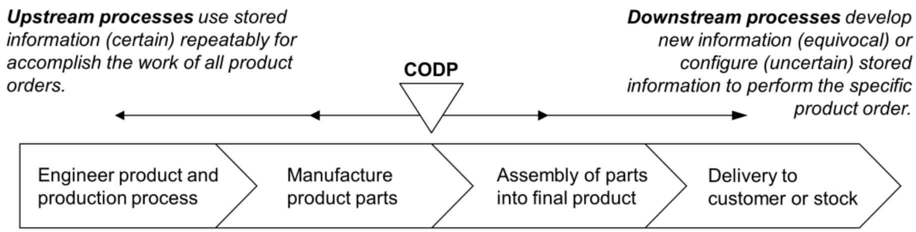


Figure 8:2 A producing firm's product realization process uses different control mechanisms depending on where the CODP is located. Upstream processes are executed based on stored information used for accomplish all product orders. Downstream processes develop new information, if the firm uses an ETO topology and the order situation is of equivocal type, or configure the stored information, if the firm have MTO or ATO topology and the is order situation is of uncertain type.

For example, conventional construction firms that use ETO-topology perceives their markets as extremely volatile and unpredictable and therefore develop new products for every project (see e.g. case study A). The need for information storage in advance is therefore low. Instead larger amount of information must be developed and processed for each project. The reason is the complexity of the product and the nature of housing projects the information that needs to be processed is equivocal. This implies comprehensive processing work until the information is explicit and useful for all involved project parties (cf. Schrader et al., 1993).

On stable markets the customers' needs can be identified in advance, such as the situation is for mass producers and in case C, i.e. situations when MSP-topology is appropriate. Based on this certain information, the product offer and the production system can be developed, standardized and formalized, which means that a large quantity of information can be stored within in the organization. The advantage is a radically reduced need for information processing per order in comparison to a volatile market situation and the ETO topology. When producing very standardized products the need for processing information is minimal, see for example the DLL-case. In this case it was more about planning the production process so the appropriate amount of materials and resources were in place when needed.

Still, the market can be more or less dynamic and unpredictable as the case is for the mass customizers, e.g. in the cases of NCC Komponent and Scania. In these markets each customer wants products that are different from others, which require an increased need of information processing per order in comparison to mass producers. In order to manage this, the companies prepare the organization for producing high variances of products in advance. But they wait until the customer arrives to specify exactly what produce for each order by delay the operations with order specific settings. In fact, the customized order become specified and planned through configuration of the stored information. By storing information in advance industrial mass customizers do not process as much information per order as firms with an ETO-topology (see figure 8:3). Depending on if the production topology is of MTO or ATO type the information processing amount will vary. In conclusion, the configuration process is information processing of stored information, which does not require as much resource's as new product development for every product order (cf. Dosi et al., 2008; Schrader et al., 1993; Daft and Lengel, 1986).

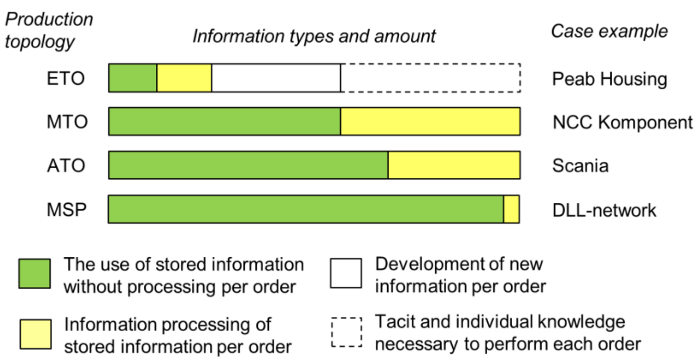


Figure 8:3 Principle illustration regarding the relatively use of stored information with no processing per order and need to process different types of information per order for each production topology. Note that the illustration is not appropriate to compare the topologies to each other considering the information aspects, for that purpose see figure 6:15 on p. 113.

When comparing the differences between the production topologies, it is interesting to note that in conventional construction the same amount of information is not developed to accomplish each project as in the industrial organizations. The reason is that it would have required too much of the resources to be effective – instead construction companies rely on highly skilled craftsmen that can interpret low informatory instructions (e.g. blue prints), see the dotted lines in figure 8:3.

In conclusion, in order to be competitive a firm must design its organization structure and production system in accordance with the strategy’s information requirements considering:

- the storage of information in advance for repeatable use when producing product orders, and
- the information processing per order.

## 8.3 Categorization of the case study organizations

The empirical validation of the PTO-model only becomes relevant if the investigated cases can be explicitly categorized based on their customization strategy, product structure and production topology (see figure 6:6, p. 95). Respectively production topology should correspond to the different information requirements and thereby imply observable specific organization design configurations (see figure 6:1, p. 90).

The categorization of the case study organizations to respectively production topology corroborates with the theoretical predictions (see figure 6:7, p. 96). Case study A, the craft-based house builder that used an ETO-topology, is consistent with the typical characteristic of conventional house builders (Bresnen et al., 2004; Winch, 2003, Kadefors, 1995). The industrial mass customers, case study B and D that used a MTO respectively ATO-topology, and the mass production topology or MSP, see case study C, corroborates with the common descriptions of these types of firms (e.g. Stuvrulaki and Davis, 2010; Hvam et al., 2008; Hallgren and Olhager, 2006; Duray, 2002). On the other hand, the findings do not supports the research by e.g. Lennartsson (2012) and Lind (2011) who assert that all construction is of ETO-type, due to production starts when the order is contracted. This assertion is a far too simple explanation; for example, Wikner and Rudberg (2005) and Hvam et al. (2008) elucidate that product structures, product configuration and production system parameters must be considered. Hence, the trade-off box (see figure 6:6, p. 95) seems to be a suitable illustration of the relations between the product configuration strategy, the product architecture model, and the production flexibility level.

Table 8:1 summarizes the findings from the case studies and shows that respectively case organization possess the predicted characteristics (compare it with table 6:13, p. 112). In conclusion, each case study represents one of the four common production topologies with the typical information conditions. Each case study organization should therefore possess the specific design configurations that correspond to the particular information needs (see the forth coming sections).

Table 8:1 A summary of the case study organizations' characteristics regarding the market situation and the strategic enablers – each case matches the predictions in table 6:13 on p. 112.

| Characteristic factor | Case study A<br>Peab | Case study B<br>NCC Komponent | Case study C<br>DLL-network | Case study D<br>Scania |
|---|---|---|---|---|
| Perceptions of market environment | Volatile and equivocal | Dynamic and uncertain | Stable and relatively certain | Dynamic and uncertain |
| Customization strategy | ETO | MTO | SPV | CTO |
| Product structure type | NPD | PMPS | IPS | SMPS |
| Production system flexibility | Transformable system structure (project) | Flexible at process level (production) | Setup changeability at operation level | Re-configurable assembly process level |
| Production topology | ETO | MTO | MSP | ATO |

It is apparent that the perceived market situation impacts the strategic choices in certain directions. For example, in the conventional housing firm, case study A, the perception was that the market required an optimized house for each project location regarding architecture and quality. Thereby, the company was forced to develop new and unique products for each project. These market conditions (volatile and equivocal) imply that future demands are severely captured and forecasted. The firm will therefore not risk spending loads of resources on development of information for storage, because it is highly uncertain that this information will be used in the future (cf. Arslan and Kivrak, 2008; Gann, 1996; Winch, 1989).

Stable markets are more easily surveyed and forecasted than volatile ones. It is also highly probable that the market needs are relatively homogenous and does not vary too much, meaning that product solutions probably can be reused multiple of times. Therefore, investment in resources for pre-development and storage of information in advance, e.g. regarding e.g. product structure, production technology, and processes, can be spread out among all the product orders and pay off (cf. Ståhl, 2006; Galbraith, 1974). Case study C, the DLL-network organization, is good example of this; the standardized product was developed once then produced in a great number. The information that must be processed per order to produce the standardized products in comparisons to conventional housing was set to a minimum.

In dynamic markets there is some uncertainty, which implies that additional information processing per order may be required to make the unclear situation certain. This drives the need of configuration of stored information to specify exactly what information to use for the production of the particular product order (cf. ElMaraghy and Meselhy, 2009; Jiao et al., 2007). Both the NCC Komponent and Scania cases are typical examples of this, even though these firms used different product structure and production system flexibility solutions to manage the configuration. These empirical results corroborate with the conceptual findings by Wiendahl et al. (2007) and Blecker and Abdelkafi (2006b). These authors asserted that the more comprehensive the configuration of the production system was the more complex and demanding the production management became. In conclusion, each case represents one of the common production topologies and confirms the different information requirements.

However, when the pattern matching for each case and the predicted configurations of the organizational mechanisms were conducted a few anomalies appeared. Next section will clarify the deviations and discuss if it is based on errors in the PTO-model, in the empirical investigation, or if the business organizations were not optimally designed. Some suggesting explanation for the irregularities will also be provided.

## 8.4 Organization elements and information need

The PTO-model suggests that the different information needs will favor certain control mechanisms that constructs the organization structure and production system. Some mechanisms will mainly contribute to an organization’s information storage, others to the information processing need or both. For example, the organization division structure directs the resources towards to work process in a certain way and thereby only facilitate specialization (information storage) or flexibility (information processing). Nevertheless, *per se* it does not contain or process information for explicit use when performing a task (Daft, 2009; Burke, 2003; O’Neill et al., 2001). The structure rather possesses information on how to direct the resources and where to use the explicit information (Mintzberg, 1979), e.g. process/product descriptions and models, tools and machines, physical components products, individuals and groups (cf. Linderman et al., 2010; Martinsson, 2010; Aggestam, 2006).

The need for information processing emerges when new usable information is necessary in order to accomplish new work process objectives, e.g. a product order or new performance objectives. Interesting to note, is that very few organizational mechanisms actually conduct the information processing, the use of ICT-systems and certain analytical tools (e.g. calculating and planning tools) are exceptions, instead many devices facilitates the information sharing and processing activities for the performing individuals (e.g. Ott et al., 2011; Fairbank et al., 2006; Daft and Lengel, 1986). The following paragraphs analyze the empirical findings of each element of the PTO-model.

### 8.4.1 Corporate governance and steering

Corporate governance and steering contains the principles of how the organization coordinates and controls the information to realize the products. Its constructing mechanisms are more of explaining nature than being devices to conduct the work. Instead each configuration seems to naturally emerge in accordance with the firm's strategic and organization design choices, which are driven by the information situation. Table 8:2 summaries the case study findings.

Table 8:2 Summary of the pattern matching of the corporate governance steering element. Anomalies from the predictions are marked in red.

| Mechanism | Case study A<br>Peab | Case study B<br>NCC Komponent | Case study C<br>DLL | Case study D<br>Scania |
|---|---|---|---|---|
| Coordination mechanism | Mutual adjustment | Standardization of work | Standardization of work and mutual adjustment | Standardization of work |
| Authority system | Selective decentralization | Limited horizontal decentralization | Limited horizontal decentralization | Limited horizontal decentralization |
| Decision flow | Organic/adhoc | Bureaucratic standardization | Bureaucratic standardization | Bureaucratic standardization |
| Dominating organization part | All | Techno structure | Techno structure and middle line managers | Techno structure |

As predicted, major difference between the cases, especially between case study A and the others was found. This acknowledges those who stress that conventional construction is very different from other kind of production such as industrial manufacturing (e.g. March, 2009; Winch, 2003). For instance, the conventional house builder, perceived every project as unique in order to respond to the volatile market conditions. This makes it hard to standardize and formalize management procedures as well as the project processes. Therefore, different types of information must be processed per project which cannot be predicted. Instead, the decision flow within the company varied between each project, meaning that different roles influence each project in different ways, depending on which competence that was necessary and available. This explains the findings of Styhre and Gluch (2010) and Roy et al. (2005) who claimed that construction seldom developed and use formalized processes and instructions. Similarly, findings have been identified around the world, e.g. in Hong Kong by Chen and Mohamed (2007), in Britain by Mossman (2009) and in Sweden by Simu (2008). In a long-term perspective no organizational part becomes dominating, the decision flow becomes organic and the authority system selective (cf. Mossman, 2009; Mintzberg, 1979). Further, it will also favor the verbal communication and mutual adjustment as the coordination mechanism. Together these organizational mechanisms explain the findings of e.g. Bresnen et al. (2005), who asserted that conventional construction firms seldom translate strategies into operational objectives and working procedures. The opposite seems to be valid for the more stable and certain market situations as the circumstance was in the three industrial case studies. These three cases provide very similar characteristics, see table 8:2, and supports the findings by Lind (2011), Mintzberg (1979) and Bertelsen (2004) that clearly demonstrates the difference between industrial and craft or project-based organizations.

Case study C provides an interesting finding; because it has some coordination based on mutual adjustment despite that it used a standardized product and produced in a factory. The reason for this is that the organization used traditional craftsmen to assembly the modules on-site and even within the factory. Thereby the production management relied on a mix of both standardization of work and verbal communication. On-site, no additional detailed assembly instructions, than traditional instructions, were actually needed or used; which had been expected if the final assembly resources were of a manual work type. These findings are consistent with previous research of industrialized housing, which had indicated that mutual adjustment are the dominating coordination mode, despite the prefabrication degree (e.g. Zhang and Skitmore, 2012; Johnsson and Meiling, 2008). Höök and Stehn (2008b) suggest that the reason for this could be that it is common for industrial construction firms to use management principles for craft-based production – although that these are inappropriate for industrial production. Assuming this is correct; it implies that the corporate norms do not supports the use of appropriate devices for information storage and processing (cf. Rowe, 2010; Hofstede, 1978). The consequence should be some management problems, planning and improvements problem; which also could be identified in the case (see chapter 7:3).

The empirical investigation also showed that the mass customizers (MC) actually have more in common with mass producers than with adhocracy organizations. In fact, NCC Komponent, the flexible industrial house builder, has more organizational and technology commonalities with Scania, the truck manufacturer, than with Peab, the conventional house builder (cf. Gerth, 2008). This is in accordance with the expectations because the PTO-model differentiates between production topologies based on the required information ability. It is also consistent with what Porter et al. (1999) and Rumelt (1991) asserted; the industry type is of minor importance to understand the differencies between organizations.

The investigation also offers some remarkable insights that differ from more recently research on mass customization, which assert that MC approaching the organization types that produces fundamentally customized or unique products (see e.g. Trentin et al., 2011;

Haug et al., 2009; Pine, 1993). This is easy to interpret as that a MC-organization has more in common with adhocracy firms, with the ETO-topology, than with or machine bureaucracy firms with the MSP-topology – which is not the case.

In conclusion, this research study expands Mintzberg's theory to categorize mass customizers as machine bureaucracy organizations – in his original work the mass producer was the archetype. For example, previous research asserts that the MC-organization must be more decentralized and organic (e.g. Trentin and Forza, 2010; Radder and Low, 1999; Burns and Stalker, 1961). The result of this study indicates that the techno structure is the dominating organizational part and heavily relies on formalization and standardization of work; even though the operative sales function have more influence on what to produce. However, the managerial and decision flow is still bureaucratic and standardized – it does not become organic just because it involves more departments when realizing the product order. Actually this is in line what Pine et al. (1993) explains; the strategic and tactical management should be executed by central units even if some operational decision has been decentralized.

### 8.4.2 Super structure

The mechanisms within the organization element super structure describe how the organization virtually is structured and explains the production topology. The result of the case studies shows that three of the cases match the PTO-model's predictions, while the last one diverges (see table 8:3).

Table 8:3 Summary of the case study findings regarding the organization element super structure.

| Mechanism | Case study A<br>Peab | Case study B<br>NCC Komponent | Case study C<br>DLL | Case study D<br>Scania |
|---|---|---|---|---|
| Organizational structuring principle | Product market location | Functional | Functional | Functional |
| System structure flexibility | Transformable system structure | Production process structure flexibility | Production process structure flexibility and operation level | Assembly process (cell) configurability |
| Pre-CODP (Production) | - | - | Changeable standardized processes | Standardized process lines/cells |
| CODP process position | Design | Manufacturing | Delivery | Assembly |
| Post-CODP (Production) | Project process, intermittent flow | Flexible production processes/cells | Project process | Reconfigurable assembly process/cells. |
| Span of control | Wide | Narrow | Wide | Narrow |

There are several reasons for why the DLL-case stands out. The case study focused mainly on the business network organization, and not its interaction between the production processes of the other standardized products. However, when investigating the factory it was obvious that the many product variants must be considered in order to explain the flexible processes and the substantial use of craftsmen. Interesting to note is that the staff and management levels work of the product DLL did not considered this. Despite this the result of case study corresponds to the prediction in general level, but not on production process flexibility level (compare table 8:1 and 8:3).

The result of the case studies indicates that the more stable the market conditions are the more favorable is it to specialize the resources to certain tasks, i.e. use a functional organization principle. In case study A the market was volatile and the information equivocal, which implied that the firm must be able to use necessary resources to develop the essential information for accomplish the project. Therefore, the company used a flexible local organization to interpret the market conditions for each case. In order to match the appropriate resources to the specific project settings the firm used an organic decision flow (cf. Mintzberg, 1979). This organization design is very similar to the one that was empirically identified by e.g. Warsame (2009), Dainty et al, (2006) and Fryer (2004). However, the case result contradicts the findings by Anumba et al. (2002) who asserted that the construction firm's organization was too functional divided. Therefore, they suggested that the firms should keep upper level of structure intact, but increase the organic and flexibility possibilities at portfolio and project level. The Peab-case corresponds to these suggestions well, by having a centralized and permanent office for investment decision while the local organization may influence the decision by providing decisions support reports.

On the contrary, the functional divided organization principle is mainly about specialization of the resources, which facilitates information storage and formalization of the working procedures. It is therefore appropriate for industrial companies regardless if it is of mass production or customization type (see section 8.4.1). This could also be explicitly observed in case study B and D, and some extent in case study C. In case C the specialization was observable, but the use of formalized instructions was not, which can be explained by the use of craftsmen. These findings also indicates the correlation between the organization structuring principle, the system structuring flexibility, process formalization and the production topology – a correlation that is often missing in previous research (e.g. Trentin and Forza, 2010; Wiendahl et al., 2007; Slack et al., 2005; Mintzberg, 1979).

For example, the more postponed the CODP is the more standardized (inflexible) can the production process be, and the more specialized can the resources to particular tasks be (e.g.

Rudberg and Wikner, 2004). The more upstream the CODP is located, the more flexible the product realization process must be, i.e. the more operational information must be processed in order to re-set each operation per order (e.g. Wong and Naim, 2011; Blecker and Abdelkafi, 2006a). In industrial firms with a customization strategy, the necessary flexibility can be accomplished through configuration of the stored information. Thereby, this operational configuration is the dominating information processing mode in these production topologies. The industrial cases, i.e. NCC Komponent-case and Scania-case, clearly confirm this theoretical suggestion. In craft-based organizations with an ETO-topology the companies cannot pre-develop the product or the production process, which means that there is nothing to re-set. Instead the product and process must be developed for each project order. The entire production system flow becomes intermittent and project based, which corroborates the assumption that case study A is typical example conventional house builders (cf. Bresnen, 2005; Slack et al., 2005; Bertelsen, 2004).

The factor spans of control seems not to be of major importance to consider when designing the infrastructure of the organization (cf. Ott et al., 2011). However, when adding leadership and social behavior to the organization design process, it is probably a more important factor to consider due to the nature of human as a social being. Further, in practice it can be of importance when transforming the conventional construction firm into the industrial mode in order to make the new production process manageable. The reason is that the management of craftsmen requires different leadership and coordination tools than the management of manual laborer (e.g. Banks, 2010; Clarke and Wall, 2000; Gann, 1996; Stinchcombe, 1959).

### 8.4.3 Task and processes

The organization element task and processes describe the nature and the design of the production work. Except case study C the other three case companies corresponds well to the PTO-model predictions (see table 8:4, p. 165). The reason for case study C to provide weak compliance is mainly that craftsmen were used in both the factory and in the final assembly on-site processes. This affected the configuration of all the mechanisms in various degrees. For example, the formalization was in general significantly lesser than expected. The use of craftsmen also favored enlarged job, and the traditional construction culture was pervasive among both white and blue collar-workers. The reason for this could be that the producing parts of the DLL-network were reluctant to apply and develop the organization in an appropriate (industrialized) way, including the managerial methods and employee skills. Similar, findings had been identified by Unger (2006) and Höök and Stehn (2008ab). In order to accomplish a successful transition from conventional to industrial construction the corporate culture and norms must shift and be entirely pervasive within the company (cf. Gerth, 2008).

Table 8:4 Summary of the pattern matching of the organization element task and processes.

| Mechanism | Case study A Peab | Case study B NCC Komponent | Case study C DLL | Case study D Scania |
|---|---|---|---|---|
| Process formalization | Low | Very high | Medium/low | Very high |
| Job specialization | Enlarged job specialization | Horizontal job specialization | Enlarged job specialization | Horizontal job specialization |
| Training and indoctrination | Education, apprentice program, socialization of norms | Education, socialization of norms | Education, apprentice program, socialization of norms | Education, socialization of norms+ |
| General technology level | Craft-based technology | Manual operated machines, cells and advance machines | Manual operated machines, advance machines, craft-based technology | Manual operated machines, cells and advance machines, robot lines |

The theory suggests that the more advanced technologies that were used in the production system, the more detailed the formalized and detailed the document were on the processes (e.g. Frohm, 2008, Mintzberg, 1979) – this was confirmed by the four cases. Interesting to note is that, in case study B and D the required formalization degree for the more advanced technology levels of particular operations seems to be transferred to the other processes. In case study A and C, the use of low level of production technology, e.g. craftsmen, seems to influence the formalization in an inappropriate extent.

For example, in case C many of the management processes were standardized and supported by ICT-tools, but the production was still dominated by craftsmen. However, this indication should be handle with caution due to it could be an effect of the specific organization setting. In general it is assumed that the foundation for implementation of automation is standardization and formalization of the production process – without this foundation the production will not be productive (e.g. Sandkull and Johansson, 2000; Womack et al., 1990). Further, the case study indicates that it is hard to explicitly identify the sequence of the employed steps: standardization, formalization and automation. The DLL-factory actually mixed the use of a few automated operations and craftsmen, which probably could explain the problematic production management. Case study B is an example on the theoretical suggestions: NCC Komponent developed the entire company in order to manage industrialized produced houses through the highly automated factory and manual assembly on-site. No craftsmen were used at all within these processes, and every operation was identified standardized and formalized[6]. This indicates that if construction firms shall be able to industrialize the production successfully, they should change the organization structure and replace the craftsmen with industrial workers.

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[6] or was under development (see chapter 7.2).

An interesting research finding that emerges, when comparing the construction sector cases, was that the more advanced production technology that was used, the more dominating the techno structure was in the organizations. This organizational part developed and stored the information the technology was based on. The implication was the operation core's ability to determine by themselves how the work should be done was reduced (cf. Taylor, 1967). Advanced technology also facilitated more comprehensive planning, and the production planner roles were placed within the techno structure. This finding is almost a perfect match of Mintzberg's theory and Burns and Stalker (1961) who asserted that it was the techno structure that was dominating in industrial manufacturing firms.

In accordance with Mintzberg (1979), the Peab-case showed that no particular organization part is actually dominating the others on a regular basis. On the other hand, as Taylor (1967) and Ford (1924) asserted, the operating core was the organizational part that had the most direct impact on the production cost and the product quality. That was the reason for why contract managers where trying to keep the best craftsmen longer than necessary (see p. 124). This also explains why the DLL-network management experienced problems to implement improvements of the product and processes – even if new instructions were "implemented" correctly, the craftsmen did not used them.

As asserted by numerous of scholars (e.g. Dencker, 2011; Frohm, 2008) the use of technology level was lower downstream the CODP and in the assembly lines. This was particular evident in the Scania-case, which relied heavily on highly automated cells in manufacturing process and manual work in assembly process. This tendency could also be observed in the NCC Komponent-case, but it was not so obvious due to the general lower technology degree. In the mobile assembly hall no robots or advanced machines could be found, only manually operated machines. Similar, observations was captured in the DLL-case, on-site solely traditional craft-based technology was used, but in the factory some machines and robots could be found. This is a reminder for the construction researchers who are exploring the automation of the construction process on-site (e.g. Maas and van Gassel, 2005; Richard, 2005). One can ask: if not well developed industrial manufactures use robots because it is less productive than use manual labors in the assembly process, is it even possible to implement robots in the environment that conventional construction site offers to improve the performances?

The empirical investigation also showed how the craftsman work is significantly different from manual work. The former case is based on individual skills with a minimum of work instructions developed by the staff; the latter case relies heavily on work instructions. These findings are consistent with the previous research on the transition from craft-based to industrial production in different sectors; e.g. within manufacturing (Ford, 1927; Taylor, 1967; Berggren, 1990), in construction (Stinchcombe, 1959; Gann, 1996; Clarke and Wall, 2000), and within the creative and art sector (Banks, 2010). However, these findings indicate an inappropriate correlation between the operations technology and the cognitive control in Frohm's (2008) model (see table 4:3, p. 42). Both case study A and C show that the technology level 4 and 5 was used together with the managerial and cognitive control level 1 and 2 or 3. This should be further explored in future research.

Interesting to note is that Mintzberg (1979), in contrast to Child (1972), put the technology level in the contingency factors. The contingency factors determined all the other organizational design mechanisms including the strategy choices of the firm. The current study could not support this argument, because in order to use production technology the firm must develop and formalize the processes in appropriate level. This process is similar to the one when developing working instructions for manual work. In a sense, both working instructions and machines contain stored information on how the work should be done; meaning they are devices for achieving the firms strategic objectives. Case study B and C explicitly shows that the strategic objective was the reduction of production cost, the chosen production technology level were considered as a mean to realize that goal. In case study A appropriate technology, e.g. caterpillars, were used depending on the specific conditions to achieve the project objective as efficiency as possible. Further, the project objectives were deduced from the corporate strategy. Therefore, technology is a mean to accomplish the strategy, as the other organizational design mechanisms are – not a major factor for base the business strategy on (see figure 5:3, p. 69).

Another interesting finding is that the mechanism culture and socialization of norms was unable to demonstrate the assumed impact correlation of increased standardization and formalization the less pervasive the culture should be (cf. Mintzberg, 1979). This finding corroborates more with resent research on corporate culture, i.e. high performance firm had pervasive culture that in supports the organization ambition (e.g. Höök and Stehn, 2008a; Kates and Galbraith, 2007; Schein, 2004; Chandon and Nadler, 2000). However, remember that the thesis does not focus on this issue, so the finding should be interpreted with caution.

### 8.4.4 Planning and control systems

The planning and control system element is the active control system for steering the production system. Here the mechanisms that facilitates strategic and operational goal setting, planning procedures and devices for transfer of necessary information between processes, groups and individuals can be found. All of these are necessary for having a functional regulating system, even if the scope and detail level of each mechanism vary depending on the type of organization. Every case organization possesses some degree of steering solutions for each mechanism. The variations could be explicitly identified by the cases studies (see table 8:5).

Table 8:5 Case findings regarding the element of planning and control.

| Mechanism | Case study A<br>Peab | Case study B<br>NCC Komponent | Case study C<br>DLL | Case study D<br>Scania |
|---|---|---|---|---|
| Performance control systems | Medium | High | High | High |
| Action planning systems | Low | High | Medium | High |
| ICT-systems | Low | High | Low | Very high |
| Integration devices | Very high | High | Some | Medium |

As predicted the Peab-case was significantly different from the other industrial cases (cf. Kenley, 2005; Olhager and Rudberg, 2002; Mintzberg, 1979). The *performance-control-system* (PCS) was relatively well specified and applied. It allowed the company to fast control of projects' current output and compare the status with the general objectives. The low standardization degree and organic decision flow, which changes from project to project, makes it more or less impossible to have a detailed and accurate *action-planning-systems* (APS). These findings are consistent with research of e.g. Keegan et al. (2011), and Sanchez and Robert (2010), who asserted that resource allocation on portfolio level and the projects planning, through *critical-path-method* (CPM), was conducted at different organizational levels and by different roles. It also explains why the projects' schedules seldom were accurate, often failed and required additional resources (e.g. Blichfeldt and Eskerod, 2008; Engwall and Jerbrant, 2003). Instead, the firm used numerous of integration devices and craftsmen for coordination the production work informally. Based on the nature of this case company, nothing else could be expected, which also match conclusions by Daft and Lengel (1986). The authors claimed that the more uncertain and equivocal the information processing task was the more integration devices must be used (see figure 6:14, p. 110).

These finding supports the previous work by Mintzberg (1979) and Galloway (2006), who asserted that adhocracy firms use APS in very limited degree and all the organizational parts was involved within the development of orders. The reason is that ETO-firms, e.g. the Peab-case, do not have the formalized processes detailed enough to possess information necessary for using action planning methods. The necessary detailed level is never developed, instead the planning become objective and norm based, and firm must trust the employees to possess the necessary skills to interpret the plans. In fact, this is an efficient way of manage extremely flexible production systems; if each construction project was developing the production instructions and schedules in the same detail level as industrial firms, the projects would be to resource demanding to be accomplished. For example, even if the construction of a house is accomplished by similar operations they cannot be time framed in an accurate way. The reason is that each operation is accomplished in different ways depending on the performing craftsman's skills and experience. An average operation time is possible to obtain, but on individual level it vary too much for the project managers and staff to make detail and accurate production plans.

Interesting to note is that the DLL-case showed similar characteristics as the Peab-case: which also explains the differences from the predictions based on its production organization topology. As in the Peab-case craftsmen were used which does not need detailed formalized instructions. Despite this, the instructions in the DLL-case actually were more detailed than for conventional construction. However, the problems the management and techno structure experienced with planning and implementation of improvements clearly supports the assertion of Ford (1924) and Taylor (1967): in craft-based production it is the workers who determine the efficiency and product quality of the firm, not the white-collar workers. Further, due to the relatively low production process understanding, at techno structure level, the instructions could not be detailed and monitored in an appropriate level to capture relevant production data. The appropriate amount of information was not developed and stored for use when planning and steering of the production process. Instead the steering relied on liaison devices, which had been superfluous if the design of the organization had been based on the industrial production principles.

However, the *performance-control-system* (PCS) was the mechanism that showed most similarities among the cases. The reason is probably that all organizations have a strategy and operational objectives that the firms are designed to achieve (e.g. Kates and Galbraith, 2007; Porter, 1991). These objectives are often the basis for prioritization of operational planning and managerial decision (Day, 2006). There was also a notable tendency that the case study organizations with well-developed *action-planning-systems* (APS) had more detailed PCS. This empirical finding corroborates with work of e.g. Lauras et al. (2009) and Aladwani (2001) who asserted that development and design of ERP or MRP systems must consider corporate strategy and multiple functional departments' objectives and duties. Further, based on the above discussion regarding craftsmen in case study A and C, and their impact on firms' ability to information storage and information processing, the degree of use of ICT-systems in the production within respectively case becomes self-explanatory.

Interesting to note is that both case study B and D, which relied on industrial and lean-principles, emphasized their use of integration procedures, and many liaison devices could also be observed. However, these focused mainly on how to collaborate and develop processes between the product orders: thus, not in order to accomplish the single product order as the case was for case study A and C, but to accomplish improvements. This indicates that because everything was already prepared in advance, there were no particular needs for collaboration to accomplish each single operation. This supports and complements the common suggestion of general integration of industrial firms in order to increase the flexibility and performances (e.g. Trentin et al., 2011; Marcheridis and Knutsson, 2007; Pine, 1993).

In conclusion, when necessary information regarding what to produce and how to produce it is formalized and stored, the use of this information reduce the need for using liaison devices to realize the products. On the other hand, it shows that improvement or development (information processing) is facilitated by liaison devices – a result that is consistent with findings of e.g. Daft and Lengel (1986) and Schrader et al. (1993). The final conclusion of this study related to the organization element "Planning and control systems" is, if the enterprise does not have developed appropriate amount of work process information in advance it cannot make detail production plans.

## 8.5 Reflection on the information storage and processing

The previous section indicated that the configuration of the organization structure mechanisms corresponds to the required ability to store and process information. These principles are based on the emphasized importance of information processing for the realizing products (e.g. Galbraith, 1974; Tushman and Nadler, 1978; Schrader et al., 1993; Burke, 2003; Wickstrøm et al., 2012). The PTO-model complements the generic principle of information processing with the storage dimension: because the former cannot explain the several variations of organizational structures' and production systems' design in a satisfactory way. It is acknowledged that strategic processing precedes information storage, but strategic information processing is of different type than operational processing per order, and therefore requires different organizational solutions to be realized (cf. Olivera, 2000).

The correlation between the information requirements and the organizational mechanisms' capacity to respond to these could not be directly observed. Instead, logical reasoning based on the empirical findings was accomplished. In fact, the few empirical research studies that exists which consider similar correlations between information processing and with organizational aspects and process actions was conducted in similar ways, e.g. Engström (2012), Lucas (2010), Trautmann et al. (2009) and Kamara et al. (2003). The reason is that an empirical or experimental validation would require an understanding on how much information each mechanism can manage. This knowledge is still missing and therefore an area for future research (see chapter 9).

The implication of the indirectly empirical but theoretical logic derivation is that there can be alternative explanations for the each mechanism's design. Information is probably the most generic aspect to consider when considering the management of organizations and production systems. Reconnecting to the definitions and purpose of organizations and production systems it is obvious that depending on the corporate strategy the two different information phenomenon must be managed. It is self-explaining that every business organization must be developed, managed, and respond to its business environments. In summary, an organization consists of information that had been strategically developed and then stored. During the management and customization process the stored information is used, configured or developed, i.e. information is operationally processed.

In a sense, this can be seen as design axioms in accordance with axiomatic design developed by Suh (1990). Suh assert (p. 18) *"axioms are formal statements either of what people already know, or of the knowledge imbedded in many things that people do or use routinely".* Most people would intuitively support the statement that every part of an organization, which is necessary to accomplish a specific task with a certain performance, contains or even is information. Further, when developing and steering the work someone has to analyze, make decision and implement the orders, which is difficult to denote as anything else than information processing.

## 8.6 General comments considering the study approach

The use of four deep and qualitative case study organizations instead of one increase the generalizability of research result. The cross-case analysis was conducted because it highlights differences among the four different case organizations and reduces risk for subjective and biased interpretations of the single-cases (cf. Yin, 2007). It also creates a frame work for comparing diffuse judgments of values, such as high, low, maximal and minimal. For example, in the organization element *Planning and control system* this was a major issue: what are an appropriate level considering the numbers of objectives and their detail level for the organization type that each case represent. By comparing the different case companies some kind of starting point emerged for analyze; i.e. for each generic organizational mechanism differences between the empirical cases could be identified. These variations could be correlated to the PTO-models founding information principles (see figure 6:3, p. 92).

The use of a case company from different industry sector (case study D) is motivated in a similar manner. First, it provides a mean to evaluate the rather juvenile industrial construction firms, and to compare these to the systematic and highly developed truck manufacturer. Further, the Scania-case had a customization strategy of CTO-type and a production topology of ATO-type, which required less flexibility than the NCC Komponent-case but greater than DLL-case needed (see table 8:1, p. 158). Thereby, when evaluating the cases' empirical output for each mechanism, the Scania-case acted as a reference point (see table 8:2-5). Second, it also increases the generality of the research result: if the PTO-model can predict the result of construction firms design as well as a truck manufacture's it should be valid for more sectors than only construction.

The DLL-case possesses major discrepancies to what the PTO-model predicts, both regarding the information storage and processing mechanisms. In essence it was because of the network organization, the comprehensive use of craftsmen and reluctant to apply industrial principles. Based on this, one could argue that this case should be removed from the study, due its ill appropriate fit for the research objective. However, it provides some interesting findings, and the many irregularities actually explain the correlation between the information capacity requirements, organization structure mechanisms and performances. Moreover, this kind of "network-based-industrialization" is a rather common business solution in practice; many major contractors are trying to improve their performances based on these. This case study, however, indicates that many obstacles must be solved in order to accomplish that objective. Therefore, the case was not dismissed, but actually worthwhile to use and analyze.

# 9 Conclusions and Future Research

*This chapter summarizes the conclusions of the research findings in the light of the thesis' objective and the research questions. It highlights the scientific and business contribution, and suggests future research directions.*

## 9.1 Conclusions

The objective with the research was to explain why and how the change of production topology requires adjustment of the organization structure and the production system. The PTO-model is described in chapter 6, its usefulness is exemplified in chapter 7 by the case study descriptions, and its scientific relevance is analyzed in chapter 8. Together these chapters highlight important organizational and production system aspects to consider when firms changing their customization strategy. Especially when housing firms does the transition from being craft-based to be industrialized, i.e. going from an ETO-topology to an industrial production topology of MTO, ATO or MSP-type. The model also provides fundamental explanations for why the common production topologies require different organizational configurations in order to realize the firms' strategic objectives.

### 9.1.1 The answers to the research question

**The first question reads:**

- *What are the generic causes that explain the organization structure differences between firms with diverse production topologies?*

The explanation is; to work the four generic production topologies require different amounts of information storage in advance and information processing per order. It is the organization structure that possesses the stored information and creates the ability to process information per order (see also figure 9:3).

How the firm perceive its market affects the business strategy and how it chooses to compete. If the firm's market is interpreted as volatile extreme product customization as a competitive factor will probably be prioritized. This requires an ETO-topology and an organic organization structure, because these concepts offer a possibility for comprehensive processing of equivocal information for each project order. If the environment is dynamic a mass customization strategy will be favored, based on its ability to offer some product customization to relatively low production costs. The firm will be developed for managing uncertain information by using the MTO or the ATO production topology. The organization structure will be designed to both store and process information. In stable and predictable markets the organizations will possibly produce standardized products and use a MSP-topology. The organization structure will probably be designed to store certain information for continuously use when producing the products. Figure 9:1 illustrates how the market impacts the customization strategy, production topology and the organization structure type, which are necessary to manage the different amount of information storage and processing.

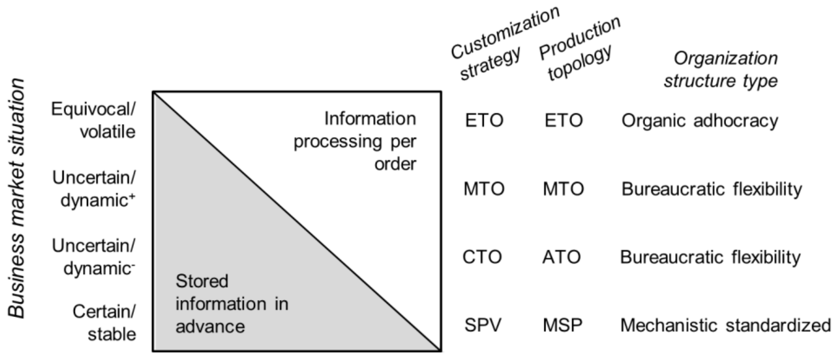


Figure 9:1 The relation between the business market situation, different information storage and information processing requirements and the different customization strategies, production topologies and the organization structure types.

Further, the product customization degree affects the placement of the *customer-order-decoupling-point* (CODP) in the product realization process, and thereby the production topology. Upstream and downstream processes the CODP require fundamentally different organizational structure solutions and managerial devices, which explain why a firm's organization must be developed if the production topology changes (see figure 9:2).

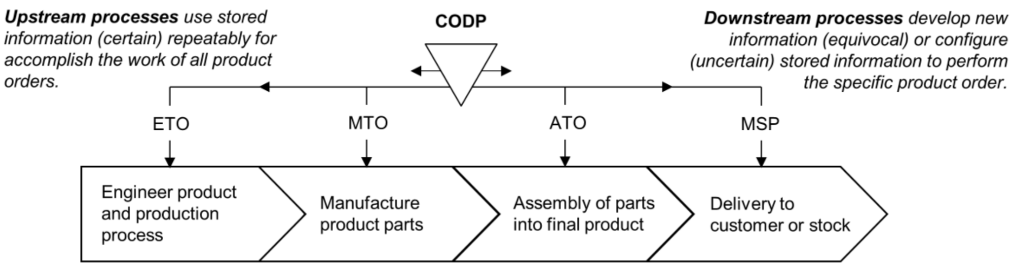


Figure 9:2 Processes upstream and downstream the CODP are executed based on different types of information and therefore require different organization structure mechanisms to be managed.

**The second research question reads:**

- *How does the change of a firm's production topology affect the design of the organization structure and the production system?*

A change of the business strategy, which considers the customization degree and the production efficiency, implies a change of the production topology and the organization structure (see figure 8.2, p. 155). The reason is that this changes the CODP placement within the product realization process (see figure 4:7, p. 52). Processes pre-CODP are mainly managed based on strategically stored information with minimal additional information processing per order. Post-CODP located processes are often managed based on stored information, but require additional information processing per order. Note that the ETO-topology is significantly different from the other topologies, because it only utilizes stored information in minor extent. If the number of processes up- and downstream the CODP change it will impact the information requirements. The intra-organization units that manage these dissimilar process types must be: designed differently; use different organizational devices; and be steered differently (see table 6:10, p. 98). Thus, the new information requirements induce re-design of the organization structure in order to manage each process effectively. Table 6:14 on p. 114 shows how different information requirements can be met by the generic production topologies and appropriate configuration of the organization mechanisms within the PTO-model.

In chapter 6 it is showed how the configuration of the different organization factors and devices will facilitate and favor the two information dimensions in various degrees. If the four major constructs elements: corporate governance and steering, super structure, tasks and processes, and planning and control systems (see also figure 6:5, p. 94), gets appropriate designs, their ability to deal with the information that is suitable the firm can realize the objectives. It is apparent that some mechanisms will mainly contribute to information storage; these will therefore be favored and dominate firms with a MSP-topology. In contrast, mechanisms that facilitate information processing will be comprehensive in organizations with ETO-topologies. Conventional construction firms, which use craftsmen and produce unique buildings, are organizationally very different from mass production firms. The reason is that it is inefficient to store information when there is a risk that this information will not be used in other projects. Instead, construction firms process a lot of information on both managerial and craftsmen level for each project and operation. Consequently, organization structures for ETO-topologies will not be designed to store information. On the contrary, in mass production firms the information processing mainly appears at management and staff level. The manual laborers are in most cases following detailed instructions for each order; therefore, the information processing devices will be very few in this type of organization.

Mass customization firms must possess the ability to both store and process information. The reason is that in industrial firms information storage is a prerequisite, regardless the ability to customize products. Thereby, the organizational mechanism that enables information storage will be comprehensive but complemented with information processing devices (see table 6:13, p. 112 and table 6:14, p. 114).

## 9.2 Scientific contribution

The major scientific contribution of this thesis is the division of the information processing theory into two dimensions: the strategic information processing that develops information for storage within the organization structure for repeatable use when producing the products; and the operational information processing that clarifies exactly what to produce for a given order based on the available stored information (see figure 9:3). This complements the previous information processing theory and significantly increases the ability to predict, analyze and explain organizations' design and behavior.

For example, it is often asserted that construction firms, i.e. craft-based organizations with a production topology of ETO type, are fundamentally different industrial organizations. The motivations for this statement are often limited to business and technical arguments, e.g. the novelty of projects. The underpinning explanations for the differences have been scarce. The previous information processing theory could only explain the differences considering the production of product orders, not the overall organization design or the behavior. By using the two information dimensions the PTO-model can explicitly explain both the order realization mode and the general characterization of organizations with different production topologies. Thereby, the PTO-model can move the scientific discussion to the next level and be applied to clarify many various obstacles for the industrialization of construction.

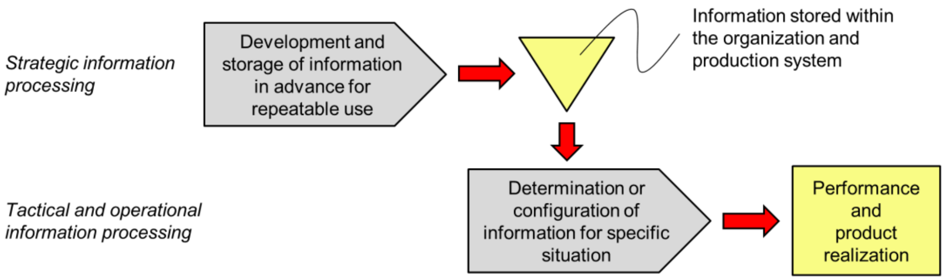


Figure 9:3 The two fundamental information dimensions used in the PTO-model to explain why organizations with different production topologies are structured in dissimilar ways.

In conclusion, the PTO-model provides a mean to predict, analyze and understand the differences between firms' organization structure based on their production topologies. This research shows that industrial construction firms have more in common with industrial manufactures than with conventional construction organizations. Likewise, craft-based manufactures with an ETO-topology, in the manufacturing industry, should organizationally possess more similarities with conventional construction firms than with industrial manufactures. Therefore, the findings are not limited to the construction sector: it is probably more relevant to distinguish firms based on their production topology instead of their industry belonging.

In the paradigm of mass customization, the PTO-model can be used to review and discuss previous research findings. The discussion about the necessary flexibility and its impact on the organization, management and the production system mainly considers the information processing approach. Information storage is a prerequisite for industrial production, which often seems to be forgotten in industrial manufacturing debate. If flexibility is going to be truly understandable both information storage and information processing must be considered. For instance, the appliance of the two information dimensions on the postponement theory can probably increase understanding of what is causing the different characteristic of pre- and post-OPP/PC processes.

### 9.2.1 Industrial contributions

In practice the PTO-model is useful because it explains why it is important to focus on the organization structure, the production system and the technology level when implementing a new strategy or trying to improve the performances. In construction, most performance improvement programs are technology driven, but too often the organizational aspects are forgotten or neglected. This thesis provides insights on what to consider when the conventional or industrialized construction firm develop their production systems or changes the product customization degree. The PTO-model can also be used as an analytical tool to investigate whether the current business organization design is appropriate for the strategic objectives. If the performances are dissatisfying the model can motivate re-organization projects, to align the business organization with its production process.

## 9.3 Future work

The conclusions of this research study are based on four cases, which motivate further validation to secure the generalizability of the PTO-model. Especially considering the two information dimensions: if these are not true the entire model collapse. In order to further challenge the verification process more quantitative oriented studies, supported by for example: axiomatic design, system dynamics, cross-sector case studies and surveys, are suggested.

### 9.3.1 Further verification of the PTO-model and improvement areas

Empirically, more cross-sector case studies are needed that include organizations with different topologies to provide detailed examples and analyses. This will increase the understanding of the relation between the organization design mechanisms and the information storage and processing. Either will such studies further reinforce or reject the PTO-model's predictions. Such "replicate" investigations would also be able to improve the model by identifying any over- and underestimated organizational factors, or even forgotten or unnecessary ones. Comprehensive quantitative surveys can also be performed in order to identify optimal ranges of information storage and processing for different production topologies. Thereby, the generality of the PTO-model can be quantitatively validated based on empirical data.

A weakness with the PTO-model is the emphasis on the organization construct mechanisms and devices; their relations are only indicated. To fully understand and predict the behavior of organizations as systems these relations must be clarified. With system dynamics' tools (simulation models) the behavior of the PTO-model's internal organization mechanisms could be further explored. For instance, the relation between specific structural mechanisms' configurations under different information situations should be possible to investigate and elucidated further. Based on causal loop diagram the specific configuration of the mechanisms could be visualized, and based on simulations the interventions and feedback loops determined.

Through the way the PTO-model manage information it could be the key to interconnect axiomatic design to organization structure theory for more accurate mathematical representation of organization design. This requires, however, that the information storage and processing amount, in order to realize certain functional requirements, is further explored. The relations between the intra-organizational mechanisms must also be further clarified (see above discussion).

### 9.3.2 Suggestions of new research assignments

Many scholars are using the words organic and decentralization without any deeper reflection of what these concepts mean. If these concepts were clarified and updated to the current research and practice it would significantly contribute to the understanding of organization structuring and management of production flexibility. Another academic issue is that organization and production engineering research use the concept of technology in different ways. A harmonization of this phenomenon should be a great contribution for future research, especially today when the world is asking for more integration. Additionally research is also motivated for exploring what changes that are needed to realize mass customization from different perspectives. For example, how impacts the current position of the CODP the required organizational changes for realizing customized products produced in a topology with a different CODP position?

Industrial housing can hardly be understood and developed if research and practice solely is based on conventional construction knowledge: therefore, cross-sector research and business benchmarking studies are suggested. It is when comparing different phenomenon new insights emerged and the previous ones will be challenged. This thesis argues that the sector categorization of firms is highly limited when trying to understand firms' design and behavior – however, this pre-assumption should be challenged. Other interesting questions are (when considering the transition from conventional to industrialized construction): whether a project and a product order are each other equities; and, is a conventional construction project accomplished within a production system? If, as it is argued here, it should imply that a production system of construction firms' delivers many projects. This idea severely challenges the current approach to construction production management, which fundamentally comprehends production from single project and on-site approach – both on academic level and in practice.

Whatever the answer is, construction research should increase the efforts for developing theories of production. Today, when comparing the production knowledge of construction and industrial manufacturing, the building sector lags far behind – this could be a reason for the weak performance development. For example, in the construction the productivity debate lacks a discussion about what is required to achieve improvements. It seems to be more about defense the construction productivity development in comparison to other sectors. A more interesting question is: do conventional construction firms possess the capabilities to improve their productivity to the same extent as the industrial manufacturing firms? If not, what should be developed? What will the sacrifice be? A trade-off research debate between product flexibility, production cost, and productivity improvement would probably be highly knowledge rewarding.

Finally, in this research information was assumed to be the most generic attribute: however, could anything else be more fundamental that the design of producing organization relies upon?

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# Appendix A

Principles of industrial construction
Gerth (2008, p. 81-82)

# Principles of industrial Construction

A production system for industrial construction is characterized by industrial manufacturing of components and modules in factories. These parts are delivered to the fixed location where building will be erected in order to assemble in a predetermined and standardized way. Multiple building orders will be produced within the same industrial production system and based on the same (generic) product model.

The foundation for industrial construction is the same as the principles for industrial manufacturing, which were developed by Taylor (1967) and Ford (1924) to transform the automotive sector from being craft-based to industrial in order to improve the productivity. However, Gerth (2008) adapted these principles (see below) to the requirements of construction and the perceived necessary product flexibility. The principles are based on each other in sequence, i.e. a latter one will not work without the former one(s).

1. ***Standardized but flexible product models***

A standardized product model describes the constituent components, how they are arranged and which product features that can be created. Standardized interfaces between the components and modules create the product flexibility, and predefined combination rules determines how the product can be configured. In true industrial construction, the use of a generic product model is mandatory for being used repeatable when realizing each project order.

2. ***Formalized and standardized flexible processes***

Standardized processes mean that all the operations and tasks in the workflow is defined and correlated to detailed working instructions. Each operation is correlated to the production of a specific component, which implies that every time this component is produced the operations follow the same procedures. The accomplishment of each operation in accordance with the instructions if severely facilitates the planning, process monitoring controlling and quality control. Productivity improvement is created by introduce changes in the operation instructions, which after the implementation is used every time the operation is performed. Process flexibility is managed through combination of the sub-processes and operations, driven by the product order configuration.

3. ***Manual labor, mechanical and automated production equipment***

In industrial construction the craftsmen are replaced with manual labor, i.e. all operations are executed exactly according to the regulating instructions. The standardized process also allows the usage of mechanized or automation of operations to further makes the work more productive. When the work is mechanized the manual work content is reduced to be regulated by the machine and instructions. Automated operations mean that the work is fundamentally performed by robots, and the human effort has been reduced to monitor the machines work.

## 4. *Process orientation of the industrialized construction firm*

Process orientation means that the resources within the firm and the production system are organized around the standardized but configurable product realization process. The resources, e.g. people and production technology, should be arranged in such a way that it optimizes process material flow and value stream flow of the generic product offer – not for each single product configuration. Thereby, the improvement of a single component in the generic product model or of an operation in the production system will improve the whole firm's performances and not only the specific project order.

## 5. *Production and process flow management*

The process orientation together with previous principles enables the workflow through the entire product realization process so that it can be more easily coordinated, balanced and controlled. The reason for this that all information that is used to steer the process is available, and does not need any development, only some minor additional specification (configuration) of specific order requirements may be needed. In turn, the whole firm and the production system become much more predictable than the case is for conventional construction companies.

# Appendix B

The flexible industrial construction firm
Gerth (2008, p. 83-86)

# The flexible industrial construction firm

Industrial construction is a business and production strategy with the purpose to improve the firm's competitive advantage. In comparison to conventional construction, this strategy changes the organization structure, marketing and business customer relation, the product architecture structure, the production system and technology, and the information and communication management (see figure A1).

The figure presents the infrastructural parts of an industrial construction business firm which can produce and offer customized buildings. The business idea and strategy is perceived to be the foundation for the entire company. The wall pillars are the primary operational parts which highly integrated and are important to realizing the customers' products. When a contract is customized and realized information from all these areas are needed. Therefore, part information and communication management is illustrated as a beam which integrates and transfer information between the operational pillars, in order to satisfy each single customer on the determined market segment. Note that this model relies on the industrial principle in appendix A.

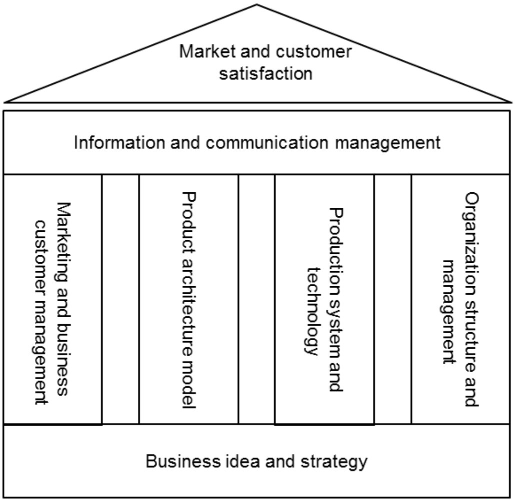


Figure A1: Illustration of the parts of the "flexible industrial construction model", from Gerth (2008).

***Business mission and strategy***

The business idea and strategy describes the basic purpose of the firm to create a solid base for the rest of the business. It includes the company's vision, mission, strategy and culture. The vision is to create a mental vision that in the long run creates development efforts and clarifies ambition. The mission intends to capture the company's focus, core and the market for the business. The corporate culture can create a sense of belonging for the organization members as well as impact their working behavior. These three factors should be considered when developing and formulating new strategies, due to that it severely impacts the progress of organization change and implementation.

***Organization structure and management***

This part gives the other operational parts structure, i.e. it regulates how the other parts should be designed and interacts. The factor organization structure describes how the formal division of work, the duties of each unit, and the units interfaces' with each other. This factor is severely integrated with the system of processes, which include all sub-processes and operations of the product realization process and the staff and managerial processes. The factor steering devices will vary depending on how the company has defined, designed and accomplish the processes.

***Market and business customer management***

The strategy has major impact on how the firm acts on the market and makes business with the customers. This is considered in this part, which includes the factors: marketing, product offer, and customer value. In industrial construction companies, the chosen market's needs must be identified and translated to generic customer values. These customer values that are translated to functional product requirements and be the design base for the generic product model. When the actual business contract, i.e. a project order, is discussed with a clients or a customer, it is the total market offer (all the possible product features or customer values the generic product model can create) that is customized, or configured, into specific project features. In order to accomplish this process effectively ICT-system as product configurators and ERP systems are often used.

***Product architecture model***

The generic product architecture model is necessary to create and realize customized products. Depending on the type of product architecture different degrees of product flexibility can be created. The factor product structure and standardization level describes how the customer values is correlated to different standardized levels of components, modules or platforms depending on the standardization degree. The products structure describes how the different generic parts are interrelated and the configuration regulation steer how these parts can be re-arranged to create specific customer values. The product architecture is very integrated with the production process and operations, due to each component must have instructions on how they are produced so that the correct product feature can be created.

***Production system and technology***

The production of customized products requires a flexible industrial production system. The part production system and technology can be described in terms of the factors manufacturing system layout and technology level (see appendix A), which are self-explanatory. The material supply considers the internal and external material flow and the production steering principle, i.e. the planning horizons, production reconfiguration, process planning and preparation.

***Information and communication system***

When a product is customized in an industrial construction firm pre-developed [stored information] information is managed from most of the organizations units and processes. It is only through the updated use of information from the generic product model, the production system processes, and the material supply chain, the control of specific order customer values regarding cost, delivery time and product features is possible. Thereby, the information and transfer of the correct information pieces can become very complex, which motivates the use of ICT-systems. Product configurators are IT-tools (software) that combine information stored within other IT-system, e.g. PDM, ERP, and MRP. A seamless information and communication flow between the different IT-systems and the different department within the organization is a key to customize products in industrial construction companies effectively. However, depending on the product and production flexibility it requires different management devices.

# Appendix C

Interview guide 1 (Swedish and English)

# Swedish version

*Introduktion – hur X är som företag*

( ) Berätta lite om dig själv, vad du har för bakgrund och när du började på Peab?
( ) Hur skulle du beskriva X som företag? Hur har X förändrats sedan du började?
( ) Vad är karakteristiskt för företaget? (kultur)

*Vad arbetar du med? Vad innebär din roll?*

( ) Vad arbetar du med? Vad är ditt ansvar och dina befogenheter?
( ) Hur har din roll utvecklats över tiden? (erfarenheter, inspiration, kunskap)
( ) Hur syns eller märks detta i ditt sätt arbete?
( ) Försöker du sprida dina erfarenheter? Hur och till vilka?
( ) Det du arbetar med, finns det uttalat eller dokumenterat någonstans?
( ) Hur vet du vad ska göra? Hur vet du att du gör det på rätt sätt?

*Hur styrs du uppifrån av din region och division?*

( ) Peab har ju en ny vision och strategi, har denna blivit nedbruten till en affärsplan för din region och till en handlingsplan för dig? Finns det konkreta (mätbara) mål i denna för dig och din arbetsgrupp? Ex. på mål?
( ) Hur styrs din division av koncernledningen? Hur styrs din region av divisionen?
( ) Hur koordineras regionens arbetschefsgrupper av regionen?
( ) Hur ofta pratar du med din regionchef (via möten och på tu man hand)? Vad pratar ni om då?
( ) Vad tags upp på dessa möten? Vilka möten är viktigast för ditt arbete?
( ) Vad följer din region upp för din grupps verksamhet? Exempel?
( ) Hur styrs din grupp mot målen i affärsplanen?
( ) Vad händer om du och din grupp inte når de uppsatta målen? (Affärsplan/handlingsplan)
( ) På vilket sätt stöttas du och din organisation i arbetet med att uppfylla målen?

*Hur skulle du beskriva din arbetschefsgrupp?*

( ) Hur är din arbetsgrupp organiserad? Vad gör respektive roll?
( ) Hur många projekt har ni igång just nu? I produktion och i tidiga skeden?
( ) Hur många projekt är respektive roll involverade i samtidigt?
( ) Hur är yrkesarbetarna placerade? Vem har medarbetarsamtal och personalansvar?

*Hur arbetar du och din organisation fram bostadsprojekt?*

( ) Vad tycker du om verksamhetsledningssystemet och de formella processerna? Använder du dessa i ditt arbete? I vilken grad använder dina projekt dessa för de faser där du inte arbetar så mycket?
( ) Diskutera runt dokumentet ”Bostadsprojektprocessen från idé till förvaltning”.
( ) Vem gör vad i processen? Vad gör respektive roll? (DC, RC, PU,AC, PC, AL)
( ) Vilka delar är du mest involverad i? Vilka faser är du ansvarig för?
( ) Hur initieras eller tilldelas din grupp projekt? (Markköp)

*Hur utformas och planeras nya projekt?*

( ) Vad är ett framgångsrikt bostadsprojekt enligt dig? Finns detta formulerat någonstans?
( ) Hur arbetar din grupp för att projekten skall uppnå detta?
( ) Påverkar affärsplanen ett projekts utformning? Hur då?
( ) Hur tar man fram ett projekts projektmål? Ge exempel på projektmål? Vem gör detta?
( ) Hur planseras och styrs ett projekt för att projektmålen skall uppnås?
( ) Vad baserar sig tidplanerna på? Vem planerar? Hur uppdateras aktivitetstiderna?
( ) Hur säkerställs det att bemanningen av respektive projekt har rätt kompetens i rätt mängd? Vilka roller dedicerar man till vissa projekt?
( ) Hur beaktas tidigare projekterfarenheter vid projekteringen och planeringen av nya projekt? Varifrån hämtas/kommer dessa erfarenheter?

*Hur koordineras pågående och inkommande projekt?*

( ) Din grupp har ju flera projekt igång samtidigt - hur vet ni/du att det finns tillräckligt med resurser i pågående projekt när nya projekt skall starta?
( ) Hur koordineras tidplanerna och bemanningen mot de andra projekten som din grupp redan har igång?
( ) Har regionen möten för att diskutera bemanning och resursfördelning av pågående och nya projekt? Tidshorisont?
( ) Hur ofta görs detta? Vilka är med på dessa möten? Vad diskuteras?
( ) På vilket sätt är du uppdaterad projektens status inför dessa möten? Vad är det som följs upp i respektive projekt?
( ) Hur prioriteras projekt? Vad avgör bemanning och annan resursfördelning?
( ) Hur planeras din grupps verksamhet? Långsiktiga och kortsiktiga tidplaner?

*Hur styrs och följs projekt upp?*

( ) Vad följs upp i pågående projekt? Ge exempel? Hur ofta? På vilket sätt? Vad diskuteras?
( ) Vad görs om det finns risk att projektet inte kommer att uppfylla uppsatta mål?
( ) Hur fångas erfarenheter från ett genomfört projekt upp? Hur återanvänds dessa i nya projekt? När är det viktigt att beakta dessa erfarenheter?
( ) Hur hanteras funktionstester, besiktningar, projektrevisioner? Andra sätt att fånga upp produktionserfarenheter? Lagras dessa någonstans?
( ) Försöker man minimera antalet anmärkningar/avvikelser/brister? Hur då? Hur förebyggs liknande problem kommande projekt?

*Avslutning*

( ) Utifrån det vi har pratat om - vad tycker du är viktigt att fokusera på för att vi ska kunna förbättra och effektivisera våra arbetssätt och vår bostadsproduktion?
( ) Hur gör ni för att effektivisera era projekt?
( ) Hur gör du för att hålla nere produktionskostnaden?

# English version

*Introduction – how is X as a company*

( )  Tell us little about yourself, what your background is and when joined X?
( )  How should you describe X as a company? How has X evolved since you started?
( )  What is characteristic for the company?

*What is your role and duties?*

( )  What are you working with? What are your responsibilities and authority?
( )  How has your action within this role been developed since you started?
( )  Do spread and support others with your experiences? How? Why? Who?
( )  The stuff you are working and do with, is it expressed and described anywhere?
( )  How do you know what to do? How do you know that what you do is the right way?

*How is your division, region, department or working unit manage or controlling your work?*

( )  X has a new strategy, has it been developed and implemented as a business plan for your department? Are there any measureable goals for you and your unit? Give me some examples on these goals?
( )  How is your division managed by the corporate management? How is the division controlling the region? How is the region controlling your project portfolio?
( )  How is the regions contracts managers' groups management by the region manager?
( )  How often do you speak with your manager?
( )  What is considered during the management meetings?
( )  What is controlled and measured for your working unit? Example?
( )  How is you managed/steered towards the business plan goals?
( )  What is happening if you and your group do not is achieve these goals?
( )  How is you and your group supported to achieve the goals?

*How should you describe your working unit (contract manager group)?*

( )  How is your group organized? What does respectively role does?
( )  How many projects have your group currently running? (early phases and in construction phase?
( )  How many project is respectively role active and involved in?
( )  Where is the craftsmen placed? How are they organized? Who is the responsible manager?

*How does your group develop and realize housing projects?*

( )  What do you think about the management and project process system? Are you using these when accomplish the projects? In which processes and in what extent?
( )  Can you explain the housing development and construction process for me? (Show the company's process chart)
( )  Who does what in the project process? Does it change from project to project?
( )  Which parts are you mostly involved within?
( )  How are projects initiated? (real estate investments)

*How are new housing project realized?*

( )  How would you describe a successful housing project?

( ) How is your group working to accomplish this?
( ) Does the business plan impacts the design of new projects?
( ) How are new project goals developed? Can you give any example? Who does this?
( ) How is the new project planned and design to realize the specific goals?
( ) What is the development of the time schedules based on? Who plans the projects? How and when is the action plans updated?
( ) How is it ensured that the project participants have the right competence? Which roles are dedicated to specific project processes or projects?
( ) How are previous project experiences considered when designing and planning new housing projects? From which positions/roles/individuals are these experiences are collected?

*How are project in progress and new ones coordinated?*
( ) Your group have many projects in progress simultaneously, how do you know that there is enough of resources to manage both the ongoing and new ones?
( ) How is the action scheduling of new projects coordinated with the resources of the currently projects?
( ) Does the region management have meeting to discuss the resource coordination between the contracts mangers' project portfolios? Which is the time horizon during these meetings?
( ) How often is these meeting accomplished? What is discussed? Which roles participate?
( ) How is you updated on the status of your projects before these meetings? What are you controlling in your projects? What is controlled within the projects on the regional management meetings?
( ) How is project prioritized? Who execute this and the resources allocation?
( ) How is your groups operational business planned? Strategically (3-5 years) and short termly (0-2 years)?

*How are the project operationally managed and controlled?*
( ) What is continuously controlled in running projects? How often? How is this performed? (Example)
( ) If there is a risk that a project does not will achieve the targets, what do you do?
( ) How is experiences from a performed project collected? How are these re-used in new ones? When is important to consider previous experiences?
( ) How are functional tests, building quality and project revisions managed? Are these revisions reports stored anywhere? Do you review these? Are there any alternative ways to capture quality problems (and production knowledge)?
( ) In your work group are you trying to avoid and prevent construction problems and inspections remarks? How?  How is similar problems prevented to happen forthcoming projects?

*Final questions!*
( ) Based on what we have been talking about; what do you think is the most important to focus on for the company to improving the corporate and the projects business performances?
( ) How do you work with improvement in your projects
( ) What do you do to reduce the production cost and improve the product quality?

# Appendix D

Interview guide 2 (Swedish and English)

# Swedish version

Företagets utformning och marknadsinriktning

( ) Hur skulle du beskriva företaget?
( ) Hur är företaget organiserat? (organisationsschema med enheter)
( ) Hur ser produktframtagningsprocessen ut? (från utveckling, via produktion till leverans)
( ) Vad är respektive enhets uppgift och roll i de steg de är involverade i?
( ) Hur ser ert marknadssegment ut? Vilka är era kunder?
( ) Vilka är era konkurrenter? Vad är ert främsta konkurrensmedel gentemot era konkurrenter?

*Modularisering - produktstrukturer och produktutveckling*

( ) Hur ser modulariseringsprogram/byggsystem ut? (artikelstruktur/modultyp/produktstruktur)
( ) Vad innebär det? Vad är kärnan och syftet med det?
( ) Finns det en produktstruktur för respektive kundsegment eller är den gemensam? Varför?
( ) Finns det en tanke om hur varje komponent/modul bygger upp slutproduktens kundvärde?
( ) Hurdan information hanteras om komponenterna och modulerna?
( ) Hur lagras information om produktprogrammet och ingående komponenter/moduler?
( ) Hur används denna information i produktframtagningsprocessen?
( ) Hur standardiserat är produkt-/byggsystemet? Är samtliga komponenter och moduler fördefinierade? Vad är variabelt och standardiserat? (komponenter, moduler, regler)
( ) Hur flexibelt och standardiserat är produkt-/byggsystemet? Är alla möjliga slutproduktvarianter fördefinierade?
( ) Vilka faktorer är extra viktiga att beakta när en komponent/modul skall förbättras/utvecklas?
( ) Vad optimerar företaget produkt-/byggsystemet mot?
( ) Hur återförs produktionskunskap om moduler, komponenter och processen till produkt-/byggsystemet? (tider, kvalitet, slöserier, material)
( ) Hur hanteras kvalitetskontroller? (komponent, modul, slutprodukt, process, operation)
( ) Utifrån företagets perspektiv vad krävs det för att modulariseringsfilosofin skall fungera?

*Kundanpassning/produktkonfigurering*

( ) Vad är syftet med att ni arbetar med kundanpassning? Vilka för- och nackdelar finns det med kundanpassning i förhållande till det vandliga sättet i industrin?
( ) Hur kundanpassas produkterna av kunden? (metod)
( ) Hur används produktprogrammet för detta?
( ) Hur ser kundanpassnings ut (från kundkontakt till order)?
( ) Förklara respektive steg.
( ) Vilka verktyg används i denna process (IT och manuella)? Hurdan information används i respektive steg?
( ) Varifrån hämtas denna information?
( ) Utifrån ert perspektiv, vilka förutsättningar måste vara uppfyllda för att ett företags kundanpassning/produktkonfigurering skall fungera?

*Produktion*

( ) När en kund har specificerat sin produkt och lagt en order vad händer sedan?

( ) Hur ser produktionsproduktionsprocessen ut? (övergripande processnivå order till leverans)
( ) Hur styrs/planeras och bereds produktionen (mot order, förbrukningsstyrd, mot prognos)?
( ) Hur hanteras ingående material? (JIT, lager, halv-fabrikatstillverkning)?
( ) Är det lika för samtliga delar inom produktionen? (pre- och post-CODP, fabrik, byggplats)
( ) Vilka delar av tillverkning är manuella, maskinella och automatiserade?
( ) Hur är maskinerna/robotarna integrerade med varandra? Hur styrs de (ställs de)?
( ) Är samtliga aktiviteter och metoder i tillverkningsprocessen fördefinierade och standardiserade? På vilket sätt? Hur efterlevs beskrivningarna/instruktionerna i verkligheten?
( ) Hur hanteras olika order i slutmonteringen med avseende på materialförsörjning och att respektive order i princip kan bestå av olika och antalet komponenter?
( ) Om en kund ändrar sig under pågående produktion kan en order förändras? När och hur?
( ) Hur kommunicerar företagets respektive tillverknings- och montageenheter med varandra samt med leverantörer? Hur kommuniceras överlämning av en komponent och modul till nästa steg i processen?
( ) Vilka förutsättningar måste vara uppfyllda i produktionen för att tillverkningen av kundanpassade order skall fungera?

*Process och IT*
( ) Används IT-system för att stötta produktframtagningsprocessen? (Typ/vilka)
( ) Var i produktionsprocessen används ar respektive system? Hur används informationen?
( ) Vad är respektive systems uppgift?
( ) Är IT-systemen integrerade?
( ) Hur hanteras orderunika komponenter samt moduler i processen och av IT-systemen?
( ) För att konfigurera en produkt behövs IT-system? Vilka behövs? Varför?

*Avslutande och sammanfattande fråga,*
( ) Vad krävs det således av ett företag som erbjuder kundanpassade produkter?

# English version

The company's organizational design and market

- ( ) How would you describe the company?
- ( ) Can you explain the organization structure (chart) with the main units?
- ( ) Which are the major step in the product and product realization process?
- ( ) What is respectively organization unit's role in this process?
- ( ) What is your market segment? Which are your customers?
- ( ) Who are your competitors? What is your primary competitiveness factor?

*Product structures, modularity and product development*

- ( ) Can you describe your product structure/building system? (e.g. modularity, standardization, inter-change of parts)
- ( ) What is purpose with this system in comparison to the traditional products in the industry? What is the core?
- ( ) Which are the major parts?
- ( ) Is there a thought on why and how every part contributes to the final product's customer value?
- ( ) Have each market segment, customer group or product line its own product structure? Why?
- ( ) What kind of information does the product system contain and managed regarding the components and modules?
- ( ) How is this information stored?
- ( ) How is this information used when producing customized products?
- ( ) How flexible is the product structure? Is ever final product variants pre-developed?
- ( ) Are every part and module standardized and pre-defined before the customer arrives? What in the product structure is changeable and standardized?
- ( ) Which factors are essential to consider when developing components or modules within the product structure or the product structure its self?
- ( ) What is the company optimizing the product structure towards?
- ( ) How is production knowledge for manufacture the modules and components fed backed and re-used to the product structure development? (e.g. time consumption, quality, waste, material types, manufacturability, assembly)
- ( ) How is quality control managed?
- ( ) Based on a corporate approach what is necessary to make the modularity or customization concept to work?

*Customization and product configuration*

- ( ) Why do you work with customization? Which are the advantage respectively drawbacks with customization in comparison to the traditional way of managed this in your industry?
- ( ) How is the products customized by the customer?
- ( ) How is the product structure used for this?
- ( ) Can you explain the customization process? (from custom contact to delivery of specified order)
- ( ) What kind of information is used in respectively sub-process?
- ( ) Which tools are used to manage this process? (IT-based or manually)
- ( ) Where does this information come from? Where is the information stored and located?

( ) Based on your experiences, which requirements must be solved in order to make customization to a competitive advantage?

*The production process*

( ) When a customer has specified the product and order it, what is happening thereafter?
( ) Can you explain the production process from order specification to delivery)?
( ) How is the production planned and managed? (pre-CODP and post-CODP, stock vs. order driven)
( ) How is the material flow managed? (e.g. JIT, stocks, suppliers, part assemblies, conveyors, transportation)
( ) Is it similar for all production processes? (processes pre-CODP respectively post-CODP, in factory and on-site)
( ) Which parts of the production processes are manual, heavily machine supported and automated?
( ) How is the machines and robots managed and integrated with each other?
( ) Is every part and activity of the production process pre-defined, standardized and formalized? How is these instructions followed in reality?
( ) How is the final assembly of several orders at the same time managed considering the material flow and the fact that each product order contains different modules and components?
( ) If customer change its mind regarding a specified order, can this order re-specified? When? How?
( ) How is the companies different production units and groups communicate with each other? With suppliers? How is the delivery of components and modules communicated between these parties?
( ) Which requirements must be fulfilled in order to make the production of customized products productive?

*ICT and processes*

( ) Is IT-system used to support and manage the product realization process?
( ) What kind systems is used? What is the purpose of each system?
( ) Which major processes use which IT-systems? How is the information these systems possess used? For what actions are the IT-system used?
( ) Is the systems integrated?
( ) How is order specific components and modules managed by the IT-systems?
( ) In order to configure a product must IT-systems be used? Why? Which system are the most important ones?

*Final questions*

( ) Based on what we have been discussion, what is required by a company that offer and produce customized products?

# Appendix E

Interview respondents

## Case A – Peab

Division manager
Region manager
Project manager
Business process developer
Environment manager
Staff members
Contract manager
Real estate developer
Human resources
On-site manager
Project engineer

## Case B – NCC Komponent

CEO
Market and sales manager
Production manager
Product engineer
Project coordinator
Project manager
Product design/architecture
Purchasing and logistic
Process planner
Product engineers
Assembly manager
Assembly foreman

## Case C – DLL-network

Department manager (NCC)*
Project coordinator (NCC)[1]*
Project developer (NCC Construction)[1]
Project manager (NCC Construction)[1]
On-site manager (NCC Construction)*
Production manager (Finndomo)[1]
Project manager (Finndomo)[1]*
Product engineer (Finndomo)*
Architect (Finndomo)[1]

## Case D - Scania

Organizational development manager
Market and sales manger
Product development manager
Business system manager (ICT)
Process planner
Purchasing and logistics
Production manager
Line manger

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*Explanations*
[1] Interview respondents
*Participants in group discussions

Note that in most cases multiple individuals with the same position were interviewed.