Master's degree thesis

LOG950 Logistics

"Analysis of visibility dimensions in make-to-stock and engineer-to-order manufacturing strategies: A Case Study of Pipelife AS and Kleven AS.

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Abstract

Purpose –Supply chain visibility has gained much attention even though it still remains a poorly understood concept. Traditional enablers of visibility mainly include information sharing, IT implementation, use of tracking devices, cyber-physical systems, and the degree of collaboration and relationships between supply chain partners. Make-to-stock an engineer-to-order environments are to opposite manufacturing strategies in which the main difference lies in the position of the customer order decoupling point, which influences the degree of collaboration between supply chain partners, level of information shared as well as coordination of operations and processes taking place. The purpose of this study is to investigate factors influencing the need for visibility in make-to-stock and engineer-to-order manufacturing strategies, and assess the effect of increased visibility based on the customer order decoupling point.

Methodology – An extensive literature review revealed main characteristics of MTS and ETO strategies which was further evaluated in conjunction with factors determining the need for visibility dimensions. The main visibility dimensions suggested are within the areas of demand, order, supply, warehouse, personnel and process visibility, in which each dimension are assessed through factors determining the need for visibility. The research was further conducted through two case studies within the shipbuilding and pipe industry. The case companies present two different manufacturing strategies, Pipelife as a make-to-stock company and Kleven as an engineer-to-order company. Semi-structured interviews were carried out with case company representatives in addition to company visits and observations. Finally, an analytical model was developed in order to investigate in which the effect of increased visibility has greater impact on the two manufacturing strategies.

Findings – The results of the case analysis clearly illustrate that ETO environments requires higher degree of visibility within the dimensions presented due to low demand predictability, low order steadiness, complexity of contractual terms, manual manufacturing processes, non-routinized work methods, and due to high product complexity and order frequency. The results also reveal that the effect of increased visibility in ETO manufacturing environments are significantly higher compared to MTS strategies. In MTS environments, the need for visibility was determined by high order frequency and high inventory levels which resulted in need for order visibility and warehouse visibility.

Practical implication – The visibility dimensions suggested and the developed analytical model aims to reveal factors of manufacturing strategies determining the degree of visibility and to what extent the effect of increased visibility has on the respective manufacturing strategies.

Keywords: Visibility in manufacturing, supply chain visibility, information sharing, collaboration, manufacturing strategies,

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Abbreviations

ATO	Assembly-to-order
B2B	Business-to-business
B2C	Business-to-consumer
CODP	Customer Order Decoupling Point
CRM	Customer Relationship Management
EDI	Electronic Document Interchange
EPCIS	Electronic Product Code Information Systems
ERP	Enterprise Resource Planning
ETO	Engineer-to-order
FP	Finished products
HR	Human Resources
IOT	Internet of Things
IT	Information Technology
LT	Lead Time
MTO	Make-to-order
MTS	Make-to-stock
NO	National organization
PG	Purchased Goods
PLC	Product Life-cycle
RFID	Radio Frequency Identification
SA	Sub- assemblies
SC	Supply center
SPC	Statistical Process Control
SCM	Supply Chain Management
VMS	Vendor Management Systems
WIP	Work in Progress
WMS	Warehouse Management Systems

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1.0 INTRODUCTION

The increasing pace of complex manufacturing operations and multiple tier supply chains creates a rising challenge for managing manufacturing operations and supply chains. Due to high globalization and usage of advanced production technology, supply chain operations are becoming more complex, costly and more difficult to control (Butner 2010). This thesis mainly started as my interest and curiosity of RFID technology, enabling traceability and tracking objects across the supply chain and in manufacturing operations, by gaining valuable information through information technology. The increased interest was an impact of how it could simply generate transparency and information across relevant individuals and further be used for better support and decision-making. However, as the research continued and literature reviewed, one main concept caught my attention: visibility.

Within the literature of supply chain, visibility has gained much attention although it still remains a poorly understood topic. Assumptions have been given considering supply chain visibility and how it improves organizational performance. In this thesis, supply chain visibility is defined as the identity, location and status of entities, captured in timely messages about events, along with the planned and actual dates/times for these events (Francis 2008).

Visibility within manufacturing strategies are defined as gaining production and operational data at plant floor level including information of inventory, production processes, schedules, and coordination and flow of materials and information through the manufacturing plant (Boe 2015). Hoerig (2015) recognizes the need to improve visibility, efficiency and transparency with the usage of real-time shop floor control technology to prioritize, track and report production orders and schedules. The solution provides visibility into each production activity to maintain effective control for managing production processes. However, to which degree visibility is required based on implemented manufacturing strategy has not been assessed.

Manufacturing strategies are widely discussed in the literature, recognizing different production methods, mainly based on product complexity and customer order decoupling point. The degree of information sharing, collaboration and coordination within manufacturing operations and external participants is suggested to differ with the type of manufacturing strategy. The various categories generate diverse operations and information sharing across and within the supply chain centered on the goods supplied.

ETO strategies constitutes highly complex manufacturing/assembly processes, working disciplines, and high degree of integration and coordination between multiple supply chain partners. The characteristics of the shipbuilding industry necessitates concepts considering product development and its interface with manufacturing processes (Hicks, McGovern og Earl C.F 2000). On the other hand, MTS strategies encompasses standardized and automated processes, which enables production of large quantities at a shorter time, encompassing higher degree of routine work, but with highly technical and advanced manufacturing equipment and machinery for welding and molding.

Based on the two manufacturing strategies focused on in this thesis, the degree of visibility is suggested to be diverse. This paper suggests that the need for visibility in different manufacturing operations also changes along with the manufacturing strategy environment. This thesis addresses the need for diverse dimensions of visibility and the effect it has on the already existence of manufacturing characteristics. The choice of manufacturing strategy can be explained by the position of the customer order decoupling point, at which MTS strategies are located downstream in the supply chain whereas ETO strategies are located on the opposite side. However, the manufacturing characteristics can also be associated to similar characteristics for make-to-order and assembly-to-order environments as some overlaps.

The solution regarding this thesis does not aim to provide a universal solution and definition of visibility dimensions based on manufacturing strategy. What is essential is how the level of visibility differentiates between manufacturing strategies, namely make-to-stock and engineer-to-order, by evaluating the characteristics and features of the manufacturing environments and its impact on material and information flow, collaboration, and communication technology.

In order to evaluate the need for visibility in make-to-stock and engineer-to-order environments, The *Theory Development* chapter introduces external and internal dimensions of visibility and factors influencing the need for the specific visibility dimension. The theory development chapter also proposes a model aiming at illustrating the significant effect of increasing visibility in engineer-to-order strategies compared to make-to-stock strategies.

2.0 RESEARCH REVIEW

This chapter gives an overview of the key research areas and comprises the contextual background for the thesis, problem statement and research questions, target group, delimitations and further outline of the paper.

2.1 Background

Between autumn 2015 and autumn 2019, a comprehensive research project concerning the manufacturing industry in Norway is conducted by Molde University College, Norwegian University of Science and Technology (NTNU) in Trondheim and actors from Møre and Romsdal in Norway, which is stated to be the largest research project managed by the research community in Møre and Romsdal. The research project has a vision to develop a platform of knowledge between research and industry, which will result in the Norwegian production industry to expand the concept of industry 4.0 to integration of global production networks. The research partners include Ikuben, Ekornes, Norwegian Rooms, Kleven, Pipelife and Brunvoll. The project is apportioned into four work packages, 1) focusing on value chain configuration including sourcing strategies, 2) innovation in production network, 3) the next generation of production, as well as 4) collaborative planning and control in value chains.

This thesis is part of the research project, and aims at evaluating degrees to which increased visibility has an impact on the respective manufacturing strategies. The thesis concerns the assessment of manufacturing companies in Norway, in cooperation with Pipelife and Kleven as the two main case companies. Further, the need for increased visibility covers a wide scope of viewpoints, including the operations, processes and supply chain linkages across companies.

2.2 Objective and Research Questions

The focus of this study aims to reveal the factors determining the need for visibility in make-to-stock and engineer-to-order manufacturing strategies. Further, the research also aims to identify the effect of increased visibility based on the existence and characteristics of manufacturing environments, in terms of inequalities and similarities.

The objective of this master thesis is to:

"Investigate the impact of visibility in make-to-stock and engineer-to-order manufacturing strategies".

The following research questions have been addressed in order to support and answer the overall objective:

RQ1: What are the main factors influencing the need for visibility in ETO and MTS manufacturing strategies?

RQ2: How can dimensions of visibility be categorized based on the characteristics of manufacturing strategies?

RQ3: How does the position of the CODP effect the need for manufacturing and supply chain visibility in ETO and MTS strategies?

The first research question aims to realize the characteristics of ETO and MTS manufacturing operations and factors of significant impacting the need for visibility including information sharing and collaboration between supply chain partners and intra- related manufacturing operations, as well as coordination of such activities. The second research question aims to discover areas of visibility in order to evaluate dimensions of visibility in ETO and MTS environments. The last question points to reveal the effect of increased visibility based on the existence of manufacturing strategy and the position of the CODP.

2.3 Target Group

The primary target group of this master thesis is comprised by manufacturing companies and researchers that wish to gain insight into how different manufacturing strategies reflects on the need for various dimensions of visibility. Another target group that may hold interest in this thesis would be other master students in logistics and supply chain management, as well as lecturers and professors interested in the field.

2.4 Delimitations

Case company perspective - The research of this thesis is based from the case company`s point of views, which can be defined as the manufacturer governing over the supply chain, has bargaining power and manufactures end-products. Companies involved in this thesis, Pipelife AS and Kleven Verft AS, can be classified as the focal companies in their separate supply chain.

The main focus of this thesis emphases the degree to which visibility is desired based on manufacturing strategy, and does not aim to discover the methods for increasing visibility in manufacturing operations and supply chain. However, methods and tools for increasing manufacturing and SC visibility have been shortly described based on previous literature.

B2B perspective - The focus of the research is on linkages between business-to-business relationships in the supply chain as well as internal visibility concerning manufacturing operations and processes. However, the research uses the customer order decoupling point as a reference to differentiate manufacturing strategies due to the degree of external and internal integration, collaboration, coordination and information sharing in a supply chain.

In this study, the term visibility is an outcome of information sharing, collaboration, reliable data collection and transparency of material flow at manufacturing plant and across supply chain partners. It involves visibility at two levels: physical visibility of materials and operations, and visibility through information technology enabling collecting value-added data and relevant information. However, it does not aim to discover types of information technology systems for different purpose and areas, or how it provides relevant data in real-time for greater visibility.

2.5 Outline of the Thesis

The **Introduction** provides an overview of the term visibility, the main manufacturing strategies and industry involved in the study to acquaint the reader with the main research study areas of this thesis.

The **Research overview** presents the background for the research, the main research objective and research question. Further, the chapter addresses convenient audience for further exploration, as well as delimitations in order to constrain the reader to the areas of this thesis.

The **Literature review** describes relevant theoretical topics, theory development of visibility dimensions and analytical model. The literature review consists of two main subjects; 1) The concept of visibility in manufacturing and supply chains including benefits and approaches to gain visibility, and 2) Manufacturing strategies and the disparities of ETO and MTS strategy. The theory development is based on assessing different types of visibility indirectly proposed by various authors. The analytical model is based on the need for visibility, and the effect of increased visibility based on manufacturing operation.

Research methodology presents an overview of how the research was conducted, including number of articles collected and key searching terms. Further, it describes choice of research methodology and choice of case companies. Additionally, method for data collection and data analysis is highlighted, and the degree of reliability and validity concerning data collection and execution of this thesis. Finally, main limitations of this thesis is presented.

Further, the **Empirical findings and case analysis** describes the empirical evidence exposed from the case companies involved (Pipelife and Kleven) linked to the theory development and analytical model. Thus, the chapter describes the specific manufacturing strategies and relevant data for assessment. Further, current level of visibility dimensions and the impact increased visibility has on the respective manufacturing environments for each case company.

Discussion and theoretical contribution reflects and evaluates what was known prior to the study, and how the empirical findings have enlightened and enlarged the understanding of visibility based on manufacturing strategies.

The **Conclusion** reflects on the limitations of the research, and suggestions for further research and investigation.

3.0 THEORETICAL CONCEPTS AND FRAMEWORK

This chapter reviews previous literature on the concept of visibility in manufacturing and supply chain and literature on engineer-to-order and make-to-stock environments. The subjects reviewed in this chapter provides acquiring insight into existing theory and research practices, and identify impacting areas. The latter part reveals a gap in the literature, which further introduces development of theory and analytical model.

3.1 Visibility in Manufacturing Operations and Supply Chain

The concept of visibility has been widely discussed in the literature due to its recognition from supply chain managers and researchers (Aberdeen Group 2013; IBM 2007; Capgemini 2014). Visibility in general terms can be defined as ”the state of being able to see or be seen” (Oxford Dictionary 2016), and might refer to the degree of having transparency of relevant events and objects that might be defined as value-added or critical for performance. In the context of manufacturing operations and supply chains, it might concern to the degree of information sharing and availability of that information on strategies, operations and processes from and to supply chain partners. Several authors have suggested visibility improvements as a tool in supply chains and manufacturing operations for better decision-making and support.

The supply chain consists of diverse businesses, involving supplier, manufacturers, distributors and consumers, which is described as a network of companies influencing each other from raw materials to finished goods (Chan 2003). Several areas of visibility have been indirectly proposed, which includes the need for visibility of demand, inventory, supply and shipments as well as visibility of manufacturing company operations comprising visibility of WIP- products, processes, assets and labor (Aberdeen Group 2013; Capgemini 2014; IBM 2007). Therefore, the term visibility comprises various denotations dependent on the type of processes, operations and objects that is desired to have visibility upon. In conjunction with this thesis, the main focus of visibility lies in manufacturing operations and strategies and visibility from customers and suppliers in the supply chain. Therefore, definitions regarding visibility in supply chain and manufacturing operations are further presented.

3.1.1 Definition: Supply Chain Visibility and Manufacturing Visibility

Supply Chain Visibility

A common and general used definition of the concept SC visibility do not yet exist, even though the expression is well-used (Francis 2008). Many researchers and practitioners have formulated a definition depending on perception and the setting of convenience. One definition that has been formulated and used among several is:

"Supply chain visibility is the capability of a supply chain player to have access to or to provide the required timely information/knowledge about the entities involved in the supply chain from/to relevant supply chain partners for better decision support"
(Goh, et al. 2009: 2549).

The definition involves SC visibility as a tool for better decision support, which raises the need to gain information or/and knowledge that is accurate, trustful and useful in a specific setting. It involves providing access and transparency of transactions and relevant information and knowledge within and across businesses, and being able to have the right information at any point of time. McIntire (2014) have also proposed a definition of the term based on previously definitions, and define SC visibility as:

"A process of four meta-steps: capture data, integrate data, create intelligence, and interrupt decisions. Either the data being collected or the decisions being interrupted should be supply-chain oriented, and should span outside of a single organization`s boundaries".
(Mcintire 2014: 24)

The definition highlights data across businesses in a supply chain, in which visibility is an outcome of the captured data and information sharing through information technology systems. Compare to the previous definition given by Goh et al. (2009), the latter definition also highlights that the relevant information should generate and support decision-making across supply chain partners. According to Zhang et al. (2008) SC visibility can be explained as a multilateral concept involving people, processes, information sharing, and technology that interacts through the supply chain. In such, increased visibility through the supply chain indicates a good view of upstream and downstream inventories, demand and supply conditions, in addition to production and purchasing schedules from a focal company in the supply chain. The focal company in this term can be defined as the company who has bargaining power and governing over the supply chain (Christiansen 2015).

Furthermore, Francis (2008) argues for misinterpretations among the terms and definitions, in which he proposes a definition of SC visibility as:

> "*the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events*".
> (Francis 2008: 182)

An entity refers to item, packages, customer order, form of encasement for the order, shipment, lading asset, or a vehicle. He includes event as the specific time when location or status of the entity changes, while message referring to the communication containing information about the entity.

The preceding definitions of SC visibility mainly focuses on the information sharing to support performance and decision-making in real-time across supply chain partners. For this thesis, the definition from Francis (2008) is most suitable as the definition refers to an entity as the movement of physical materials, transactions and information acquired through information technology systems. The definition does not state precisely the recipient, but emphases on information transiting through the supply chain, which includes relevant information, identity, location, time and status of a specific entity. The definition also contains gaining desired information about an entity in real-time.

Manufacturing visibility

The term visibility reveals to have an implication on manufacturing operations as well as SC visibility. Misalignment between plant-floor performance measures and complete corporate measure continues to challenge manufacturers (Apriso 2013). Manufacturers are increasingly considering the criticality to have visibility into plant operations and process flows, enabling rapid access and visibility upon new and existing plant floor operations, machine labor tracking, production performance, labor analysis, equipment maintenance, quality planning and execution as well as visibility of inbound and outbound logistics.

Several definitions of visibility linked to supply chain and manufacturing operations refers to information sharing and traceability, but SC visibility goes beyond simple tracking certain objective information in the supply chain (Penfield 2008). It also involves visibility of assets and processes (Stefansson og Tilanus 2001), which connects the physical material flow with information systems in manufacturing operations. Hence, it implies visibility of both physical materials as well as information sharing. Another issue regarding the concept is to define which processes are most affected by visibility, in order to know what kind of information should be shared, and to evaluate the degree visibility generates added value.

Based on the suggestion for increased visibility at plant floor, manufacturing operations includes a wide-range of activities which according to Roos (2016: 39) include "*the whole chain of activities from research and innovation through to recycling of the provided object."*. The definition therefore suggests that manufacturing operations comprises activities from design phase to reprocessing procedures, which also encompasses other upstream tier suppliers and downstream customer in a supply chain. Furthermore, the definition of manufacturing operations further insinuates that different type of manufacturing strategies generate degrees of information and collaboration with supply chain partners.

The statement "you can`t improve what you can`t measure" can be seen in the light of manufacturing visibility. The statement further states that "you can`t measure what you can`t see/sense" (Ubisense 2014), signifying the ability to have visibility upon manufacturing operations. A study consisting of 252 U.S. based manufacturers, highlights that 10% of factories spend half their day looking for equipment and products used in production. The total annual costs of looking for such equipment amounts to thousands of dollars in lost inventory costs (Ubisense 2014), in which increased visibility into such operations would enable to reduce wasted time and improve production and work flow.

3.1.2 Benefits of Increasing Manufacturing and Supply Chain Visibility

Supply chain visibility

The benefits of SC visibility have been addressed by numerous research papers. Many view SC visibility as a purpose for improving company performance (Wang and Wei 2007; Caridi et al. 2010a; Holcomb et. al 2011). Many benefits are derived from the advantages of information sharing, such as reduced lead times, more accurate demand forecasts and capacity planning and inventory control (Kaipia og Hartiala 2006).

Several reports emphasize on SC visibility and the growing demand for increased knowledge and awareness of the concept (Capgemini Consulting 2012; Aberdeen Group 2013; IBM 2007). Barrat and Oke (2007) have suggested that the level of collaboration, information sharing and visibility differs across linkages, depending on the importance, significance and dependencies between individuals and companies. The need for visibility also depends on the position of the company in a supply chain, the product complexity, production processes and supply chain networks (Caridi et al. 2010a). Also, a previous master thesis conducted by Semianiaka and Silina (2012) proposes types of SC visibility linked to implementation of global identification standards and type of SC designs in the retail industry, which divided types of visibility into demand, order, supply, shipment, and inventory visibility.

As suggested by definitions of the concept, visibility in a supply chain and within a business is supposed to operate as a decision-support for individuals managing SC operations (Mcintire 2014). Weiner (2014) describes benefits of SC visibility as the goal to 1) reduce business and supply chain risk, 2) improve lead times and performance, and 3) identify shortage and quality problems along the supply chain. Hence, SC visibility may be used as a tool to simplify supply chains, accelerating it, reducing the chances of failure, or improving the completeness of the group involved. A research study conducted in 2013 shows that lack of visibility across SC linkages is one of the top three barriers to achieve SC goals (Gilmore 2013).

In previous literature, SC visibility has been associated with traceability and tracking systems of objects in transportation, production, warehouse, and inventory, in which the main purpose of SC visibility is to capture relevant data through a broad range of processes. According to Schwägele (2005:166), traceability and tracking can be defined as "*the ability to follow the* *path of an item as it moves downstream through the supply chain from beginning to end*". In this case, visibility has been recognized as a tool for improving supply chain performance based on three layers of business processes (Joshi 2000: 47):

- A mechanism to locate an object
- A mechanism to gather relevant data on the object
- A mechanism to interface the relevant data with other IT applications.

The three layers implies tracing goods in transit between supply chain partners and at manufacturing plant floor level. It also signifies the integration of information technology systems for sharing data across relevant users.

Another research conducted by Aberdeen group, consisting of 149 companies with global supply chains, shows that increasing global operations and complexity (45%), and the need for accuracy and speed (43%) is the top key drivers for centering on improving visibility (Aberdeen Group 2013).

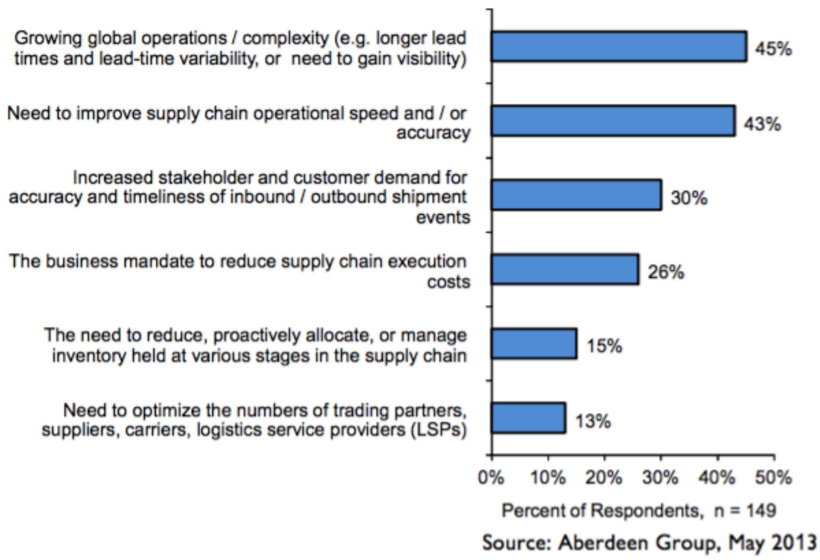

Figure 1: Key drivers for improving visibility (Aberdeen Group 2013)

In other words, the need for SC visibility has been desired in order to meet customer requirements including delivery reliability, quality assurances, control efficiency, risk reduction and transparency of work flow operations in order to evaluate performance to better meet desired goals and profitability. In addition, improving SC visibility provides increase demand accuracy and timeliness of inbound and outbound shipment events (30%). As a response to the growing globalization and complexity of supply chain, a strategic action that companies pursue is improving internal cross-department visibility by increased collaboration to synchronize and integrate data across management systems (44%).

Manufacturing visibility

A comprehensive study conducted by Ubisense (2014) revealed that 40% out of 252 manufacturers have no visibility into real-time status of their manufacturing processes. Balakrishnan et al. (1999) describes visibility in manufacturing as doing two things: 1) Faster and more complete data to support decision- making, and 2) access and involvement by more stakeholders in the decision-making processes.

Within manufacturing operations, visibility have the potential for resource and cost savings, and improve productivity. The research conducted by Ubisense (2014) revealed that gaining visibility through all aspects of a manufacturing plant enables to:

1. Identify the right areas for improvement along the manufacturing process
2. Prioritize process improvements and product repairs
3. Reduce waste
4. Proactively address issues before they become problems
5. Track quality metrics

The suggested benefits imply that increased visibility into manufacturing operations enables to support decision-making as previous suggested by Balakrishnan et al. (1999), by gaining transparency and information on all activities conducted at manufacturing plant and use the information for improvements and reduce non-value added operations.

The benefits of increased visibility into manufacturing operations have also been proposed by Jennings (2015), who mainly consider the direct impact increased visibility has on specific procedures and processes, which includes potentially 1) reducing cycle time 2) reducing WIP-inventory 3) minimize non-value added work 4) gain detailed insight by correlating operational data with real-time process interactions, as well as 4) enable more flexible manufacturing practices by uncoupling processes from fixed work zones.

Reducing cycle time causes increased throughput, shorter production lines and less staffing. Detailed insight into real-time processes combined with operational data enables to gain information on what, how, when and by whom certain activities have been conducted.

The lack of visibility in manufacturing processes was also picked up by the research union for economy and science in Germany, which introduced industry 4.0 - a high-tech project started by the German government aiming at promoting the computerization of manufacturing, which generates real-time visibility of manufacturing processes. The concept of Industry 4.0 includes processes in which visibility is desirable. Figure 1 illustrates the main stages, from the 1st industrial revolution, which introduced mechanized production using water and steam power to the 4th industrial revolution emphasizing on smart manufacturing based on cyber-physical systems enable to monitor physical processes and machines with the capability to communicate with each other by using sensors and tracking devices. In such, supply chains can automatically adjust itself to changes in demand or production capacity and products can communicate to machines about how they should be processed, which support increased visibility into manufacturing operations.

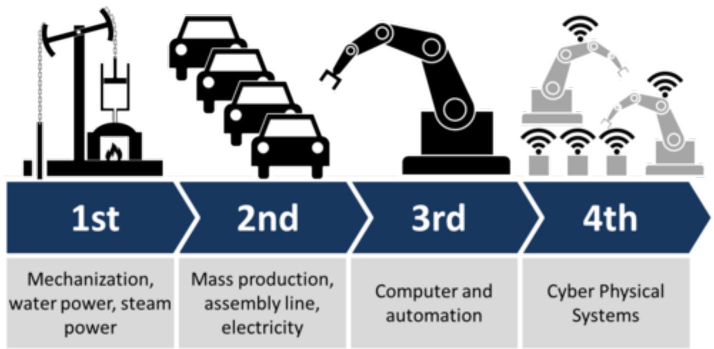

Figure 2: From Industry 1.0 to Industry 4.0 (Roser 2015)

The study conducted by Ubisense (2014) revealed that most manufacturing companies execute operations based on 2.0 and 3.0 concepts, being the second and third industrial revolution. The extent to which a company defines itself on the basis if the 4 industries may also be diverse due to market segment and product complexity, in which highly mechanized production systems requires innovative solution for processing manufacturing and assembly activities. Hence, the need for manufacturing visibility depends on the type of manufacturing operations and how the associated characteristics of supplied goods demand such visibility.

Furthermore, the suggested benefits of increasing manufacturing visibility mainly concern internal performance measurements based on determined goals or optimization of manufacturing processes. However, the need for visibility in manufacturing operations are also influenced by economic factors affecting demand and supply in the market. In such a case, five market forces have been identified driving the need for greater visibility into manufacturing operations in real-time (Gordon 2015):

1. **Accelerated new product introduction**: involves greater visibility between the design phase and physical manufacturing operations, which enables to reduce the time from the design of the goods are approved to the production processes involved in producing the specific products at the work centers.
2. **Greater product localization:** Local preferences still exists even though manufacturing and supply chains are becoming more global. Therefore, manufacturers must be able to shift product mixes, which depends on having visibility upon accurate demand data and sequence of production.
3. **The need to improve quality**: involves achieving delivery consistency by gaining visibility into granular quality data at manufacturing plant.
4. **The productivity trap**: Manufacturing companies are constantly seeking methods to increase productivity, especially concerning production of higher quantities in short periods. However, greater productivity results in higher capacity utilization due to higher production volumes, which again translates into aggressive pricing, and again higher levels of productivity in order to stay profitable. The trap signifies the need to prioritize right improvements and to not overstretch productivity improvements.
5. **Global compliance to regulations**: Global supply networks involves managing regulatory compliance, which spans outside a management of manufacturing plants. Regulations concerning health, environment, and safety monitoring (such as in the construction industry) involves the entire supply chains. Therefore, visibility across operations are necessary to meet regulatory requirements and being risk averse.

Hence, the need for visibility of manufacturing operations are generated from the desire to achieve efficient manufacturing performance, but also as an impact of several market factors which forces manufacturing companies to increase visibility on overall operations.

3.1.3 Approaches to Gain Manufacturing and Supply Chain Visibility

Several authors suggest different methods and tools to gain visibility in manufacturing operations and across supply chain linkages. Visibility into manufacturing operations and across SC linkages can be achieved in several ways depending on the object of entity the company wants to increase visibility upon. Many companies are leveraging technology to gain visibility across SC partners. Others emphasize on increased automated processes, but is insufficient in complex products and supply chains. The main approaches considered in the literature are further presented, which mainly include the use of information technology systems.

Technology Infrastructure

Various IT-systems have been developed with the goal to monitor and manage internal operations and attaining SC information from other partners. Every company within manufacturing are operating with software, such as Enterprise Resource Planning (ERP), and Electronic Data Interchange (EDI), to be able to track, monitor, coordinate, and evaluate the flow of products, from supplier delivery of raw materials to completion of production of a particular product. Visibility simply equates tracking key elements including parts, processes, supplies and orders in production, in which manufacturing ERP systems allows managers to know exactly where a job is in the fulfillment process (Stadelman 2015).

Enterprise Resource Planning - A study consisting of 252 U.S. manufacturers reveals that 91.3 % of the companies uses software such as ERP for scheduling, inventory control or purchasing business processes (Ubisense 2014). Enterprise Resource Planning (ERP) software enables to link a company`s systems with its customers, suppliers, distributors and others, and might include inventory, production, sales, project management and procurement business processes (Magal and Word 2012; Rainer and Cegielski 2011). ERP systems includes functions and modules such as CRM, human resources, CRM, finance, procurement, manufacturing, project management and more, and are specifically designed to a company based on specifications and requirements. Through master data, IT-systems enables management of business processes and numerous of stakeholders.

Internet of Things (IoT) - The concept of Internet of Things was originally introduced by Kevin Ashton, co-founder of the Auto-Id Centre at MIT, who described the potentials of using RFID tags in supply chains (Serbanati et al. 2011). IoT have been given several definitions, in which Varmesan et al. (2011:10) have defined it as *"a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical* *attributes, and virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network".* The main idea is to have control over a complex chain of integrated events that can communicate with each other as well as with employees, which allows to monitor physical objects, capturing useful data across software applications. In other words, IoT can be interpreted as a system of technologies, humans and networks that has unique identifiers and has the ability to communicate over the internet anytime, anyplace, with anything and anyone (Amini, et al. 2007).

Radio Frequency Identification (RFID) – RFID has become a cost- efficient technology that increases visibility and accuracy of process information. In this study, RFID is defined by Hunt el al. (2007:1) as "*a wireless communication technology that is used to uniquely identify tagged objects or people*". The information is sent to an electronic product code information systems (EPCIS), allowing trading partners to share information about physical movement and status of products as they travel through the supply chain and enables to answer what, where, when and why questions of the tagged object. RFID can improve traceability and provide visibility of products and related information throughout the supply chain, leading to efficient material flow and provide more accurate and detailed information (Sarac et al. 2008). Ferrer et al. (2010) investigated the benefits by studying 21 RFID applications and discovered four mutual benefits; replacement of labor through automation, cycle time reduction, enabling self-service and inventory loss prevention. RFID enables real-time information to people involved within a system or a supply chain, which can further be used to manage demand and timely adjust production plan to improve processes more efficiently.

3.2 Manufacturing Strategies and Supply Chain Structure

Manufacturing strategies is often classified in regards to the degree of technological processes, markets, products and internal processes of their organization. Four main manufacturing strategies suggested by previous literature comprises:

- **Engineer-to-order (ETO):** Products are specifically designed, developed and produced for a particular customer with specific requirements.
- **Make-to-order (MTO):** Mainly raw materials and components are kept in stock, in which products are manufactured after receiving a customer order.
- **Make-to-stock (MTS):** Finished produced products are held in stock at the end of production process and further sent directly to several customers.

- **Assembly-to-order (ATO):** Only components and other systems are held in stock at manufacturing center, in which the final assembly of the product takes place on the basis of a specific customer order.

The literature has dedicated significant emphasis on industries that constitutes mass production, while other manufacturing environments, such as ETO, still lacks literature and theory surrounding the complexity of supply chains, coordination and integration (Gosling og Naim 2009). However, main characteristics describing the different manufacturing environments are well-developed, which is further presented.

3.2.1 Customer Order Decoupling Point

Numerous authors have described manufacturing strategies based on the customer order decoupling point (Gosling og Naim 2009). Hoekstra and Romme (1992) was the first who introduced the customer order de-coupling point (CODP), and can be used as a reference point to distinguish SC structures and manufacturing strategies from each other. The CODP is based on the master production schedule (MPS), in which demand changes from independent to dependent. It is the point when a company, as opposed to a customer, becomes responsible for determining the timing and quantity of material to be purchased. The figure below illustrates the differences between manufacturing strategies and the nature of decision making, in which all upstream activities (towards supplier) are forecast-driven and all downstream activities are order-driven. Hoekstra and Romme (1992) describes this process as the structure of the physical goods flow in the supply chain, with the CODP determining which activities are based on forecasts and which activities are based on customer orders, as well as the last point at which inventory is held (Sharman 1984). Thus, the CODP recognizes the influence customers has on overall involvement in production and at what stage in the supply chain (Hoekstra og Romme 1992).

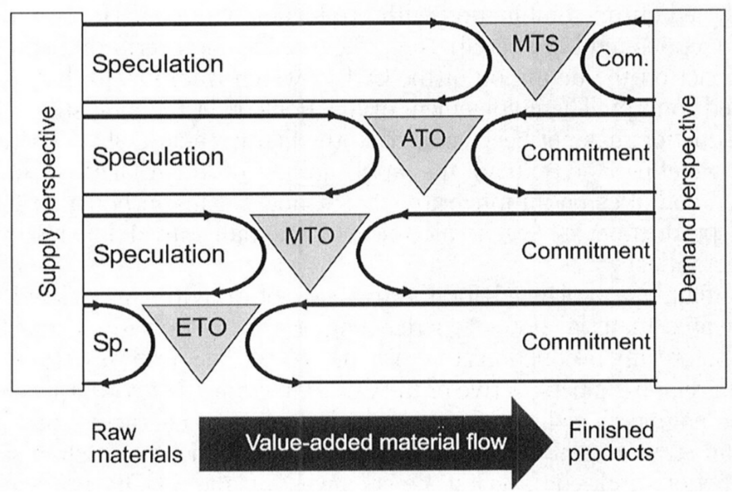

Figure 3: Customer Order Decoupling Point (Wikner and Rudberg 2005)

Previous research implies that the material decoupling point should be as close to the customer in order to maximize performance (Mason-Jones og Towill 2000). As opposite, the information decoupling point should be placed as far upstream as possible in order to increase SC partners` access to real-time data and further reduce uncertainty (Stevenson og Spring 2007).

The figure further presents MTS as a very cost efficient manufacturing strategy in which the CODP is positions downstream in the supply chain. As the opposite, the CODP for ETO strategies is positioned upstream in the supply chain, in which products are highly specialized and the supply chain is defined by high flexibility and agility due to specific customer orders. Further, MTS and ETO manufacturing structures and associated characteristics are further presented.

3.2.2 Make to Stock (MTS)

MTS- situations can also be defined as mass production systems, in which analysis of previous sales and forecasts triggers the order processing activities, i.e. the CODP implies that customers have no involvement and influence on production. MTS manufacturing strategies produces standardized goods of large quantities, with short customer delivery time, such as tools, clothes, shoes, appliances and food. The interface with the customer tends to be distant and they are unable to express preferences with regards to the product design or modifications. High volumes and standardization, low profit margins and commodity products focusing on dependability form the basis for this strategy (Hofmann, Beck og Füger 2012). The figure below given by Altekar (2012) illustrates the main processes in a ETO environment.

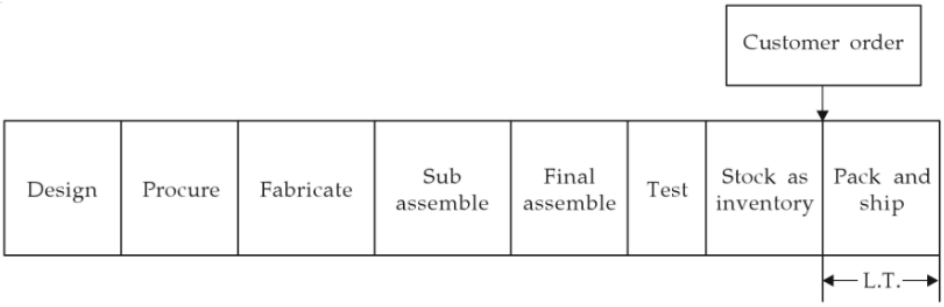

Figure 4: Make to Stock environment (Altekar 2012)

MTS manufacturing environments can also be defined as a continuous/ process manufacture, which involves continuous/repetitive production of a product and often involve using chemicals and physical/mechanical futures in production (Scallan 2003). Such products can be exemplified with commodity products such as sugar, plastic, glass, steel and fertilizer production and more. Workforce is likely to vary in terms of skill level depending on their role at manufacturing plant and the degree of automated and mechanized equipment. Continuous processes tend to be the most efficient, but the least flexible of the manufacturing systems.

3.2.3 Engineer to Order (ETO)

In ETO-situations, a customer order not only triggers the order processing activities, but also activities involving design, procurement, manufacturing, and finished goods inventory. Each received order is a culmination of a unique product design with differentiations in the set of parts, components, bill of material and routings (Altekar 2012), and encompasses products such as bridges, machines, vessels etc. It can be defined as an extension of MTO strategy with higher customer involvement and communication in the design and engineering phase (Scallan 2003). The complexity in ETO strategies lies in the management and coordination of large amount of people, information, equipment and materials (Asbjørnslett 2002).

Other characteristics of ETO environments gives similarities of the construction industry, which also operates in MTO environments, but the differences lies in where the work is performed and duration of projects. Such characteristics include fluctuating demand cycles, project-specific demand, uncertain production conditions, and the combination of specialized skills (Dainty, Briscoe og Millett 2001).

The ETO manufacturing strategy also comprises both low and large volumes of specific components for assembly, in which the main products are recognized with complex product structures with levels of assembly processes (Mello og Strandhagen 2011).

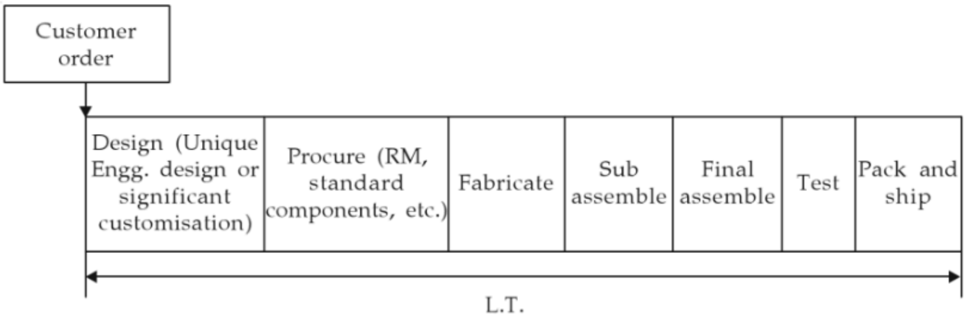

Figure 5: Engineer to Order environment (Altekar 2012)

The ETO approach is based on companies that specializes in a specific kind of production with high focus on engineering functions with and are described by large, complex and often singular project, in which customer requirements have a direct impact on the design and engineering stage of the product, pulling the product through the entire production process (Hofmann, Beck og Füger 2012). The product range is rather broad, in which flexibility is regarded as crucial in order to meet the requirements given by the customers, and engineering of complex products. This necessitates coordinating activities and information due to the large amount of data during design development, engineering and production processes (Mello og Strandhagen 2011).

3.2.4 Disparities between Engineer-to-order and Make-to-stock Environments

Previous literature highlights numerous differences between ETO and MTS strategies. Strategies, operations and processes conducted for MTS environments are differentiated for those regarding ETO environments. Due to these differences, solutions proposed for MTS environments cannot be adopted to ETO companies and must be approached differently. This section presents differences identified through an extensive literature review in order to establish how SC visibility differ from the two manufacturing systems.

Rahim and Baksh (2003) summarizes the differences in terms of operations and product design. In terms of operations, customer interaction in ETO companies begins when customers give their attention to a particular product in the design phase, which also approves every design changes before manufacturing. Cost control is emphasized in ETO environments, whereas cost reduction is highlighted in MTS companies. Requirements from customer are very specific and technical in nature, in which assembly work is mainly manual, as compared to MTS environments where production are either mechanized, semi- automatic or fully automatic. Few or none products are developed simultaneously in ETO companies, with different technical requirements from the customer. Project management is used as a technique for production planning, which is very dynamic, while MTS situations emphasizes on material requirements planning (MRP) and other software where production is more stable and predictable.

Table 1: Distinctions of ETO and MTS strategies in operations (Rahim og Baksh 2003)

CRITERIA	ETO	MTS
Production volume	Batch of one to very low volume	Medium to high volume
Interaction between customer and manufacturer	Intense	Little or no interaction
Organization structure	Team or matrix based	Function based
Technical competency	Essential for all team members	Depend on function
Cost control	During design	During manufacture
Customer requirements	Very specific	General to most customers
Assembly	Mainly manual	Mainly mechanized and automated
Work methods	Not routine	Routine, established methods
Type of operation	Labor intensive	Capital intensive
Labor skill	Specialized skills	Little or no specialized skills required
Labor flexibility	High	Low
Product range	Frequent	Quite stable
Inventory	Little inventory	Normally high inventory
Equipment type	General purpose	Dedicated equipment
Types of customer	Industrial customers	Usually general public
Use of auxiliary support	Yes	Generally no
Pilot run	No	Yes
Production planning	Dynamic and sometimes chaotic	Generally stable
Major production activity	Assembly	Manufacturing and assembly
Customer negotiating power in terms of price, delivery date and product performance	High	Low

Type of inspection	100 %	Sample
Use SPC and sampling techniques	No	Yes

In terms of product design Rahim and Baksh (2003) recognizes several differences between ETO and MTS environments. ETO product is exclusively customizing products for a particular customer, in which the frequency of design is high (each product requires its own design).

Table 2: Distinctions of ETO and MTS strategies in product design (Rahim og Baksh 2003)

CRITERIA	***ETO***	***MTS***
Design	Usually exclusive to one customer	General market
Frequency of design	Very frequent	Low to frequent
Use of design codes and standards	Yes	Generally no
Effort and cost in design per product	High	Low
Chance of design rework and improvement during manufacture	High	Low
Design of prototype	No	Yes
Tooling requirement	Limited	Many
Constraint in design	Limited to availability of off the shelf components and parts	No limitation
Involvement of manufacturing Engineers in design	Always	Rare
Design dependency on similar product	High	Low
Prototype	No prototype	Use prototype
Customer input during design	Customer input during design	Customer rarely involved during the design process
Customer approve design	Yes	No
Product test and commissioning	Usually at customer site	At manufacturing site
Customer`s technical knowledge of the product	High	Low
Certainty of customer requirement	High	Low
Product complexity	High	Low
Product size	Generally big	Small and medium size
Customer requirements	Specific and technical	Vague and non-technical
Interpretation of customer requirements	Direct	Indirect
Supplier involvement in design	Seldom	Rare
Contractor involvement in design	Seldom	Rare
Dry run/pilot run	No	Yes
Market research	Minimum	Extensive

Product launch	No	Yes
Market	Pull	Push
Product life cycle	Long	Short
Compliance with legal requirements	Always	Rare
Documentation requirement by customers	Extensive	Minimum

Low production volume makes effort and cost per product high compared to MTS companies producing in high quantities of standardized products. Further, MTS companies' forecasts what product to make, in what volume and delivery time, in which ETO companies focus more on what skills and capacities to require for production and design. Customer input in design stage is high as the company needs to comply with strict engineering requirements and design standards. Product size are quite large and complex in its nature with long product life cycle (PLC). On the opposite, MTS products are small to medium size with shorter PLC. The documentation required for ETO products are quite extensive due to significant customer specifications and agreement of contract that has been established in the design stage. On the other hand, the documentation required for MTS products concerns product information and content usually labeled on the finished product, in a market characterized as a push system.

3.3 Literature gap

The term SC visibility has gain much attention the last decade, but the theory and literature on the topic is not well developed, especially on strategies and actions to increase visibility and further implementation. The comprehensive literature review reveals that few authors provide dimensions of visibility in different context, but a variety of visibility within manufacturing operations and supply chain gives suggestions on the existence of visibility dimensions, which has been described through various implications and suggestions in the context of information sharing, traceability of goods and material, collaboration and coordination between supply chain partners and intra- related operations.

Few authors suggest and evaluate levels of visibility in manufacturing operations and in supply chains, in which visibility can refer to transparency of physical goods, but also data and information on processes gained through a range of information technology systems. Barrat and Oke (2007) has stated in their research article that the level of SC visibility differs across linkages, depending on the importance, significance and dependencies between individuals and companies. The statement further implies that the level of visibility may be divers depending on manufacturing complexity and the interrelated processes it constitutes.

Theory and literature on various manufacturing strategies, has been widely discussed and identified in terms of different CODP, production volume, work methods, assembly processes, product range, types of customer and industry, design and product complexity, and other characteristics given in the literature review. However, the literature lacks contribution to the significance of visibility in different manufacturing strategies, which is also a result of poor conceptualization on the concept of visibility.

An opportunity exists to contribute to theory by linking the two main topics presented in the literature: To operationalize the need for visibility in MTS and ETO based on main characteristics, discover the main factors influencing the need for visibility and finally translate future findings into a model that links the need for visibility and the greatest effect it has on current manufacturing strategies.

3.4 Theory Development and Analytical Framework

In order to evaluate the need for different dimensions of visibility in make-to-stock and engineer-to-order manufacturing strategies, it is necessary to operationalize the concept of visibility from a manufacturing point of view. Previous literature does not provide such, in which this section reveals dimensions of visibility through the type of manufacturing strategies.

3.4.1 Need for Distinctive Dimensions of Visibility in ETO and MTS Environments

According to the literature review in section 3.1, visibility contributes to better operations and information sharing across supply chain partners as well as internal operations within a manufacturing plant. The benefits proposed by various authors are numerous, but the dimensions of visibility in terms of where and what to increase visibility upon is not provided. Further, the literature review in section 3.2 recognizes several characteristics of different manufacturing strategies based on product complexity, CODP, and diversity in operations. This suggest that visibility dimensions may vary depending on a company`s manufacturing strategy.

Based on the literature review, contribution to how visibility varies between manufacturing strategies can further be analyzed, which emphasizes on main characteristics of ETO and MTS strategies and how the factors impact the need for visibility by determining dimensions of visibility. The impact of increased visibility can further be analyzed in a model which proposes the largest effect increased visibility has on ETO and MTS environments. Based on previous literature and disparities between ETO and MTS strategies in table 1 (Distinctions of ETO and MTS strategies in operations) and 2 (Distinctions of ETO and MTS strategies in operations product design), the main elements and characteristics of manufacturing strategies are given in table 3. The foremost characteristic distinguishing MTS and ETO strategies lies in the position of the CODP, and at which stage manufacturing companies stock finished goods. Hence, it concerns the type of product a company provides to their customer segment. Therefore, the characteristics are mainly based on the CODP and linked factors that forms and separates a manufacturing strategy from another.

The linked concept to how visibility may vary between companies is noted by Barrat and Oke (2007), who recognizes that the level of visibility depends on the importance, significance and dependencies in a supply chain. Semianika and Silina (2012) also proposes type of visibility, but concerns entire SC visibility in the retail industry. From a manufacturing point of view, this implies that the need for visibility in different areas and operations varies based on the industry and complexity of production functions.

Table 3: Main attentive characteristics of ETO and MTS manufacturing strategies

MTS	**ETO**
Low product complexity	High product complexity
Demand based on forecasting and previous sales	Demand based on customer specific orders
Transactional relationships	Collaborative relationship
High order frequency	Low order frequency
Fixed delivery	Mixed delivery
Near standardized contractual terms	Highly complex contractual terms
Normally high inventory level	Normally low inventory level
Mainly mechanized and automated processes	Mainly manual processes
Routine and established methods	Not routine
Quite stable product range	Frequent product range

The chosen characteristics should be evaluated on the same basis in other companies operating with ETO and MTS manufacturing strategy, and the dimensions of visibility should be assessed in conjunction with the theory development. In other words, the characteristics provided are identical in companies operating with the same manufacturing strategy.

The characteristics of manufacturing strategies have been divided into dimensions of visibility linked with specific characteristics defining a manufacturing strategy. The dimensions of visibility have been proposed based on the analysis of literature in the context of manufacturing strategy characteristics; demand visibility, order visibility, supply visibility, warehouse visibility, personnel visibility, and process visibility. Further, suggested benefits revealed in previous literature are given to the respective visibility dimension.

Note:

+ denotes greater need for the particular visibility dimension

- denotes less need for particular dimension

Table 4: External and internal visibility dimensions

Type of Visibility		**Factors influencing need for visibility dimension**	**Main benefits**	**Contributing Research**
External Visibility	Demand Visibility	• Demand predictability - • Level of collaboration -	Plan production capacity; reducing bullwhip effect; matching demand with supply	(Småros, et al. 2003); (Aberdeen Group 2013); (Caridi et al. 2010b);
	Order Visibility	• Order frequency + • Order steadiness - • Order status +	Coordination of assembly and production processes; matching demand with supply	(Capgemini 2012); (Romanow 2004); (IBM 2007); (Blacharski 2015); (Bartlett et al. 2007)
	Supply Visibility	• Contractual terms +	Traceability; ensuring safety and legitimacy;	(Aberdeen Group 2013); (IBM 2007);
Internal Visibility	Warehouse Visibility	• Inventory level +	Monitor and manage materials for production: Identify stock-location; potential stock-out situations; Inventory optimization	(Agrawal 2014); (Capgemini 2014); (Roberto 2006); (Aberdeen 2006); (Bartlett et al. 2007)
	Personnel Visibility	• Process automation – • Routinized work methods -	How paid time is spent; tasks performed; employee identification; Unnecessary overtime; non-productive time.	(Aberdeen 2006); (O`Connor 2015);
	Process Visibility	• Product complexity + • Process automation – • Product range +	Process performance; consistent with key business goals; traceability	(Capgemini 2014); (Jennings 2015); (Vaidyanathan 2016);

External visibility and internal visibility - The visibility dimensions are divided into internal and external visibility, in which increased visibility of external factors enables to monitor goods and gaining transparency and information of suppliers, distributors, wholesalers, customers and others. External dimensions of visibility indicate achieving awareness of processes outside the manufacturing site (case company) which influences the production processes and internal operations. On the other hand, internal visibility implies having information and transparency of materials, components, spare parts and overall processes and operations within a manufacturing plant.

Demand Visibility

Demand visibility refers to the information available of demand, which enables manufacturing companies to produce the right quantity of goods for a given period of time, plan production capacity, as well as reducing the bullwhip effect. Demand visibility varies according to how simple it is to predict demand for a specific product, and the degree of collaboration between supply chain partners, which is different in MTS and ETO environments.

Demand predictability is determined by product complexity, customer market and the level of collaboration between supply chain partners. Customer of general public purchases products and services for private use in a business-to-consumer (B2C) market, while industrial customers are those who intent to purchase products intended for operating a business such as manufacturers, government bodies and educational and medical institutions in a business-to-business (B2B) environment.

Table 5: Customer market segments

		Type of customer	
		Industrial customers	General public
Number of customers	Few customers	Ship building, public buildings,	Private yachts, high value villas and houses.
	Many customers	Tools, screws, office supplies	Clothing, food, automobiles, jewelry.

Demand from general public can be calculated by previous forecasts and sales, in which products are produced in high quantity batches, in which demand visibility is more obvious. Companies offering goods and services to industrial customers are based on customer specific orders, in which the time used in production is significant higher.

According to Chopra and Meindl (2010), demand predictability is further determined by the uncertainty of demand and the supplied product, illustrated in figure 8.

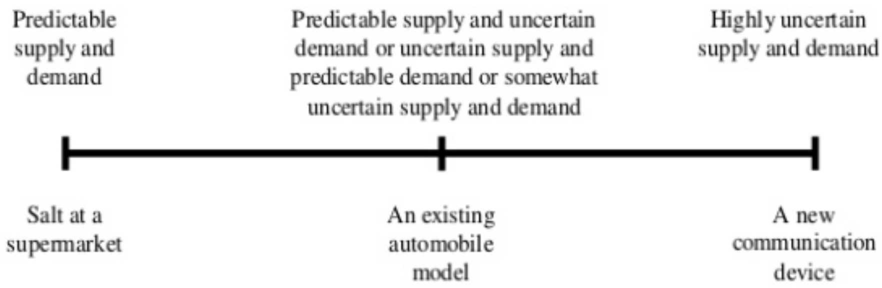

Figure 6: Implied demand and uncertainty spectrum (Chopra og Meindl 2010)

The figure illustrates that demand is more predictable for products supplied in large batches such as salt, while high-tech devices have more uncertain demand. The majority of MTS forecasts and estimate production volumes based on previous sales, in which products are produced in high volume batches. In opposite, production of highly complex products associated to ETO strategies are triggered as a response to a specific customer order with the goal to produce a single product. Each of the two cases presents two different means of demand predictability, in which demand can be more uneven and unpredictable in ETO environments due to uncertainty associated with receiving customer orders. This would indicate that manufacturing companies with high demand predictability requires less need for demand visibility.

- ❖ The higher the demand predictability, the less need for demand visibility.

Demand visibility also depends on the level of collaboration between manufacturer and downstream supply chain partners e.g. wholesalers, retailers and end customers, and the willingness to share information on demand and sales as it occurs. Collaboration between supply chain partners generate greater benefits and may reduce risks by sharing necessary information in a cooperative relationship. In highly collaborative supply chains, demand visibility is simpler to gain as partner’s voluntary or are obligated to share such information, which is the case of ETO companies. However, when there is only a transactional relationship, such as in MTS environments, information is more difficult to inquire which requires higher demand visibility.

- ❖ The higher level of collaboration, the less need for demand visibility.

Order Visibility

Order visibility refers to the ability of tracking purchased orders in transit or movement and delivery schedules of material, components, and semi-finished goods for production. Order visibility enables manufacturers to coordinate and plan production and assembly processes in accordance to the material needed for each production activity. In association to ETO and MTS manufacturing strategies, certain characteristics can be associated to the need for order visibility which is influenced by order frequency and steadiness.

Order visibility depends on the frequency of orders, which is associated to how often orders are placed at a particular supplier, but independent on the volume purchased. Higher order frequency indicated more resources for tracking i.e. greater need for order visibility. MTS environments requires higher order frequency as they continuously purchase raw materials and components for high volume production, whereas ETO environments only purchases parts and semi-finished products referencing a customer order. Thus, based on the characteristics given for each manufacturing strategy, MTS requires greater order visibility due to high order frequency.

- ❖ The higher order frequency, the greater need for order visibility.

On the other hand, MTS and ETO environments have been characterized by the degree of order steadiness, which indicates to what degree orders are replaced at suppliers over a longer period of time. The steadiness of orders from suppliers may vary as some companies have continuously fixed deliveries, such as in MTS strategies, while others order components and goods as customer specific orders are registered. High order steadiness indicates that materials in the purchase business process are performed repeatedly with little and simplified modifications. This suggest that the higher the steadiness of orders, the less need for order visibility as they are performed in a routinized manner.

- ❖ The greater steadiness of orders, the less need for order visibility.

Supply visibility

Supply visibility refers to the importance of having detailed information on materials, components and other relevant information regarding a delivery from suppliers. Supply visibility benefits a manufacturing company by ensuring safety and legitimacy in the material and product itself. In this case, it can be related to the complexity of contractual terms in MTS and ETO environments, which also reveals the complexity of the supply and the product itself.

Contractual terms of non-processed raw materials are simplified and standardized containing details on quantity, prize, type of material, delivery etc., which can be associated to MTS strategies with high automation and limited composed materials in production. On the other hand, highly technical and engineered semi-finished products associated to ETO strategies such as the shipbuilding industry, requires heavy contracts encompassing specifications such as, size and dimensions, shape, composition, delivery, international and domestic regulations, project schedule, regulatory and classifications, etc. This implies that the greater the contractual terms, the higher need for supply visibility.

- ❖ The greater the contractual terms, the higher need for supply visibility.

Warehouse visibility

Warehouse visibility indicates having information on the right supplies in the right quantity at the right time in the warehouse facilities located at manufacturing site, which enables to better monitor, track and handle materials used for production when needed. Warehouse visibility enables to identify stock-locations and potential stock-out situations, and concerns raw materials, spare parts, components for production or produced goods at finished goods inventory. Various software tools, such as warehouse management systems (WMS) is used to support warehouse operations, which provides information and management to efficiently control, track and monitor the movement of units within a warehouse storage. The need for warehouse visibility depends mainly on the inventory level, which has been characterized as less for ETO companies and greater for MTS companies.

Warehouse visibility depends on the quantity of units in the warehouse, in which a high amount of units requires higher degree of tracking and location information to identify where and what types of units is stocked. Manufacturing companies with low supply levels requires less warehouse visibility as the units are easier and simplier to identify and locate.

- ❖ The higher the inventory level, the greater need for warehouse visibility

Personnel visibility

Labor visibility indicates having information of real-time attendance, and scheduling of employees working on the manufacturing site. With businesses focusing on gaining information on material flows through manufacturing plant may cause lack of visibility on labor expenses. As a result, they lack visibility of work execution of employees and how it can affect costs and productivity. Gaining visibility of employees gives awareness of how paid time is spent including for what tasks, when and by whom. This helps to avoid unnecessary overtime and non-productive time. The need for personnel visibility can be determined by the degree of automated manufacturing processes and the degree to which the work can be categorized as routine-work. Further, each of the factors influencing the need for personnel visibility can be related to the distinct characteristic of manufacturing strategy.

First, personnel visibility depends on the level of automation in manufacturing processes, in which manual processes involves subsequent assembly stages in which a product is passed from station to station singularly or in batches with each work station requiring product modification. Manual processes require educated workers to perform and execute tasks that is given which results in higher regulations of testing, follow-up and work control, which can be associated to ETO environments. On the other hand, automated manufacturing systems enables production processes to be run by mechanized machinery which execute most of the transformation work. Manufacturing systems recognized as mechanized and automated assembly processes requires less staffing as production is managed by machinery which only requires more surveillance and support for machines to operate.

- ❖ The higher automated manufacturing processes, the less need for personnel visibility

Personnel visibility also depends on the type of work method performed, in which routine work and established methods simplifies the equipment usability as employees are familiarization of the work to be performed as they currently perform the work and use equipment in a routinized manner. However, work methods that can be associated to each unique customer specifications, requiring distinct operations for each project. Hence, the equipment are used in different modes for “not-routine” manufacturing and engineering processes, which again suggests that the need for visibility is higher.

- ❖ The higher degree of routinized work methods, the less need for personnel visibility.

Process visibility

Process visibility in this setting can be defined as the ability to accurately and completely view the physical activities and transactions in manufacturing operations, in which the goal is to gain visibility for better performance. Visibility of operations enables to determine how well processes are running and if processes are consistent with key business goals. Process flexibility is generated from product complexity, which determines the degree and amount of methods and procedures of production at manufacturing plant. Example, Vessels and aircrafts can be regarded as highly complex objects compared to consumer goods. The need for process visibility also depends on automation of manufacturing processes.

Process visibility helps to answer where the product or component is in the process, in which higher level of traceability and tracking technology is needed. Status of a process can be measured in several ways such as feedback from robotic elements in the production system saying that the process is complete or try to monitor the movement of products in the plant, in which the motion is an indicator of the status of the process. The need for process visibility can be related to characteristics of ETO and MTS environments concerning degree of product complexity and automated processes, as well as product range. ETO environments are recognized as strategies producing highly complex products, with manual assembly and manufacturing processes and high product range as each product is specified according to customer requirements, whereas MTS environments are categorized with low product complexity, automated manufacturing operations offering a range of standardized products. Further, the factors determining the need for process visibility is described in more depth.

Process visibility depends on the complexity of the supplied good. Highly complex products with advanced production process requires greater visibility of work flow and coordination of activities to be conducted in order to keep up with the production timeline. Products with standardized manufacturing operations consisting of few assembly processes requires less visibility due to established and routinized methods.

- ❖ The greater product complexity, the greater need for process visibility.

Automated and manual manufacturing processes also influences the need for process visibility, in which manufacturing operations with manual processes requires high workforce involvement for completion. Automated processes are managed through machines with less employee involvement, which can be managed through computerized and mechanical tools but requires surveillance and support.

- ❖ The higher degree of automated processes, the less need for process visibility.

Finally, Process visibility also depends on product range offered, in which case diverse companies may manufacture standardized products for a long period of time with few changes, and others make adjustments and modifications to serve the customer needs and requirements. This implies greater need for process visibility with wide product range due to changes of components, modules, and mechanisms it consists of.

- ❖ The broader the product range offered, the greater need for process visibility.

The theoretical development covers a wide range of visibility dimensions that may vary according to the importance of each dimensions for a specific company. Some visibility dimensions may be significantly more evaluated than others. For example, a company operating with MTS strategies may have great warehouse visibility due to optimized inventory management through identification and tracking systems and solutions for picking and packing. On the other hand, companies may have fluctuating demand and low degree of collaboration with suppliers, which increase the need for demand visibility. However, the theory development tries to reveal different dimensions of visibility based on the main characteristics of manufacturing strategy.

Type of manufacturing strategy may influence the need for different visibility dimensions based on the typical product itself and how it affects overall operations, information sharing and characteristics of manufacturing design and operations. For example, manufacturers producing for make-to-stock based on previous forecasts and sales may not value demand visibility as it is already incorporated on a weekly basis, while engineer-to-order companies continuously need to buy components, raw materials and semi-finished products from different suppliers and further modifies customer order after the initial order has been received, which implies the need for order visibility. Figure 9 pictures the types of visibility dimensions presented from and internal and external perspective.

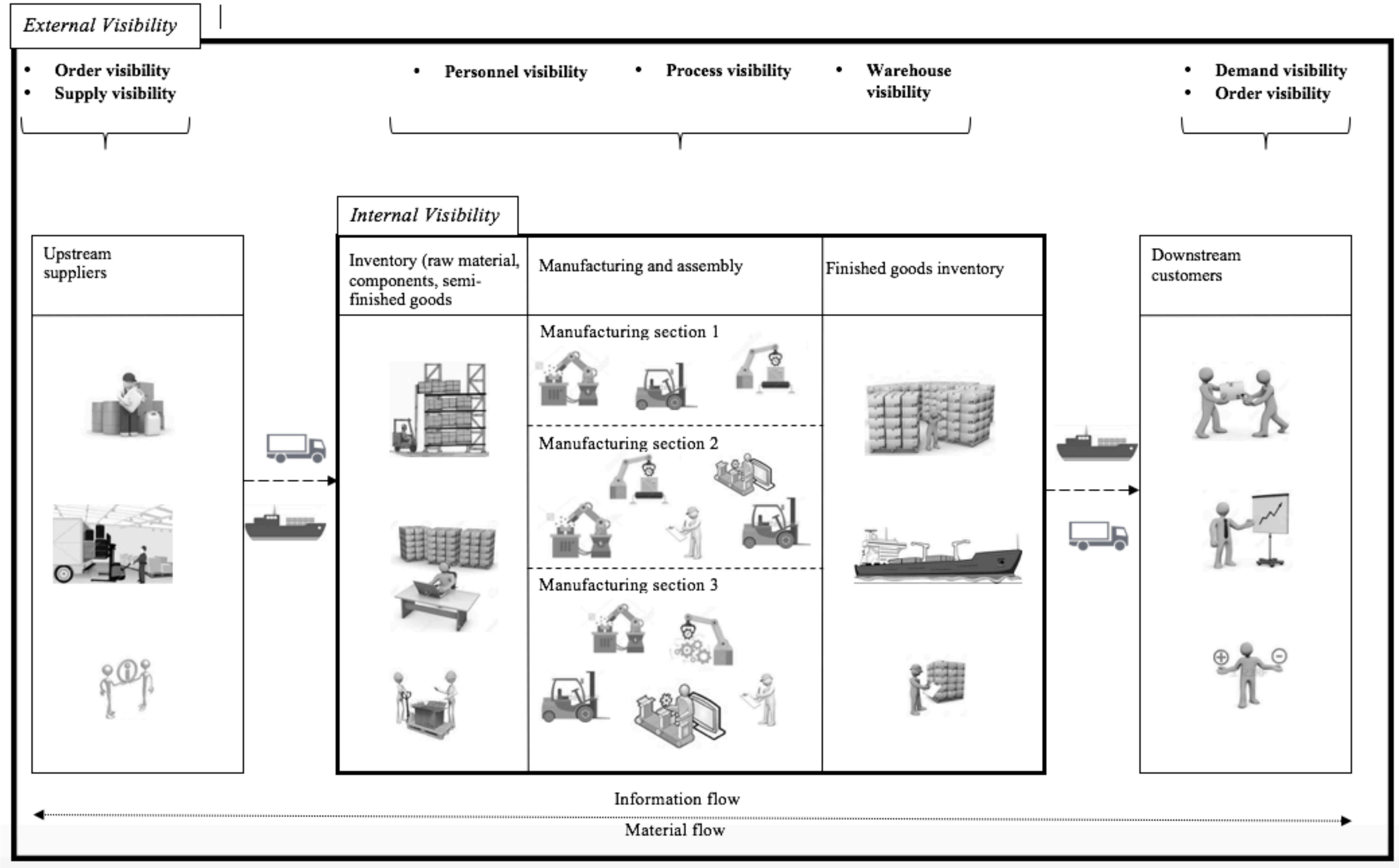

Figure 7: External and internal visibility dimensions

As the visibility dimensions are based on the main characteristics of ETO and MTS manufacturing strategies, several other factors also determine the need for visibility. Such dimensions include the product life cycle, company size, hazardous working environments, the importance of having information on order and process status, and the degree to which the company are incorporated in a global supply chain. For example, product life-cycle influences the need for visibility in terms of time to market, product quality and best-before date. However, the product life-cycle differs across manufacturing strategies, which is not an appropriate factor in this case as the the factors determining the need for visibility only conveys the main characteristics of manufacturing strategies.

The proposed visibility dimensions must be seen in the light of manufacturing strategy and not the industry it involves. Thus, the type of manufacturing strategy is extended over different industries. The need for visibility in divers manufacturing strategies serves different markets and requires different views on how to assess the need for visibility.

Table 6 summarizes the relationship between developed dimensions of visibility and main characteristics of manufacturing strategies revealed in previous literature. The main characteristics chosen for this thesis is based on an extensive literature review revealing the most common characteristics of MTS and ETO manufacturing strategies.

Table 6: The relationship between visibility dimension and manufacturing strategy

		Manufacturing characteristic linked to visibility dimension	
Visibility dimension	**Factor influencing the need for visibility**	**MTS**	**ETO**
Demand visibility	Demand predictability	Forecasting and previous sales	Customer specific orders
	Level of collaboration	Transactional	Intense collaboration
Order visibility	Order frequency	High	Low
	Order Steadiness	Fixed delivery	Mixed delivery
Supply Visibility	Contractual terms	Near standardized	Highly complex

Warehouse visibility	Inventory level	Normally high inventory	Little inventory
Personnel visibility	Process automation	Mainly mechanized and automated	Mainly manual
	Work method	Routine and established methods	Not routine
Process visibility	Product complexity	Low	High
	Process automation	Mainly mechanized and automated	Mainly manual
	Product range	Quite stable	Frequent

3.4.2 The Effect of Increased Visibility in ETO and MTS

Due to different strategies for production systems, operations and processes between MTS and ETO strategies, it is suggested that the developed visibility dimensions are diverse for the two strategies. However, based on the characteristics of manufacturing strategies, increasing visibility in one area may not constitute larger benefits for a manufacturing company. Due to the distinct characteristics in nature, the effect of increased visibility in ETO and MTS are suggested to be dissimilar.

This section tries to conceptualize at which increased visibility has largest effect on the respective manufacturing strategies based on previous literature on distinct characteristics of manufacturing environments. The theory development is based on the main characteristics of ETO and MTS approaches given in table 3, and gives a comparison based on the greatest impact increased visibility has on the respective manufacturing strategies. Further, it was previous stated in the literature review that some manufacturing companies perform a hybrid approach to manufacturing activities by for example combining a portion MTS and MTO strategies.

Overall, table 7 gives an indicator at which the impact of increasing visibility in ETO manufacturing strategies are greater than increasing visibility in MTS environments.

Further a description of why the effect of increased visibility is greater in ETO manufacturing strategies are described.

- The blue cells highlights at which the impact of increased visibility are more significant compared to the other.

Table 7: The effect of increased visibility dimension comparing ETO and MTS strategy

Factors influencing visibility	***Characteristic of MTS: The greatest impact of increased visibility***	***Characteristic of ETO: The greatest impact of increased visibility***
Demand visibility	Forecasts, previous sales; Intense collaboration between supply chain partners	Customer specific orders; transactional relationship with supply chain partners
Order visibility	High order frequency and steadiness; fixed delivery;	Low order frequency and steadiness; mixed delivery;
Supply visibility	Contractual terms close to standardized	Contractual terms highly complex
Warehouse visibility	Normally high inventory	Little inventory
Personnel visibility	Process mainly mechanized and automated; routine work	Process automation mainly manual; irregular work routines
Process visibility	Low / Medium product complexity; process mainly mechanized and automated; stable product range	High product complexity; process mainly manual; frequent and continuous product range

Impact of demand visibility
Influenced by demand predictability and level of collaboration

ETO environments have uncertain demand predictability due to the characteristics of the product and customer itself. ETO companies do not know what to produce before they have received a customer order, i.e. the customer orders trigger design and production operations. The relationship between the focal company and the numerous amount of companies necessitates high integration and coordination activities with intense collaboration, which has been stated to be a challenge, especially for the shipbuilding industry (Mello og Strandhagen 2011). Thus, proper information and communication technology is vital in order to manage the complexity of operations from design phase to delivery.

MTS environments are in general stated to be based on forecasts and previous sales, which results in analyzing fluctuations and deviations in order to meet the demand and amount produced for manufacturing. Therefore, demand is more predictable in MTS environments compared to ETO strategies in which demand is unpredictable in short term. The relationship between supply chain partners in MTS environments are characterized as transactional, supporting less interactions with suppliers and customers compared to ETO environments.

Overall, the effect of increased demand visibility is greater in ETO environments due to unpredictable demand. ETO strategies cannot produce a product due to specified requirements and high involvement of customers before the production even begins, whereas MTS strategies enables to produce standardized products for inventory stocking, which can further be traded to customer. In other words, the effect of demand visibility can be associated to the position of the CODP for MTS and ETO strategies.

Impact of order visibility

Influenced by order frequency and order steadiness

ETO environment encompasses production of unique orders at any demand. E.g each assembled and manufactured vessel is different, even vessels from the same model (Mello og Strandhagen 2011). Some components, semi-finished goods and products are required in low volumes, whereas others are required in large volumes. However, the purchase order is mainly executed in linkage to the one customer order, in which the order frequency is regarded as low with highly mixed delivery from numerous suppliers. Due to the high amount of suppliers and coordination and control of multiple orders, the effect of increased visibility is significant.

MTS strategies comprises high order frequency at a transactional level, with fixed delivery. Most orders are purchased from vendors supplying raw material, intermediate goods and components of standardized products. Compared to ETO environments, MTS companies requires less materials for assembly and manufacturing, which indicate fewer number of suppliers. Therefore, order visibility has less impact on MTS environments compared to ETO strategies.

Impact of supply visibility

Influenced by contractual terms and conditions

Highly complex contracts consisting of hundreds of pages, such as in the shipbuilding industry, requires coordination across all activities and stages in a project from design phase with customer involvement to delivery. Due to the many specifications designated in the contract, the effect of increased supply visibility concerning detailed information on all aspects of the product, including materials, composition, dimensions, regulations, project schedules etc., is considered as significant.

Compared to ETO environments, MTS companies contains contracts with suppliers that are standardized on the basis of more simplified material purchase orders. The purchased orders consist mostly of non-processed, simple products, that in turn is used to transform various raw materials into another component or product. Therefore, the contractual terms contain low level of detailed specifications and are more transactional in nature. Thus, ETO companies benefits greater by increasing supply visibility in comparison of MTS companies.

Impact of warehouse visibility

Influenced by inventory level

ETO manufacturers are characterized with little inventory level, as components and semi-finished products are being delivered at the time the specific unit is needed for further assembly. The finished goods inventory cannot be applicable in ETO environments, due to the fact that the finished product itself is delivered direct to customer. Therefore, increased warehouse visibility does not have a significant impact on ETO strategies.

However, MTS environments requires a high level of stocking, both materials for production and finished goods inventory. MTS strategies implicates manufacturing before products have been purchased. Therefore, warehouse visibility has a significantly higher impact on MTS strategies compared to ETO strategies.

Impact of personnel visibility
Influenced by process automation and labor skills
Tasks associated to ETO environments mainly requires manual work with high degree of labor skills in non-routinized work environments. Regulations involving testing, work control, and work environment safety requires higher degree of personnel visibility as the activities executed has a significant value. For example, if one component is assembled incorrectly, it would affect the next operator working on the next stage of the work package.

On the other hand, manufacturing processes in MTS environments are mainly characterized as mechanized and automated. Thus, it constitutes higher degree of specialized machinery executing the transformation of materials at manufacturing plant. Compared to ETO environments, the effect of increased visibility has lower impact in MTS strategies as manual work requires a higher degree of inspection as to whether the work has been done correctly by the employees involved.

Impact of process visibility
Influenced by product complexity, process automation and product range
In terms of process visibility, ETO environments requires manual work methods, executing processes of highly complex assembly processes, information sharing across multiple parties, and the ability to operate with flexible operational plans in order to continuously meet unique customer requirements. Due to the complexity of processes involved, with long lead times in production, assembly and design phase, the impact and benefits of increased process visibility in ETO environments are significant.

MTS work method are characterized as mechanized and automated, with routinized and established methods with a focus on reducing waste. However, compared to ETO environments, MTS strategies requires less amount of process activities, in which ETO can benefit greater from process visibility.

In summary, increased visibility has greater effect on ETO environments including demand visibility, order visibility, supply visibility, personnel visibility and process visibility. The greatest impact of warehouse visibility concerns MTS environments. It also has to be stated that other conditions and circumstances involving distinct features of the company itself also impacts the effect increased visibility has on overall manufacturing strategies.

However, due to the complexity of ETO manufacturing strategy, obtaining visibility has been proven to be more challenging due to the multiple companies involved, the management of massive volume of information, and the complexity of information and material flow along the supply chain as well as intra-related operations (Mello and Strandhagen 2011). This further influences the degree to which increased visibility has an effect on the current operations and strategies. Based on the conceptualization of the need for visibility in ETO and MTS manufacturing strategies, a graph can be presented in order to recognize the greatest effect of increased visibility. The graph in figure 10 illustrates in general that increasing the same amount visibility in ETO environments are significantly greater compared to MTS strategies.

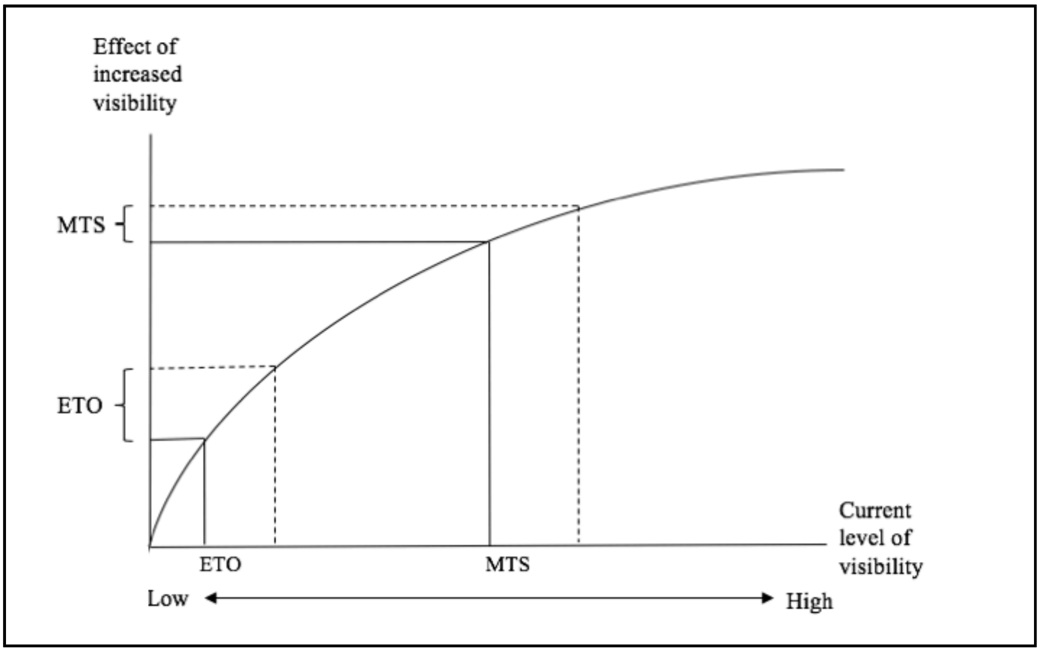

Figure 8: Effect of increased visibility in ETO vs MTS

As companies desire to have visibility in all levels, including supply chain visibility and manufacturing visibility, the level of visibility will stabilize due to optimization of all relevant visibility dimensions. Certain characteristics of MTS environments provides a higher degree of visibility compared to ETO environments. The effect of increasing visibility in ETO environments are therefore greater.

3.4.3 Analytical Model

The analytical model for assessing the effect of increased visibility in make-to-stock and engineer-to-order manufacturing strategies has been developed to fulfill the need for dimensions of visibility. The need for different visibility dimensions are anticipated to be different between manufacturing strategies. However, the effect of increasing visibility may vary according to the complexity of manufacturing environments.

The model integrates the need for increased visibility based on manufacturing strategies given in chapter 3.4.1 and the effect increased visibility has on overall performance, given in chapter 3.4.2. The model is suggested to verify that the need for visibility and the effect of it is significant higher in ETO environments compared to MTS strategies.

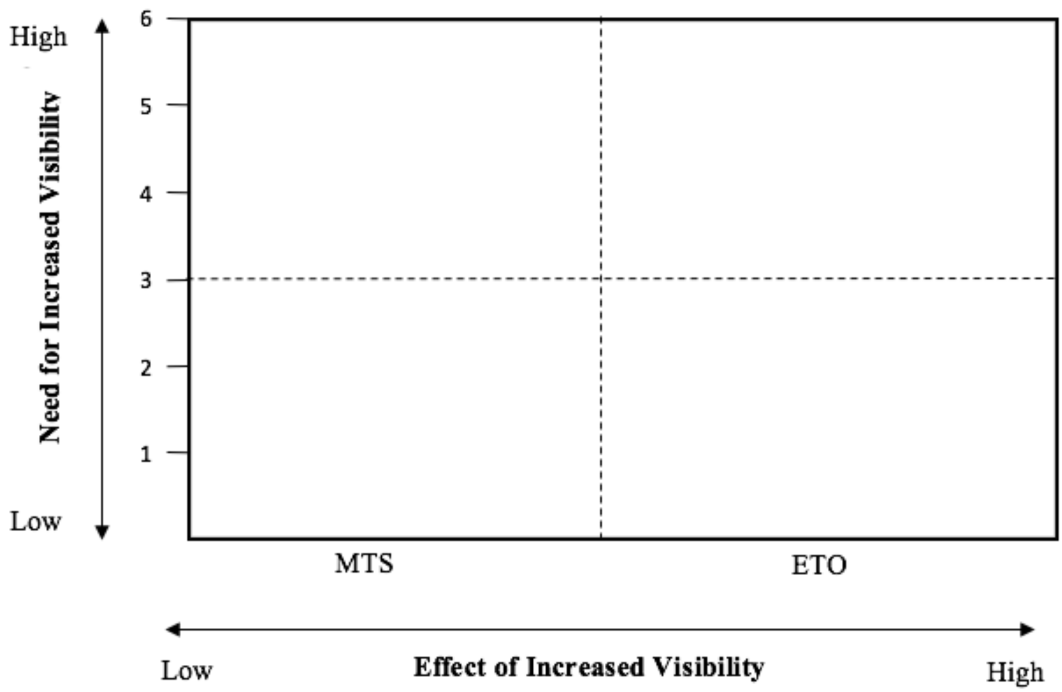

Figure 9: Effect of increased visibility on MTS and ETO environments

According to the model, manufacturing strategies that operates within ETO environments have a significant impact of improved visibility compared to MTS environments.

This is due to the fact that ETO environments involves multiple companies in design and assembly/manufacturing phase (Bolton 2001), the enormous amount of information shared between numerous suppliers, the complexity of information flow due to working disciplines and the operations itself, as well as the degree of customer involvement from design phase. Characteristics of MTS environments suggests that the degree of collaboration between supply chain partners are considered as transactional, with manufacturing being mechanized and automated, with a higher degree of demand predictability. Hence, ETO environments requires more complex operations and processes compare to MTS strategies.

The model does not aim at specifying strict rules regarding greater impact of increased visibility in ETO companies than MTS environments. However, the model proposes an approach of evaluating the effect visibility has on main characteristics of manufacturing strategies.

Usability and Diagnostic Support:

Operationalization of the axes presented in the model is accompanied in section 3.4.1 and 3.4.2 in order to attain the models usability and diagnostic support.

Usability means that the main variables should be easy to evaluate in ETO and MTS companies, in which the variables in this case is the need for visibility and the effect of increased visibility. *Diagnostic support* indicates that the axes should be useful to define the position of the type of manufacturing strategy.

Even though the model does not aim to provide strict rules of the position of different manufacturing strategies, it is still possible to approximately define the position of MTS at the the left side of the figure and ETO companies at the right side. The need for increased visibility can be evaluated through the framework developed in chapter 3.4.1 and 3.4.2.

The framework provided in the theory development chapter can be assessed through the analytical model by using a rule of thumb. Several visibility dimensions constitute more than one factor influencing the need for visibility. Thus, if one factor is regarded as significant within a visibility dimension, it will be regarded as critical in the respective manufacturing strategy. The six dimensions of visibility each stands for 1/6 of the total visibility scale.

4.0 RESEARCH METHODOLOGY

This section describes the research approach, methods applied and how the study was conducted, encompassing

4.1 Research Design

The research is conducted in seven steps (figure 11).

Figure 10: Research process

First of all, the topic of research study was discussed with supervisor, which was developed in collaboration with the research project Manufacturing Network 4.0.

Initially, literature review regarding SC visibility, manufacturing operations and strategies was carried out, and continuously modified and updated throughout the thesis work process.

Due to the lack of clarity and relevance within the literature theory, visibility dimensions was developed based on the extensive literature review. A model was developed in order to describe the relationship between increased visibility dimensions and the effect it has on ETO and MTS manufacturing strategies.

The third step involved selecting case companies for testing and illustrating the analytical model developed and to gather empirical evidence from the ETO and MTS case companies.

After the case companies was selected for the study, data were collected from the respective companies in order to identify and rate the need for different dimensions of visibility and the effect it has on the two manufacturing strategies.

Further, the collected data from the chosen case companies was analyzed and interpreted in order to evaluate and conclude the problem statement, and place the companies within the model. The last step included completion of the final thesis paper.

4.2 Literature Review and Analytical Model Development

The literature review was conducted through a comprehensive research as new thoughts, views, and new information arose. A widespread search for articles was executed in numerous databases; ScienceDirect, Emerald insight, Wiley Online Library, Ebrary Academic Complete, ProQuest, and SpringerLink.

The major keywords and linked searching terms used in the literature review is further summarized in the table to highlight the main areas of literature and theory research.

Table 8: Searching terms and key words

Keyword	Search term
Supply Chain Visibility	Supply chain visibility / definitions Visibility of / in supply chain Need for visibility in supply chains Impact / effect of supply chain visibility Approaches/methods to gain / increase supply chain visibility
Visibility	Visibility / transparency in manufacturing strategies / operations Levels / dimensions / types of visibility in manufacturing Demand / inventory / transportation / shipment / assets / process / order / labor AND visibility
Manufacturing strategies	Customer order decoupling point / customer involvement / supply chain structure / forecasts / customer order Make-to-stock/engineer-to-order characteristics / supply chain / environment
Information sharing	Information across / between supply chain partners Information / data sharing / flow /coordination AND visibility/supply chain visibility

The literature search resulted in approximately 110 articles, in which 80 was found to be the most applicable for this paper. The articles found had a date range from 1984 to 2016. Further, the most relevant articles and theory concerning the research for this paper was written in the literature review. The revised literature further supported the theory development.

4.3 Choice of Research Methodology

According to Collis and Hussey (2009), research methodology should be chosen based on the research objective, in which the objective of this thesis is to identify dimensions of visibility that is suggested as desired based on characteristics of make-to-stock and engineer-to-order strategies and the effect it has on current strategies. Firstly, this requires finding associations between the particular manufacturing strategies and factors influencing the need for increased visibility types.

According to Ellram (1996), research methodologies can be classified based on sort of analysis and data (table 9).

Table 9: Research methodologies

		Type of analysis	
		Primarily Quantitative	**Primarily Qualitative**
Type of Data	Empirical	Survey data, secondary data, in conjunction with statistical analysis such as: factor analysis cluster discriminant analysis	Case studies, participant observation, ethnography. Characterized by: Limited statistical analysis, often non-parametric
	Modeling	• Simulation • Linear programming • Mathematical programming • Decision analysis	• Simulation • Role playing

The figure distinguishes between two types of data, empirical and modeling. Further, a classification of quantitative and qualitative analysis is presented, which makes up the four basic research methodologies given in the matrix. Empirical data are research analysis employing surveys and case studies for collecting information on the subject. This research paper utilizes a qualitative case study with empirical data.

4.3.1 Type of Case Study

Ellram (1996) states that *"qualitative research is frequently expressed verbally, often to create an understanding of relationships or complex interactions".* The data collected is gathered from interviews, company visits and field studies, annual reports, articles, previous literature review, as well as informal meetings and discussions.

The study aims at finding linkages between two concepts: Manufacturing strategy and factors influencing the need for different visibility dimensions. Yin (2014) defines explanatory case study as "a case study whose purpose is to explain how or why some conditions came to be". Therefore, the research can be understood as an explanatory study, which necessitates theory and literature to support the theory development. Explanatory case studies are conducted through methodologies such as experiment, case study, grounded theory, participant observations and case survey (Ellram 1996).

Qualitative methods are preferred for explanatory research, in which qualitative methods provide depth and richness of a phenomenon being studied. The case study methodology was chosen due to several motives:

- Case studies aids to obtain in-depth knowledge about a phenomenon (Karlsson 2009)
- A case study gives deeper knowledge about a phenomenon in a specific context, and also assists developing a theory (Yin 2014)
- This type of case study is also suitable for building and developing theory that can be further tested (Ellram 1996).

4.4 Choice of cases

Choice of manufacturing strategies

The choice of manufacturing strategies was based on exploiting two contrary and diverge manufacturing environments in order to evaluate the uppermost dissimilarities when it comes to the need for increased visibility and the effect it has on current strategies. According to previous literature, MTS and ETO are to opposite manufacturing strategies, in which those where to be chosen.

<u>Choice of companies</u>

The choice of cases was decided between four companies involved in the Manufacturing Network 4.0 Research Project, namely Brunvoll, Kleven, Ekornes and Pipelife. Brunvoll and Kleven are both companies positioned in the construction and engineering industry of thrusters and vessels. Pipelife is part of several industries including agriculture, buildings, water and energy, while Ekornes is part of the furniture industry. The choice of cases was based on the type of manufacturing strategy, in which MTS and ETO are suggested to have the largest diversity seen in the light of each other, in terms of operations, processes and supply chain structure. Therefore, Kleven was chosen as the ETO company and Pipelife comprising MTS manufacturing strategies.

The aim of selecting one ETO and MTS company is to identify the need for visibility based on the two manufacturing strategies separately, and see if there is any areas in which the need for visibility is significantly higher.

4.5 Data collection

Data were collected from multiple and diverse channels. Case study allows diverse sources of evidence which can refer to data triangulation to help increase the reliability of the data collected.

4.5.1 Primary Sources

Company visit and field studies - Visits was made to Pipelife`s manufacturing facility in Surnadal, Norway, and Kleven`s production facilities in Ulsteinvik, Norway.

A visit to Pipelife was done 16th of February, in which an introduction of Pipelife and related information of the facilities and activities was given by the supply chain manager. Further, a tour through the manufacturing and warehouse facilities was given with description of processes and operations of each divided sections. After the tour, questions were asked to relevant people in different departments that could assist with answering the specified questions. Visit at Kleven was conducted 19th of February, and involved meeting with purchaser, supply chain director and IT director at Kleven. They gave us valuable information regarding IT-systems for different purposes (planning, sales, storage etc.), information and material flow, contract complexity, degree of technological competence, machines etc. The information given validated the factors influencing the need for visibility.

Interviews – Structured interviews was conducted after the company visits as more questions arose. Structured interviews are based on a fixed format interview in which all questions are prepared beforehand. The interview guide was revised and testes several times before the final interview. The interview guide was sent in advance to allow preparation, in which the interview guide for the two companies were dissimilar due to the nature of manufacturing strategies and company features. The questions were made in a structured manner, which started with general questions concerning the company and manufacturing processes and further in-depth questions revealing dimensions of visibility. The interview was further transcribed and analyzed. Further, useful information was highlighting, suggesting conclusions and supporting the theory development framework.

4.5.2 Secondary Sources

Analysis of reports – Reports from Aberdeen Group, Capgemini, and IBM contributed to better understand the concept of visibility in different perspectives, which also contributed to the theory development section of this paper.

Informal conversations and discussions **–** Other informal meetings and conversations with researches and lecturers with knowledge and competence of the companies, its industry and manufacturing strategy was conducted in order to get viewpoints on the research problem and the overall processes and operations.

4.6 Data Analysis

Company visits and interview notes taken from company visits was reviewed and transcribed and further written in more detail. The information gained from company visits and interviews was further divided into themes in evaluation of visibility dimensions.

Descriptions of the companies` manufacturing strategies and related processes, operations and supply chain were examined in conjunction with the literature review in order to verify the type of manufacturing strategies. The need for external and internal visibility was evaluated in accordance with the theory development framework.

Within-case analysis informs the effect increased visibility has on the current characteristics within the manufacturing strategy and company features. The within-case analysis was conducted in order to uncover differences and commonalities in terms of visibility dimensions between ETO and MTS manufacturing strategies.

Meeting with supervisor was conducted several times per month, to ensure progress, give comments and feedback on thesis work, which contributed to discussions and other viewpoints that was satisfying for the theory development in conjunction with the companies.

Cross-case analysis was conducted to explore and evaluate the effect of increased visibility based on factors determining the need for visibility. The cross-case analysis validated the developed model and theoretical framework in subchapter 3.4.1 and 3.4.2.

Meetings with master student groups was conducted every second week which was initiated and held by the supervisor. The master thesis was introduced and described to other master students of the same supervisor. The goal of the meetings was to continuously reach specific objectives and mile stones of the thesis, which also contributed to discussions and further progress of the thesis work. The overall strategy of writing a master thesis paper was also discussed.

4.7 Validity and Reliability

Reliability

Reliability of the research considers two aspects; replicability and trustworthiness (Collis og Hussey 2013). Replicability of the research addresses if replication is possible and if the same results would be given if the research was to be conducted again. The latter addresses the dependability of the data. Trustworthiness is supported by triangulation involving interviews from reliable sources and observations through company visits. Information gained from interviews and company visits form the major data collection of this qualitative research.

Validity

Validity refers to the extent to which the research discoveries and answers precisely reflect the phenomena studied. Validity can be divided into construct, internal and external validity (Yin 2014)

Construct validity denotes the appropriateness of measures for the phenomenon studied (Yin 2014). Construct validity in this thesis is increased through:

- Extensive literature research validating manufacturing strategies and visibility within different industries.
- Using multiple sources of evidence through data collection of both primary and secondary sources, which helps to eliminate judgements and enlarge perspectives of the phenomenon.
- Using main characteristics of manufacturing strategies in order to identify the main factors determining the need for visibility.

Internal validity is especially essential for explanatory studies, which seeks to establish and find proper connections between the concepts (Yin 2014). To support the linkages of the concepts involved, namely manufacturing strategies and visibility dimensions, company visits was conducted and interviews was sent to relevant, experienced and knowledgeable respondents for the particular topics involving manufacturing strategies and visibility of material and information flow in ETO and MTS manufacturing strategies.

External validity refers to generalizability of the study results. This research uses theoretical contribution to support the theory development, which also becomes the main point for generalizing the results of the case studies in the analytical model. The results from the case studies validates the developed model.

5.0 EMPIRICAL FINDINGS AND CASE ANALYSIS

This chapter provides analysis of two companies – Pipelife and Kleven. The analysis validates the main characteristics of ETO and MTS manufacturing strategies, and further tries to evaluate the factor influencing the need for visibility within the case companies.

5.1 Pipelife

5.1.1 Company Background

Pipelife AS is the largest producer and supplier of plastic pipe systems with 60% market share in the Norwegian market. They produce a wide range of pipes and solutions for complete water cycle, energy and power distribution for telecommunication networks and industrial applications with a product life cycle of approximately hundred years (Pipelife 2015). Pipelife Group was founded in 1989 by Wienerberger and Solvay, and are at this day established in 26 countries in Europe and USA. They have production sites in 18 countries, with 2704 employees worldwide. Pipelife`s headquarter are located in Vienna, Austria.

Pipelife`s vision is to be "the NUMBER ONE value creator" in their markets, by improving quality and provide high value solutions for the protection and flow of water and energy (Pipelife Corporate Presentation 2016).

Pipelife: Surnadal, Norway
In Surnadal, main production consists of pipes and parts in Polyvinyl chloride (PVC) and polypropylene (PP). Their largest served market is the government, namely the Norwegian Public Roads Administration (NPRA) and the municipalities in Norway.

The manufacturing facility in Surnadal is most complex regarding production operations, which produces fittings and pipes with dimensions between 16mm-1400mm. Expected production volume in 2016 is estimated to 20 000 tons.

The company are certified with ISO 9001, ISO 1400 and CF. There most successful criteria's lies in product innovation, services regarding transportation and delivery directly to customers from production site, with an emphasize on a green value chain. Incorporating a green value chain is a strategic choice, as customers value such services and by also reducing carbon footprint.

5.1.2 Supply Chain

Pipelife`s supply chain related to the production facility in Surnadal mainly consist of suppliers of raw materials, intermediate and semi-finished goods, a local distributor, piping and electrical wholesalers with the major customer segment being the Norwegian Public Roads Administration (NPRA) and the municipalities in Norway.

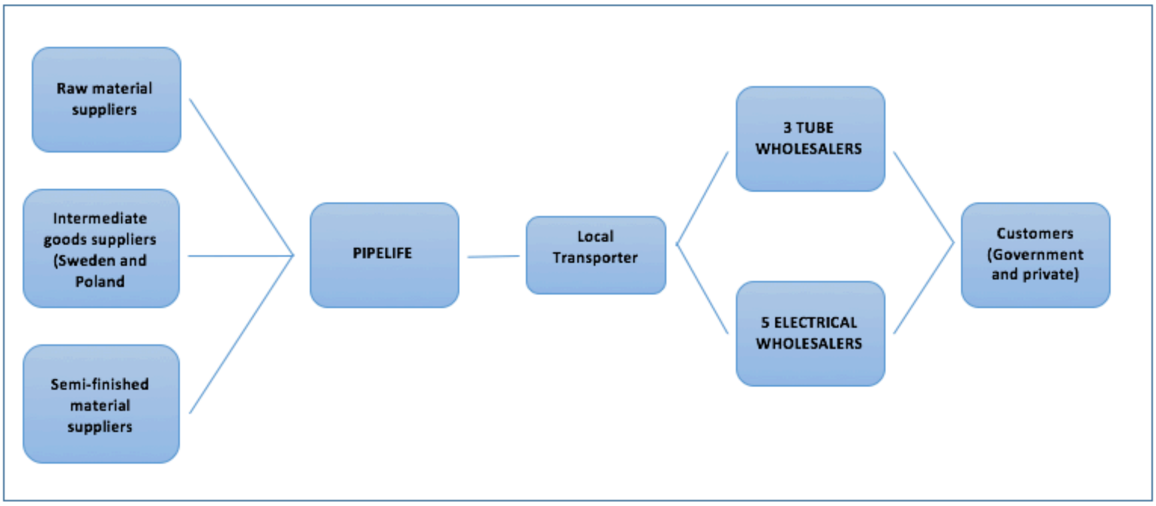

Figure 11: Supply Chain - Pipelife

Suppliers

The major categories of suppliers consist of raw material suppliers, intermediate goods suppliers and suppliers of semi-finished products. Raw materials and intermediate goods are mainly purchased from Finland, Sweden, Norway and Belgium, and encompasses raw materials and intermediate goods such as seals, frames, steel tape etc. Dye and additives are also purchased from UK and countries in Europe. Semi-finished goods are mainly purchased from subsidiaries in Poland and Sweden. 90% of all components and products are produced at Pipelife in Surnadal, while some are ordered as finished products from the latter subsidiaries.

Transporter
The manufacturing facility in Surnadal has one main distributor, namely Surnadal Transportation Partner, in which Pipelife is the main customer. (The production facility in Stathelle also have one local distributor)

Wholesalers
Pipelife sell all their products via wholesalers, with three big wholesalers for piping and 5 electrical wholesalers. They provide shipment services direct to the customers upon request, but the transaction is executed through wholesalers. Pipelife has an agreement with all wholesaler within piping, plumbing and electro in the country.

Demand
The production schedules and processes are mainly based on historical data and previous sales. It can be expressed as an "educated guess", in which they evaluate previous and present projects based on exceptions and omissions. However, demand has been difficult to predict, which is a result of served customer segment, namely the Norwegian Public Roads Administration (NPRA) and the municipalities in Norway, and the unknown upcoming events at wholesalers. Due to the availability of stocking finished goods at manufacturing location and long product-life cycles, Pipelife are able to produce a higher amount of standardized products and store finished goods at inventory. However, costs related to inventory capacity, production operations and staffing are factors that influence low visibility of demand.

Order
Materials and components for production are purchased weekly, depending on the type of material purchased. Raw materials frequently needed are ordered each week in large volumes.

Supply
Detailed information about raw materials are regarded as high at Pipelife, but also in general in the construction industry. Pipelife is a certified company, which involves abilities to have the produced products approved in e.g. water supply. Materials from suppliers are identified with specific material information data. This facilitates tracking materials back to batch number and vendor.

IT-systems for planning, storage, ordering and shipment
Pipelife takes use of M3 software, which covers planning and warehouse management. It also includes ordering processes from subsidiaries in Poland and Sweden, which also contains inventory levels and material information. Communication and ordering processes occurs through telephone and e-mail. The purchase order is generated through the ERP system, but the actual order is sent to supplier via e-mail.

Information shared to main suppliers and distributors consists of forecasted demand at production site. On a daily basis they enroll loading requirements for uploading the following day and other changes or deviations that might occur.

The required information from suppliers involved delivery date, order confirmation and demand deviations. On the customer side, elements such as forecasting and demand are regarded as valuable information.

5.1.3 Manufacturing Strategy: Make-to-stock

The production process is quite flexible in terms of facilitating numerous production lines. In the last decade there have not been any big changes in design and structure of pipes but only small modifications. Annually, they produced 20 000 tons of plastic pipes. 90% of their production is standardized, in which the remaining 10% involves customer specific requirements. This thesis focuses mainly on standardized products at Pipelife, as a make-to-stock company.

Figure 12: Pipelife AS (Surnadal, Norway)

Manufacturing processes
Pipe production mainly includes extrusion processes. The extrusion process involves melting and heating raw plastic, pressured into a tool that shapes the material into a particular product profile. Further, the process involves cooling down the shaped plastic tubes, which is subsequently cut into recorded length.. The production facility also executes molding processes, by molding plastic through a spray casting.

The time it takes to manufacture certain pipes depends on the production line for a specific machinery. Restructuring machines to produce another dimensions or set of pipes can take days depending on the complexity of current machinery to changed process. Tasks such as closing, rebuilding machinery, technical adjustments take approximately a day to execute. When the machinery is structured to produce a specific type of plastic tube, the daily production volume can be significant.

The production processes are monitored through a data system allocating real-time production processes, giving valuable information regarding what type of plastic tubes is in production, when it is finished, and what type of machine active. The production facility is based on the standardized lean system 5s, which identifies and stores equipment and tools for production at specific areas.

Labor

The production department consist of 54 employees divided into five shifts in additional to maintenance and technicians on daytime, which constitutes approximately 15 employees per shift. Total 90 employees work in the production department and storage (80 in the production department). The type of skills depends on the kind of work to be performed at manufacturing site but mostly they require certificate of apprenticeship with technician and engineering background.

5.1.4 Dimensions of Visibility

The assessment for the need of visibility requires appraisal of overall existing goods supplied, production systems and supply chain activities due to the main characteristics of manufacturing strategies evaluated. Table 10 summarizes the level and range of factors impacting dimensions of visibility.

- *Colored cells underlines which factors enlarges weight for the need of visibility dimension based on the theory development linked to the characteristics of manufacturing strategies.*
- ** denotes that the assessed factor cannot be linked to characteristics and type of manufacturing strategy, but exclusively to a particular company. In other words, the denoted dimension varies independent of manufacturing strategy.*

Table 10: Assessment of the need for visibility at Pipelife AS

External visibility dimensions	***Factors influencing need for visibility***	***Factor assessment***	***Analysis***
Demand visibility	Demand predictability	Medium	Fluctuations in demand; production based on forecasting, previous sales, and “educated guesses”; Demand still challenging to predict due to customer market.
	Level of collaboration	Medium	IT-systems connected to subsidiaries; Transactional relationship (loading information, delivery date, order confirmation),

			but also share forecasted demand with suppliers.
Order visibility	Order frequency	High	Order materials on a weekly basis, depending on the type of materials purchased.
	Order steadiness	High	Same type of raw material, intermediate materials and semi-finished products with few modifications
Supply visibility	Contractual terms	Low	More standardized contracts with low complexity (raw materials, components, and semi-finished goods)
Internal visibility dimensions	***Factors influencing need for visibility***	***Factor assessment***	***Analysis***
Warehouse visibility	Inventory level	High	Both outdoor and indoor inventory storage of large areas.
Personnel visibility	Process automation	High	Highly automated processes with mechanized machinery
	Routinized work methods	High	Production processes consist of routinized and conventional, with modifications only when in machine set-ups.
Process visibility	Product complexity	Low / Medium	Extrusion and molding production processes
	Process automation	High	Highly automated processes with mechanized machinery
	Product range	Medium	90% Standardized products, and 10% involved customer specific orders

The supply chain manager at Pipelife highlighted that outbound logistics concerning the flow from finished produced goods to stocked goods in inventory and picking products for shipments was a concern of them, due to high inventory levels and loss of tracking possibilities.

The theory development chapter indicates that the higher the order frequency, the higher need for order visibility. As analyzed in table 10, Pipelife`s need for order visibility is determined by its high order frequency. The theory development chapter also states that the higher the level of inventory, the greater need for warehouse visibility, in which Pipelife as a MTS company has high inventory levels. Both factors presented are part of characteristics which determine MTS environments.

5.2 Kleven

5.2.1 Company Background

Kleven Verft is a family driven company founded in 1944 and is a subsidiary of Kleven Maritime AS Group, together with Myklebust Verft AS, Kleven Maritime Finans AS, Kleiva Shipinvest II, and Kleven Maritime Contracting AS. They are suppliers of highly specialized vessels of different sizes and designs, such as offshore vessels, coastguard vessels, special tugs, fishing vessels and other workboats.

Kleven`s vision, together with Myklebust Verft, is to "be the preferred partner within the defined areas". Their mission is to be an attractive supplier of specialized ships and services, participating in the design phase to give the buyers value through innovative solutions.

Kleven is ISO-certified with 9001 and was the first Norwegian Shipyard to achieve an 14001 environmental certification.

Shipyard: Ulsteinvik, Norway

The yard is located in Ulsteinvik, Norway, and construct advanced offshore vessels, in which Kleven is one of few yards still manufacturing ship hulls in Norway. Kleven manufacturers several type of ships, including Anchor Handling Tug Supply (AHTS), Expedition Support Vessels (ESV), subsea mining, Multi-purpose Supply Vessel (MPSV), Platform Supply Vessel (PSV) and Offshore Construction Vessels (OCV). They have also entered a new market segment constructing super yachts.

In the last seven years they have delivered approximately 60 vessels from their two yards located in Ulsteinvik and Myklebust. In 2014 they had a revenue of 2 951 412 NOK, in which they produced 8 Offshore Service Vessels the same year (ShipbuildingNorway 2015). In 2015, Kleven Verft delivered 6 types of vessels within the offshore sector. As of December 2014, they had 15 contracts signed with delivery between February 2015 and August 2017, which estimated to NOK 12.3 billion in turnover (including 4 contracts at Myklebust Verft). In 2016, Kleven Verft is expected to have a turnover at 5 billion NOK.

5.2.2 Supply Chain

Kleven`s global supply chain consists of an extensive amount suppliers and subcontractors located worldwide, the customer (ship owner), operator and the final customer of the ship owner. Kleven has has numerous subcontractors including supplies from standardized to highly specialized components, which again differ in range of volumes. Due to the complexity of shipbuilding industry, a simplified supply chain is illustrated in figure 13, to create a picture of the parties involved. Further, short description of different suppliers and subcontractors, ship owners, operator and final customer are described to highlight the complexity of Kleven`s supply chain.

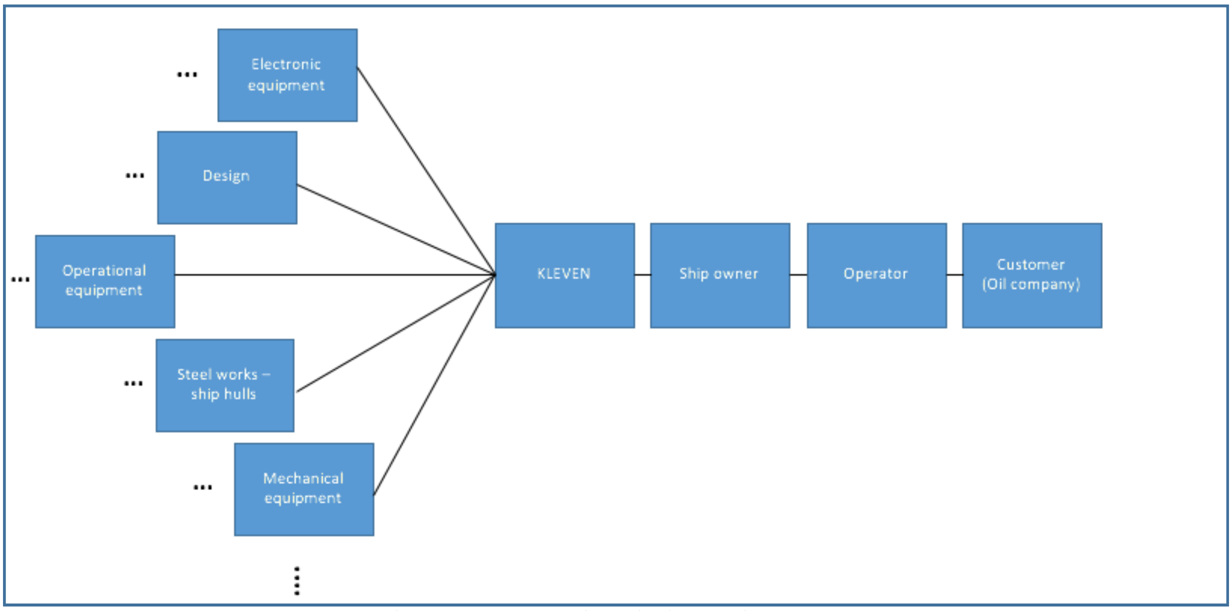

Figure 13: Supply Chain - Kleven

Kleven`s global supply chain is tremendously extensive and includes numerous and countless subcontractors and suppliers upstream in the supply chain, as well as previous and new customers which each has unique order requirements and specifications. Thus, each manufactured vessel is one of a kind and highly complex.

Suppliers and subcontractors

Kleven has between 2000-3000 suppliers and subcontractors over a wide range of services and product segments. The main categorize of suppliers and subcontractors at Kleven are suppliers for mechanical equipment, electronic equipment, design functions, operational equipment, steel works, specialized equipment, and drilling and offshore equipment.

- Mechanical equipment – such as cranes, winches, propellers, engines, steering machinery, deck machinery, generators and thrusters etc. are supplied by companies such as Rolls-Royce and Brunvoll.
- Electronic equipment – including dynamic positioning systems, specialized hardware, transformers, converter, controlling systems, communication systems, deck machinery, dynamic positioning systems, emergency generators, navigation and search equipment, and numerous other electric installations are supplied by companies such as Kongsberg group and ABB.
- *Design – includes services encompassing ship design and design of equipment packages.*
- Operational equipment – includes suppliers and subcontractors offering paint, lubricating oil, cables, chains, lifeboats, mooring winches, gangways, sanitary equipment, helicopter deck, survival suits, ventilation, heat exchange etc. and are supplied by companies such as Jotun and Norsafe.
- Steel work – suppliers and subcontractors mainly responsible for supplying ship hulls, which are mainly located in Poland, Romania and Ukraine.

The subcontractors and suppliers again have their suppliers and all the way back to the provider raw material, in which Kleven`s supply chain covers lower level of sub tiers at the supplier side.

Customers
Kleven`s current customer are Maersk Supply Service, Debmarine Namibia, ABB, IES Pioneer Ltd, Østensjø shipowner, Rem Ship AS, Rem Stadt AS, Ugland supplier, and Olympic Nor AS. The current suppliers are companies purchasing specified vessels mainly for usage in the offshore industry. The ship owners further lease the vessel over a 1-10 years period to an company operating the vessels for oil company.

Demand
Annually, Kleven constructs 7-9 diverse vessels. The manufacturing schedules at Kleven are triggered from specific customer orders, which requires high involvement from customers from design phase to delivery. Short-term demand predictability at Kleven is not present. Thus, they do not have any estimations or visibility into when a new order may be placed. However, one order enables 1-2 years of operations depending on the complexity of customer requirements, which indicates that few orders are enough to ensure operations for a long period of time. The degree of collaboration between supply chain partners and Kleven are significantly high, due to the extraordinary involvement of contractors and customers (ship owner) from design phase to delivery.

Order
Kleven places orders at suppliers and subcontractors based on the specifications and requirements from the end customer. Therefore, order frequency is low as each purchase is specifically reserved to the specific required vessel and involved further specifications in different shapes, volumes, dimensions, materials etc. Supplementary, order steadiness is also low as it encompasses mixed delivery of products, components and semi-finished goods. Order to suppliers and contractors are mainly performed through spreadsheets in excel, in which the data is recorder into their ERP system.

Supply
Due to the extensive type of highly technical and mechanized equipment, materials, installations, steel work and operational equipment, the contractual terms with customers includes extremely detailed information, and regards principal particulars and dimensions of goods and semi-finished products (For example a hull: length, breadth, depth, design draft), guaranteed concerning speed in nautical miles per hours, fuel consumption, deadweight, registrations, terms of installment, international and domestic conditions, as well as other transactional information concerning terms of delivery and payment, prize,

currency, quantity, delivery date etc. Contractual terms between Kleven and subcontractors are similar in terms of the enormous amount of details as each unit is specified in terms of matching and assembling semi-finished goods as a part of a vessel, in which the contract can consist of over hundreds of pages. The contract is divided into SFI group systems and covers all aspects of ship specifications, which provides subdivisions of technical and financial ship information. Each SFI is signed individual calculations and accounts. The designing phase is a critical part of the entire project at Kleven and in any shipbuilding industry, which further generates complex manufacturing and assembly processes. Kleven is also ISO-certified with 9001 and was the first Norwegian Shipyard to achieve an 14001 environmental certification. Therefore, the importance of tracking materials back to the supplier is crucial, but is a challenging task due to the multiple components and semi-finished goods required.

IT-systems for planning, ordering, storage, timesheets and identifications systems
Kleven uses several IT-systems for planning, ordering and warehouse information. IT-systems for planning are conducted in Primavera, which is a software systems enabling project-intensive organizations to identify, prioritize and select projects. It also involved management, planning and control of projects. IT-systems for ordering is conducted through excel using spreadsheets, which is further registered and recorded into ERP system. They also take use of Tempus, which is a web-based time sheet system enabling to track work hours of employees. An identification system, unique for each employee, also enables to register when people are clocked in and out. Further, they use Catia as a system for designing the drawings for the vessel, which constitutes creating and treating 3D models for production plans. Concerning tracking and traceability of shipments, Kleven does not have any systems for such, in which the communication goes through the suppliers and subcontractors and are further registered and recorded in terms of important specifications regarding the shipment.

5.2.3 Manufacturing Strategy: Engineer-to-order/Assembly-to-order

Kleven`s manufacturing strategy can be characterized as an ETO company, with production based on specific and specialized customer orders that requires unique engineering and design work. At manufacturing site, they have between 500-1000 workers consisting of administration and engineers at plant floor.

Figure 14: Kleven Verft AS (Ulsteinvik, Norway)

The shipbuilding construction is recognized as quite complex in nature, due to the numerous assembly and manufacturing operations required in a period between 1-2 years. Kleven operates with multiple intra- related processes in which each signed contract are unique.

Manufacturing and assembly processes

Kleven Verft has facilities for early outfitting and assembly on slipway. Their facilities include 15 000 m2 floor space, with indoor sandblasting and painting, as well as pipe workshop and steel building facilities. They manufacturing facilities includes cranes that has a capacity of lifting 2x182 tons, and multi wheeler capable of lifting more than 1000 tons. The total length of outfitting quay is 400 meters with crane outfitting capacity of 1x60 and 1x85 tons.

Kleven has one robot for assembly and three robots for welding, in which they are able to gather data on the status through the equipment as well as remotely control the robots via internet.

Kleven`s production processes, as previous mentioned, is triggered from a customer specific order with unique requirements. The requirements are further taken into the design phase, which is divided into several steps, including preliminary design, concept design, basic design and further a detailed design which constitutes information of all aspects of the specific vessel. The design phase necessitated high involvement of customer, design team production managers as well as multiple contractors and supplier due to the intra-related operations and activities across departments and supply chain parties. The design stage involves designing 3D models, generating engineering parts needed, creating production tree specifying all the operations and assembly processes taking place in a sequential order.

The planning stage begins by converting the designed models into a production plan including the sequence of activities taken place, material list, creating work packages for different elements, number of staffing, order components, products and semi-finished goods at the time required etc. Placing orders at suppliers and subcontractors are a major activity as it encompasses high coordination of operations and numerous different components from several suppliers and subcontractors.

Employee skills
Employee skills are required at all level in manufacturing and engineering processes, in which most cases are based on job experience. The specter of technological expertise is high, from how to build steel to building positioning equipment. The area comprises numerous employees in which tasks overlaps.

Divided costs of shipbuilding at Kleven
60% of the total value of the vessel produced at Kleven are signed to components, materials and semi-finished goods provided by suppliers and subcontractors. 10-15% of the total value constitutes wages and payment to workers. The remaining portion constitute financials, overheads and costs related to design.

5.2.4 Dimensions of Visibility

The need for external and internal dimensions of visibility at Kleven may be assessed based on the overall complexity of processes, operations and other characteristics of ETO environments. Table 11 summarizes the need for visibility based on the dimensions proposed in section 3.4.1 concentrating on ETO manufacturing strategy.

- *Colored cells underlines which factors enlarges weight for the need of visibility dimension based on the theory development linked to the characteristics of manufacturing strategies.*
- ** denotes that the assessed factor cannot be linked to characteristics and type of manufacturing strategy, but exclusively to a particular company. In other words, the denoted dimension varies independent of manufacturing strategy.*

Table 11: Assessment of the need for visibility at Kleven Verft AS.

External visibility dimensions	***Factors influencing need for visibility***	***Factor assessment***	***Analysis***
Demand visibility	Demand predictability	Low	Unstable demand as a result of production based on customer orders; Depended on the market forces and development in the shipbuilding industry;
	Level of collaboration	High	Share operational, technical, mechanical, and design plans of high customization with suppliers and customers.
Order visibility	Order frequency	Low	General few small to large orders to same suppliers consisting of specific requirements depending on type of components, semi-finished goods and materials for constructing specific vessel
	Order steadiness	Low	Each vessel customized to each new contract. Hence, order instability
Supply visibility	Contractual terms	High	Complex contracts covering hundreds of pages of specifications and requirements
Internal visibility dimensions	***Factors influencing need for visibility***	***Factor assessment***	***Analysis***

Warehouse visibility	Inventory level	Low	Do not have significant inventory level compared to manufacturing and assembly process of vessels
Personnel visibility	Process automation	Low	Mainly manual work with equipment for general purpose (cranes, lifts, tools, gears)
	Routinized work methods	Low	Each manufactured and assembled vessel requires distinct processes
Process visibility	Product complexity	High	Requires technical, operational and mechanical equipment of high specialization
	Process automation	Low	Mainly manual work with equipment for general purpose (cranes, lifts, tools, gears)
	Product range	High	Each produced vessel is unique with customer specific requirements

From table 10, Kleven`s need for different dimensions of visibility is determined by unpredictable demand (*Demand visibility*), low order steadiness (*Order visibility*), complex contractual terms (*Supply visibility*), low degree of process automation and routinized work methods *(Personnel visibility*), and high product complexity and product range (*Process visibility*).

The theory development chapter states that the higher the demand predictability, the less need for demand visibility. Kleven has unpredictable demand as they cannot direct anticipate demand in short terms, which indicate the need for demand visibility. Further, the greater steadiness of orders, the less need for order visibility, in which Kleven has low order steadiness and instability. This would suggest that Kleven need higher order visibility in order to gain the ability to track delivery schedules and purchase orders from numerous suppliers and subcontractors.

The theory development chapter further states that the greater the contractual terms, the higher need for supply visibility. The factor assessment shows that Kleven has high contract complexity which constitutes high level of contractual terms. Thus, supply visibility and the importance of having detailed information about materials, components and the composition of semi-finished goods are anticipated. The factors influencing the need for supply visibility can be linked to the ETO manufacturing strategy.

Further, the factor assessments of evaluating the need for personnel visibility at Kleven indicates that Kleven has a low degree of manufacturing and assembly process automation, as well as non-routinized work methods. The theory development chapter states that the higher the automated manufacturing processes, the less need for personnel visibility, and the higher degree of routinized work methods, the less need for the visibility dimension. Hence, Kleven operates in environments requiring greater need for personnel visibility.

Finally, it is stated that the greater the product complexity, the greater the need for process visibility. Shipbuilding is a highly advanced manufacturing procedure consisting of numerous parts and sub assembly processes. Further, the need for process visibility at Kleven is also determined by the degree of automated manufacturing processes. Therefore, the need for process visibility at Kleven are determined as essential. In conclusion, the majority of visibility dimensions is regarded as high at Kleven, with the exception of warehouse visibility due to low inventory levels.

5.3 Cross-case analysis

5.3.1 The Need for Visibility in MTS and ETO

A comparison of the two companies with their respective manufacturing strategy, and the need for visibility dimensions are summarized in table 12 and figure 17 in order to give an illustration of the differences. The relationship between the factor influencing the need for visibility dimension and the type of manufacturing strategy has been summarized in chapter 3.4.2.

Table 12: Comparison of visibility dimensions at Pipelife and Kleven

	Visibility dimension					
	Demand	Order	Supply	Warehouse	Personnel	Process
Pipelife		X		X		
Kleven	X	X	X		X	X

The spider diagram further illustrates the differences between ETO and MTS companies based on the characteristics of manufacturing processes compared to the results given from the respective companies.

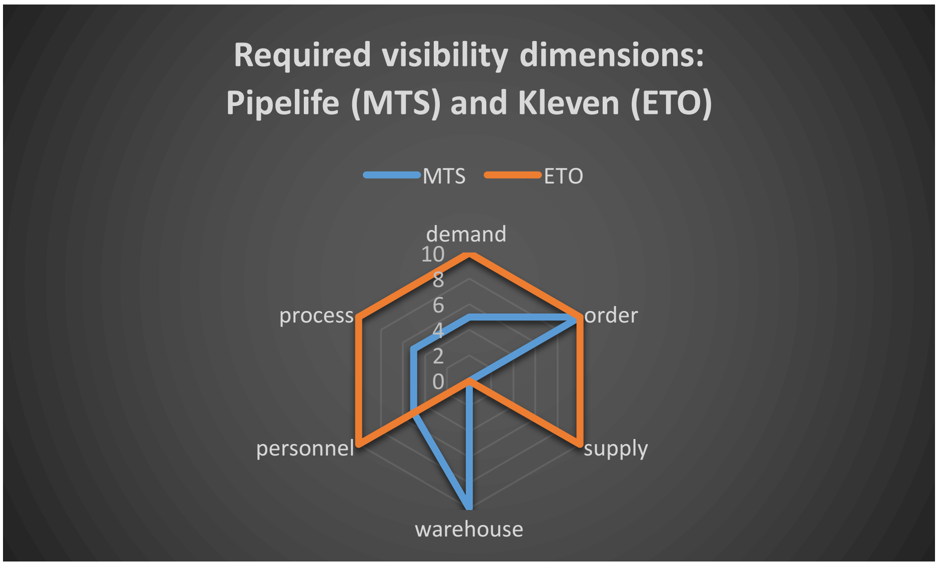

Figure 15: Variations of visibility dimensions in MTS and ETO

The diagram divides between low (0), medium (5) and high (10) level of the need for visibility based on the respective companies. It further indicates that the need for visibility in ETO environments are significant in the areas of demand, order, supply, personnel, and process visibility, whereas visibility dimensions of order and warehouse are more valued based on MTS characteristics. In MTS manufacturing strategies, demand visibility and order visibility are given the score of 5, which implies some form of visibility required but is not regarded as high as compared to others dimensions based on the characteristics of manufacturing strategy.

Demand visibility – Demand visibility is a more critical area in Kleven`s manufacturing strategy compared to Pipelife due to unpredictable demand. The need for demand visibility at Kleven is generated from the fact that manufacturing activities does not commence after receiving specific customer order. Hence, Kleven cannot predict when an order is placed due to product complexity but analyzes trends and petition within the market. The theory development therefore signifies greater need for demand visibility in ETO strategies compared to MTS strategies, in which the need for demand visibility in MTS situations are based on standardized manufacturing process before receiving a customer order.

- ETO strategies requires demand visibility due to demand based on customer specific orders

Order visibility is a main issue for both Kleven and Pipelife, but the factor influencing the need for visibility is dissimilar. The factor instigating order visibility at Pipelife is due to high order frequency, which in general can be classified as MTS enironments. The factor determining the need for order visibility at Kleven is due to low degree of order steadiness due to unique production and specifications for each vessel. The high amount of supplies needed in constructing a vessel is caused by the complexity of the product, which also define Kleven as a ETO company.

- ETO strategies requires order visibility due to mixed delivery and high range of supplies
- MTS strategies requires order visibility due to high order frequency

Supply visibility is more required at Kleven compared to Pipelife based on the complexity of contractual terms and conditions. The influencing factor can be addressed to specific manufacturing strategy based on the degree of complexity of supplies, customers, operations and processes, in which ETO involves highly complex contracts compared to MTS manufacturing companies.

- ETO strategies requires supply visibility due to highly complex contractual terms

Warehouse visibility – According to the theory development, the need for warehouse visibility is dependent on inventory level, which is more critical at Pipelife than Kleven. This is due to the fact that Pipelife as a MTS company, produce and stock finished goods of high volume batches with emphasis on an efficiency perspective. Due to continuous production lines, order frequency is regarded as high which also generates high raw inventory levels. Kleven stock certain standardized products and semi-finished goods in short periods. In addition, finished goods inventory is not present as the finished produce goods are the vessel itself, which is directly delivered to the customer.

- MTS strategies requires warehouse visibility due to high inventory levels

Personnel visibility – Low degree of automation in manufacturing and assembly operations and high degree of labor skills determines the need for personnel visibility at Kleven. The factors can be addressed to ETO strategies based on the complexity of operations, manufacturing and assembly lines. Pipelife manufacturing strategies involves high degree of process automation.

- ETO strategies requires personnel visibility due to manual manufacturing processes

Process visibility – The need for process visibility is more critical at Kleven compared to Pipelife, due to the characteristics of ETO environments given by the complexity of shipbuilding, low process automation and customer order uniqueness. In the case of Pipelife, automated processes and standardized products indicates low degree of product complexity, in which the need for process visibility is less.

- ETO strategies requires process visibility due to high product complexity, manual manufacturing processes and frequent product range.

In summary, the main dimensions of visibility that reveals diverse need for visibility lies in demand visibility, supply visibility, warehouse visibility, personnel visibility, and process visibility. The need for visibility for both companies and manufacturing strategies are order visibility.

5.3.2 The Effect of Increased Visibility in MTS and ETO

Subchapter 3.4.2 compares the characteristics of MTS and ETO manufacturing strategies in terms of in which case increased visibility has a greater impact. The need for visibility in the respective manufacturing strategies have been determined in the latter chapter, which indicates the need for visibility based on analyzing the case companies and the factor from manufacturing strategy causing the need for visibility dimension. This subchapter further explores the visibility dimensions determined in the previous subchapter and which visibility dimensions has a greater impact based on the two manufacturing strategies.

Table 6 summarizes the main dimensions of visibility needed in MTS and ETO environments influenced by a particular factor (characteristic of manufacturing strategy). The dimensions of visibility required in MTS environments are order visibility, warehouse visibility and equipment visibility. In the case of ETO strategies, all visibility dimensions developed, except warehouse visibility, has been evaluated as necessary based on the factors influencing the need for visibility.

Table 13 summarizes at which visibility dimensions has a greater impact in ETO and MTS environments (blue cells) in comparison with the visibility dimensions required based on the case companies (X).

Table 13: The need for visibility vs. the effect of increased visibility.

	Visibility dimension					
	Demand	Order	Supply	Warehouse	Personnel	Process
Pipelife		X		X		
Kleven	X	X	X		X	X

Table 13 shows that the effect of increasing order visibility has a greater impact at Kleven compared to Pipelife, which is a result of low order steadiness, mixed delivery and high range of supplies at Kleven. The need for order visibility at Pipelife has been determined based on the factor that MTS strategies requires high order frequency which again generates more resources for tracking orders. However, the order steadiness as Pipelife is recognized as high, which indicated routinized order processes enabling visibility of the order process.

Overall, the effect of increasing visibility in ETO environments have been validated to be significant compared to increasing overall visibility in MTS environments. The analysis of the case companies allows us to place them within the analytical model introduced in the theory development chapter (figure 11) in which the model has been verified.

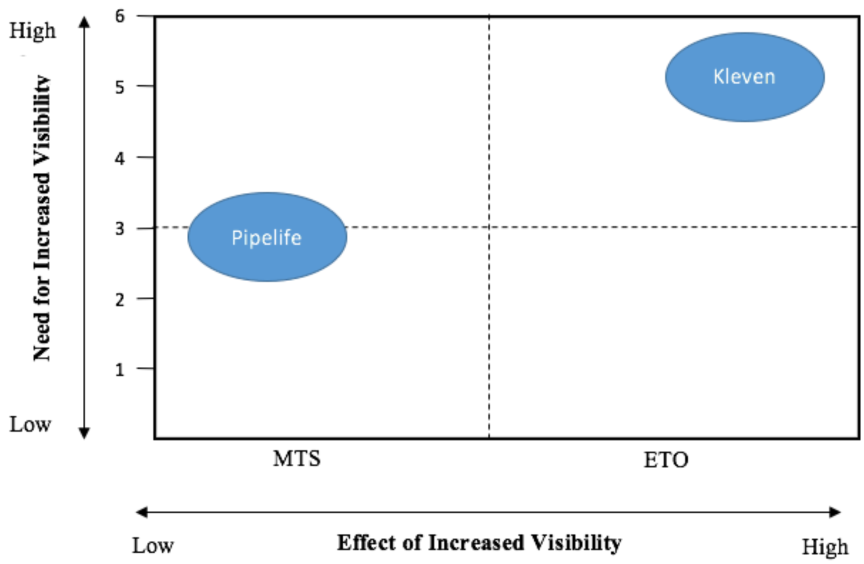

Figure 16: Effect of increased visibility at Pipelife and Kleven

In accordance to the theory development and the assessment of the effect of increased visibility in ETO and MTS manufacturing strategies, the results of Pipelife and Kleven have provided evidence that:

- ETO manufacturing strategies requires greater need for visibility dimensions
- The impact of increased visibility in ETO manufacturing strategies are significantly higher compared to MTS manufacturing strategies.

6.0 DISCUSSION AND THEORETICAL CONTRIBUTION

This chapter reflects and evaluates what was known prior to the study, and how the empirical findings have enlightened and enlarged the understanding of visibility from a manufacturers point of view concerning internal manufacturing operations and processes, as well as supply chain visibility connected to the characteristics given for ETO and MTS environments.

The thesis attempts to assess the differences of MTS and ETO manufacturing strategies in terms of the need for visibility. Thus, it tries to link the need for visibility dimensions and characteristics of manufacturing strategies, in order to identify similarities and disparities in dimensions of visibility needed in ETO and MTS environments, and at which manufacturing strategy increased visibility has greater impact.

6.1 The Need for Visibility in ETO and MTS Environments

The extensive literature review revealed that previous studies mainly concentrates on the benefits by increasing SC visibility, while there is a clear lack of understanding of the real need for visibility and different dimensions of visibility concentrating on visibility of internal processes within a company.

Several authors have suggested that visibility refers to traceability and tracking objects within and across supply chain parties. Other focuses on visibility into demand in order to reduce the bullwhip effect, or shop floor visibility to better coordinate operations within a manufacturing plant. Therefore, the term visibility connected to type of manufacturing strategies are somewhat unclear and imprecise.

The term SC visibility in this study have been defined as the identity, location and status of entities transiting the supply chain, captured in timely messages about events, along with the planned and actual dates/times for these events. Visibility in terms of manufacturing operations have been determined as having visibility and information of plant operations and process flows, production performance, labor analysis, equipment maintenance, quality planning and execution as well as visibility of inbound and outbound logistics. Therefore, the term visibility can be assessed through various areas, which requires different information about each events.

Different manufacturing companies have different motives for what type of visibility they want to achieve based on their manufacturing strategy. Make-to-stock companies produces standardized products in high volumes over a short period of time in order to serve a wide range of customers, in which production activities are triggered by forecasts and previous sales. Hence, such manufacturing companies have a certain visibility into how much they are going to produced. On the other hand, engineer-to-order companies produces unique and complex products over a long period of time aided to a specific customer. Therefore, demand visibility in such manufacturing companies is not present as they do not know the work flow and operations taking place until an order is received. However, the thesis does not take into account the time it takes to construct a product in ETO and MTS environments, which may vary depending in the complexity of the product. For example, construction a vessel takes between 1-2 years, which indicates operations for a long period of time only requiring a few orders in order to run operations. Compared to MTS environments, the throughput time in production is significant lower with high production volumes, in which demand predictability becomes more vital. However, due to the opportunity of stocking finished goods over a certain period of time, producing exceeding the demand can be compensated by reducing production volumes in the next period until the stocked inventory are at lower capacity.

The need for visibility can also be exemplified by the factors determining the need for order visibility. ETO companies requires high coordination of schedules for assembly and manufacturing processes in order to know at which stage each work package should take place. The low degree of order steadiness and frequency requires high order visibility due to continuously new specifications and requirements for constructing a vessel. On the other hand, MTS companies operate with the opposite characteristics, indicating higher order frequency and steadiness of orders. Therefore, ETO companies need to have greater information on when order should be placed and at which time they will be delivered to coordinate and plan production and assembly processes in accordance to the material needed for each production activity. In case of MTS companies, order visibility is partial given as the factors order frequency and steadiness are high, which indicates less attention to the respective dimension.

Through extensive literature review, this thesis aims at operationalizing the need for visibility dimensions through different manufacturing structures, and how the associated characteristics necessitates the need for visibility in ETO and MTS areas. The operationalization has been given through a framework based on two case studies.

Manufacturing strategy

Previous literature focuses on several manufacturing strategies, and reveals the main characteristics and associated activities. However, previous research does not focus on directing types of visibility that is necessary based on manufacturing strategy, but focus on other areas within a supply chain such as lead time, efficiency, agility, information sharing, power balance, vertical integrated supply chains and more.

6.2 Theoretical Contribution

The theory development chapter in this thesis is the fundamental element for evaluating the need for visibility dimensions based on characteristics of ETO and MTS manufacturing strategies. The visibility dimensions are based on permanent existences, which are similar in other companies operating with ETO and MTS strategies. The importance of exploiting permanent characteristics is to validate the need for visibility dimensions in all MTS and ETO companies and not only in the settings that can only be linked to the case companies.

Further, the theory development chapter aims at evaluating at which the effect of increasing visibility dimensions is greater, which has been proven to be ETO companies for most of the visibility dimensions, excluding warehouse visibility due to low inventory levels.

Based on the impact increased visibility has on ETO and MTS environments, an analytical model was proposed in order to verify that ETO circumstances requires higher degree of visibility. Further, the case companies verify the need for visibility and the effect it has on already instigated manufacturing strategy.

6.3 Fulfilment of Purpose

The main objective of this thesis is to "investigate dimensions of visibility in make-to-stock and engineer-to-order manufacturing strategies", which includes finding differences, similarities and inequalities. This subchapter tries to answer the research questions given in the research review, and whether the objective of the thesis has been reached.

> ***RQ1:*** *What are the main factors influencing the need for visibility in ETO and MTS manufacturing strategies?*

An extensive literature review on ETO and MTS manufacturing strategies and the use of two case companies revealed several factors which had an impact on the need for visibility in different areas. The main characteristics of MTS and ETO environments was validated through operations conducted at Pipelife and Kleven, which also revealed several factors influencing type of information and transparency of material flow and coordination of processes. The case study of Kleven proved to be significantly complex, in which the factors influencing the need for visibility is based on high product complexity, high customer involvement with specific requirements and specification, manual manufacturing operations, high product range, mixed delivery and low order steadiness. The main factors influencing the need for visibility at Pipelife and make-to-stock companies proved to be high degree of order frequency and high inventory level. The findings validate the complexity of ETO environments requiring a higher degree of visibility in all areas.

> ***RQ2:*** *How can dimensions of visibility be categorized based on the characteristics of manufacturing strategies?*

Previous literature has suggested the need for visibility in different areas, which was further linked to type and characteristics of manufacturing strategies and analyzed through two case companies. Therefore, dimensions of visibility were suggested through attentive factors of manufacturing strategy given in table 3. The need for demand visibility was determined by demand predictability and level of collaboration between SC partners. Order visibility was determined by the degree of order frequency and order steadiness. The complexity of contractual terms signifies the need for supply visibility. Further, the need for warehouse visibility was a result of inventory level, whereas the need for personnel visibility was influenced by the degree of automated processes and the degree of routinized work methods. Finally process visibility was evaluated based on product complexity, the level of process automation and product range offered.

> ***RQ3:*** *How does the position of the CODP effect the need for manufacturing and supply chain visibility in ETO and MTS strategies?*

The effect of increased visibility dimensions is dependent on how current manufacturing strategies and operations contains features which provide the desired visibility. The effect of increasing demand visibility, order visibility, supply visibility, personnel visibility and process visibility have been proved to be more significant in terms of ETO strategies mainly due to the complexity of the assembly and manufactured object itself which generates the higher degree of coordination, information sharing, advanced work schedules and work methods for each unique object. In MTS environments, the effect of increasing warehouse visibility is determined as significant due to high inventory levels. Hence, the position of the CODP influences the need for visibility across supply chains and on manufacturing operations.

7.0 CONCLUSION

This chapter reflects on the managerial implications, limitations and possible areas for future research and investigation.

7.1 Managerial Implications

This thesis has educational goals, in which the visibility dimensions can be used to signify the complexity of ETO environments compared to MTS strategies by viewing the analytical model presented. It can also be used to consider the factors influencing the need for information, collaboration and overall transparency of activities within and across supply chain partners. The factors influencing the need for visibility, based on the respective characteristics of MTS and ETO strategies, are considered to be equal in other industries, which would indicate that the visibility dimensions are applicable in other industries as well.

SC visibility is a recognized concept within logistics and supply chain management literature. This thesis also helps to inform the importance of having the right information in ETO and MTS manufacturing strategies.

7.2 Limitations

Certain limitations to this thesis can be addressed. First of all, the small number of interviews from the case companies provides small amount of information with unilateral responses. Additional interviews would increase the validity of the content by gaining comparable and related responses for reassurance. The interview guide could also be misinterpreted by the parties due to different perceptions, word formulation and standpoints. However, the underlining denotation of each question was thoroughly described and the questions were directed to their manufacturing strategy in order to validate the selected characteristics and relevant information and factors influencing ETO and MTS environments, which could be described as hard facts. Thus, the questions carried out were very precise in order to assess the characteristics of MTS and ETO environments.

Other limitations of this research are how the term visibility is used in previous literature, which includes a comprehensive and extensive literature review. Therefore, other factors determining the need for visibility based on manufacturing strategy may not be revealed in this study.

7.3 Further Research

This thesis aims at revealing the need for visibility based on selected characteristics of MTS and ETO manufacturing strategies, and the effect of increasing visibility based on the primary existence of such operations. The area of future research is broad and may concern other directions.

The research is based on two case companies and represents an initial step into how MTS and ETO manufacturing strategies affect the need for visibility dimensions. The next step would be to test the factors determining the need for visibility in other MTS and ETO manufacturing companies, and assess the influenced factor and the need for visibility, which would improve the validity and generalizability of the conducted research. The research would also include testing the analytical model in order to place the respective manufacturing strategies and validate that the need for visibility in ETO strategies are considered as greater.

Another area for future research is to study companies operating with make-to-order and assembly-to-order activities to reveal the differences on the perspective of visibility in supply chain and at plant floor. Further research could also compare the impact of visibility in comparing a hybrid approach vs one specific manufacturing strategy in order to evaluate how the dimensions of visibility would change.

In terms of the visibility dimensions developed, it would be interesting to investigate the benefits and obstacles for each visibility dimension presented and which factors that influence the need for visibility based on other elements defining a manufacturing strategy.

As mentioned previous in the study, the type of information and transparency desired between supply chain parties varies according to their position in the supply chain. As this thesis mainly focuses on manufacturing companies as the focal company in the supply chain, future research could be to compare companies within the supply chain and investigate the different dimensions of visibility required for each company and information asymmetry.

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9.0 APPENDIX:

The following questions was developed to gain information about the case companies, validate the selected characteristics defining manufacturing strategies, and determining factors that influence the need for visibility in the respective areas.

9.1 APPENDIX 1: Pipelife Interview Questions

General questions:

1. Please describe your supply chain (various roles of companies in your supply chain; suppliers, manufacturers, distributors, transporters, DC/warehouses, retailers)
2. How many different products does the company produce?
3. What is your market share?
4. Who are the main customer segment?

Manufacturing processes:

5. Are products standardized or specialized for customers?
6. Do you define the product produced as complex or simple based on manufacturing operations?
7. To which degree do you consider your manufacturing operations as complex or standardized?
8. Are manufacturing processes determined as automated or manual processes? (the involvement of highly technical machines, manual work etc.)
9. Describe in general the typical processes needed to produce a particular product at the manufacturing plant?
10. What do you consider as the main manufacturing processes in the production plant?
11. What is the shortest and longest time it takes to produce a product in the manufacturing system? (from beginning of production to final product)

Labor:

12. How many employees work in the production/assembly on a daily basis?
13. What type of employee skills is required to work at the fabrication? (Education, degrees, certifications etc.)
14. Do you consider the manufacturing process as routine work or non-routine work?

Information sharing:

15. What IT system does the company use for planning, ordering, storage, and shipment?
16. Through which medium is information shared between the company and suppliers and customers? (e-mail, phone, ERP, other type of software etc.)

17. What kind of information is shared between your company and other actors in the supply chain, and with what frequency?
18. How is your IT system connected to the supplier’s IT- systems? Please provide examples of how you interact electronically with a typical supplier.
19. How is the information gained from suppliers and customers used?

Demand:

20. What information from your suppliers and customers is important for scheduling manufacturing activities?
21. How do you predict demand for scheduling production activities? (forecasts, previous sales, specific orders etc.)
22. What type of information is shared between you and your suppliers?

Orders:

23. How many different suppliers can be found in the company`s source list?
24. How often do you order materials and components from your suppliers? (Order frequency)
25. How often do you place orders of the same kind as previous order for supplies of manufacturing materials? (Order steadiness)

Supply:

26. How important is it to have detailed information about raw materials from suppliers?
27. Do you define the contractual terms between you and your suppliers as complex or only based on a transactional level?
28. What details are required in a contract between you and your supplier/subcontractors?

9.2 APPENDIX 2: Kleven Interview Questions

General questions:

1. Please describe your supply chain (various roles of companies in your supply chain; suppliers, manufacturers, distributors, transporters, DC/warehouses, retailers)
2. What categorize of subcontractors and suppliers are part of the shipbuilding industry?
3. What is your market share?
4. Who are the main customer segment?

Manufacturing processes:

5. What type of operations and assembly processes does Kleven provide at their shipyard?
6. Are manufacturing processes determined as automated or manual processes? (the involvement of highly technical machines, manual work etc.)
7. Describe in general the typical processes needed to construct a vessel at the production and assembly facility.
8. What do you consider as the main manufacturing and assembly processes in constructing a vessel?
9. What is the shortest and longest time it takes to build and construct a vessel? (from design phase to delivery of vessel)
10. Please give some examples of how specific customers order varies within the assembly and manufacturing process of a vessel.

Labor:

11. How many employees work in the production/assembly facility on a daily basis?
12. What type of employee skills is required to work at the manufacturing facility? (Education, degrees, certifications etc.)
13. Do you consider the manufacturing and assembly process of building a vessel as routine work or non-routine work?

Information sharing:

14. What IT system does the company use for planning, ordering, storage, and shipment?
15. Through which medium is information shared between the company and suppliers and customers? (e-mail, phone, ERP, other type of software etc.)
16. What kind of information is shared between your company and other actors in the supply chain, and with what frequency?
17. How is your IT system connected to the supplier's IT- systems? Please provide examples of how you interact electronically with a typical supplier.
18. Give an example on how information gained from suppliers and customers are processed and used

Demand:

19. What information from your suppliers and customers is important for scheduling manufacturing and assembly activities in constructing a vessel?
20. How do you predict demand based on customer specific orders for scheduling operation activities?
21. What type of information is shared between you and your suppliers?

Orders:

22. How many different suppliers can be found in the company`s source list?
23. How often do you order materials and components from your suppliers for a specific customer order? (Order frequency)

Supply:

24. How important is it to have detailed information about raw materials, components and semi-finished goods from suppliers and subcontractors?
25. Do you define the contractual terms between you and your suppliers and subcontractors as complex or only based on a transactional level?
26. What details are required in a contract between you and your supplier/subcontractors? Give an example