Jyri Vuorela

OPERATIVE BUSINESS DEVELOPMENT THROUGH SYSTEM MODEL AND CHANGING BUSINESS STRUCTURES

ACTA UNIVERSITATIS LAPPEENRANTAENSIS 1096

LUT University

Jyri Vuorela

OPERATIVE BUSINESS DEVELOPMENT THROUGH SYSTEM MODEL AND CHANGING BUSINESS STRUCTURES

Dissertation for the degree of Doctor of Science (Technology) to be presented with due permission for public examination and criticism in the Auditorium 1318 at Lappeenranta-Lahti University of Technology LUT, Lappeenranta, Finland, on the 24th of November 2023, at noon.

Acta Universitatis
Lappeenrantaensis 1096

Supervisors Professor Juha Varis
LUT School of Energy Systems
Lappeenranta-Lahti University of Technology LUT
Finland

Adjunct Professor Vesa Salminen
LUT School of Energy Systems
Lappeenranta-Lahti University of Technology LUT
Finland

D.Sc. (Tech.) Mikael Ollikainen
LUT School of Energy Systems
Lappeenranta-Lahti University of Technology LUT
Finland

Reviewers Professor Stefan Trzcielinski
Department of Management Systems Faculty of Engineering Management
Poznan University of Technology
Poland

Professor Marius Rimasauskas
Department of Production Engineering Faculty of Mechanical Engineering and Design
Kaunas University of Technology
Lithuania

Opponent Professor Stefan Trzcielinski
Department of Management Systems Faculty of Engineering Management
Poznan University of Technology
Poland

ISBN 978-952-335-985-7
ISBN 978-952-335-986-4 (PDF)
ISSN 1456-4491 (Print)
ISSN 2814-5518 (Online)

Lappeenranta-Lahti University of Technology LUT
LUT University Press 2023

Abstract

Jyri Vuorela
Operative business development through system model and changing business structures
Lappeenranta 2023
98 pages
Acta Universitatis Lappeenrantaensis 1096
Diss. Lappeenranta-Lahti University of Technology LUT
ISBN 978-952-335-985-7, ISBN 978-952-335-986-4 (PDF), ISSN 1456-4491 (Print), ISSN 2814-5518 (Online)

Global markets and related operational activities create ever-changing challenges. The fluctuations of the global economy, in addition to customer demands, introduce dynamic challenges that a company should be able to overcome effectively. In a project business with long lead times, operational efficiency is essential while maintaining the ability to be customer oriented.

The objective of the research work was to create an intelligent business co-evolution framework based on scientific studies from systems theory, production theory and information theory. The framework is based on a combination of theories, as the research topic of this dissertation is not dominated by a single theory or discipline. The goal of the case study was to demonstrate how a theory-based framework used to develop a real-life operational business model into an updated and refined operating model brings significant operational efficiencies at the enterprise level.

The study approached the problem through four research questions and aimed to verify three propositions. As the research progressed, the need for three theories was identified. The knowledge generated by these was tested over several years in a case study in a real environment that provided answers to the questions identified.

As a result, the study found answers to the questions posed and verified the propositions made. At the same time, a system model was concluded in which the business elements work together in an integrated manner to form a streamlined operational entity.

The key contribution is that the intelligent business co-evolution framework has been created according to scientific studies and by novel proof-of-concept case studies on project business environment. The conceptual continuity has been fixed according to field laboratory test runs and implemented in real practice. The second significant contribution is the long-term development of the case study company's operational efficiency, monitored by several indicators.

Keywords: co-evolution, business structures, operative business development, system model, sustainable evolution

Acknowledgements

This work was carried out in the Energy and Environmental Technology department at Lappeenranta-Lahti University of Technology LUT, Finland.

I am very grateful to Professor Juha Varis, Adjunct Professor Vesa Salminen and Dr Mikael Ollikainen, who have been my supervisors in this extensive and long-term work. This work would not have been possible without their broad expertise, scientific visions and exceptional encouragement along the way. My warmest thanks for the many interesting and inspiring discussions I was able to enjoy with them during my work.

This research is the result of a collaboration of many people. I want to express my deepest thanks to all those who contributed to the work, especially the university and the case study company. I would particularly like to thank Lars Fagerholm of the case study company and Dan Guthrie of the parent company for their professional support and the opportunity to do the work. From the university, I would also like to thank Associate Professor Harri Eskelinen for his excellent guidance.

I wish to thank Professor Stefan Trzcielinski and Professor Marius Rimasauskas for their valuable time as reviewers of my thesis.

I want to thank Professor Stefan Trzcielinski for agreeing to be an opponent in the dissertation.

My profound gratitude goes to my parents, Seija and Eero, and my brother Pekka for their continuous support and help at different moments in life. Thank you to my close relatives and friends for their support and all the great moments.

A warm thank you to my children Robyn and Markus for your support during your own studies and challenges.

I especially want to thank my wife, Arja, for her inspiration, encouragement and love throughout all these years. Thank you for everything.

Jyri Vuorela
November 2023
Lappeenranta, Finland

Contents

Abstract

Acknowledgements

Contents

ABBREVIATIONS **9**

LIST OF FIGURES **11**

LIST OF TABLES **12**

1 Introduction **13**
1.1 Research work motivation ... 13
1.2 Research work objectives ... 15
1.3 Research questions and propositions ... 15

2 Theoretical framework **17**
2.1 Systems theory ... 17
2.1.1 System approach ... 19
2.1.2 Industrial dynamics systems ... 20
2.1.3 System of mass customisation ... 23
2.2 Production theory ... 25
2.2.1 Evolution of different production models ... 25
2.2.2 Waste elimination ... 29
2.2.3 Flow production ... 30
2.2.4 Continuous improvement ... 32
2.2.5 Value stream and current state analysis ... 33
2.2.6 Company-level improvement ... 33
2.3 Information Theory ... 34
2.3.1 Continuous integration of data ... 35
2.3.2 Industrial maturity levels ... 36

3 Methods **39**
3.1 Research approach and process ... 39
3.2 Research design and implementation ... 41

4 Results **45**
4.1 Case study ideologies used in managing business transition ... 45
4.1.1 Identify the situation and model creation ... 47
4.1.2 Revision based on interpretation of simulation results ... 49
4.2 System steps to manage business development ... 50
4.3 Value stream with steps and tack connected to flow ... 51
4.4 The System model ... 52

4.5 Obligations to customer 55
4.6 ABC product classification 56
4.7 The process of managing the offering of both standardised and customised white paper products 58
4.8 Process to improve standard products offering based on customer phase latent information 60
4.9 Model line structure follows product classification 61
4.10 Component feedback process 62
4.11 Risk assessment process for products and production lines 64
4.12 Standardisation of the document process 65
4.13 Long-time change measured on several key business indicators 67
4.13.1 Change in On Time Delivery 2012–2016 67
4.13.2 Change history in the amount of quality cases 69
4.13.3 Change history in quality costs 70
4.14 Supporting measured metrics 71
4.14.1 Product level change 71
4.14.2 Effects in resourcing 72
4.15 Maturity level change 73

5 Analysis and Discussion 75
5.1 Development of business structures in specific order 77
5.2 Business transition requires measuring system 78
5.3 Need of the system model 79
5.4 Limitations of the results 81
5.5 Future Research Challenges 81

6 Theoretical contribution 83

7 Managerial Implications 85

8 Conclusions 87

References 91

ABBREVIATIONS

ABC	Product categories
AI	Artificial Intelligence
AM	Agile Manufacturing
BPM	Business Process Management
CPI	Customer Project Information
CPS	Cyber-Physical Systems
ERP	Enterprise Resource Planning
HARP	Heightening Awareness Research Philosophy
ICT	Information Communications Technology
IMPV	International Motor Vehicle Program
IoT	Internet of Things
IT	Information Technology
LP	Lean Production
OC	Offer Calculation
OTD	On Time Delivery
PCDA	Plan-Do-Check-Act
SOA	Service Oriented Architecture
STS	Sociotechnical Systems Theory
TPS	Toyota Production System
VPS	Volvo Production System
VRIO	Valuable Rare Inimitable Organisation
WCM	World-Class Manufacturing

WIP Work In Process

XPS 'Company name' Production System

LIST OF FIGURES

Figure 1. Trend view of changes in revenue and operating margin
Figure 2. Installation of the research question and proposition
Figure 3. Setup of the theories and their perspective crossing zones
Figure 4. Industrial systems development steps
Figure 5. The dynamic system of hybrid innovation
Figure 6. Mass customisation reinforcing dynamic system feedback loop
Figure 7. The Volvo Production System pyramid
Figure 8. Phases of the Industrial Revolution
Figure 9. Industry 4.0 Maturity levels in the development process
Figure 10. Business and management research process
Figure 11. Research onion
Figure 12. Methodological choice used in research
Figure 13. The research design positioned in the research onion
Figure 14. New applied combination from different ideologies
Figure 15. Model development sub-cycle
Figure 16. Systems development model for managing business development
Figure 17. Value flow described before and after
Figure 18. Overall view of the system model and partial magnification from it
Figure 19. System model
Figure 20. Process of critical customer project information
Figure 21. Rules of product ABC-classification
Figure 22. Product update schedule
Figure 23. Offer calculation flow
Figure 24. Offer calculation collection model sheet
Figure 25. Continuous component feedback process
Figure 26. Model structure from risk assessment to customer documentation
Figure 27. Hierarchy between different systems
Figure 28. Hierarchy from engineering structure to the model line
Figure 29. Amount of quality cases with trend lines
Figure 30. Quality cost % of gross sales
Figure 31. Model of workload chart
Figure 32. Notified development change on Industry 4.0 maturity level
Figure 33. Model of the process of how to manage the business transition
Figure 34. Main measuring elements
Figure 35. Whole system model view
Figure 36. Essential business elements from quotation to customer delivery
Figure 37. How the process reflected on learning in the company
Figure 38. Conceptual framework setup
Figure 39. Research approach outline

LIST OF TABLES

Table 1. Porsche study
Table 2. Identified process operators
Table 3. On Time Delivery (OTD) development history
Table 4. Change history in product class appearance

1 Introduction

Since the early 20th century, developing different business models and production systems has played an increasingly important role in globally industrialised countries. The increasing understanding has widened the ideology of systems, production and business models used to update existing models.

The global nature of modern business significantly complicates the operational business model of companies. It is clear that there is no single original theory to manage the entire business model, especially in a global multinational enterprise. Over time, old individual theories have been developed, but a broader theoretical perspective is needed to develop a firm's operational business model. Several key theories that can be applied have been identified, widening perspectives and supporting the development process. These theories have unique and common elements. Even these common elements can be viewed from different perspectives based on the core of the underlying theory. The main theories studied, which are not limited to these, are systems theory, production theory and information theory.

These theories are introduced because of the specific areas on which they focus. Systems theory is needed to manage the whole system rather than a single element or aspect. Production theory is used to manage production and streamline Lean operations. Information theory is needed to manage information when data masses are used across all the individual elements of a business.

In business and management research, managers are unlikely to grant research permission unless they see an organisational or personal advantage, making the research more sensitive to the approach. Connecting stage holders with a wide range of knowledge allows them to discover new insights that individual disciplines cannot achieve. Business and management research needs to connect the worlds of theory and real practice (Saunders et al., 2016).

The case study in a customer-oriented global project business investigated how the development of the company's operational functions and new operating models have influenced the company's performance by selected indicators. It was decided to develop a system model where the business structures as elements work together in an integrated way. At the same time, a functional overview of the continuous change management and new business structures needed to make it work as a whole was created.

1.1 Research work motivation

The motivation arises from historical case study company problems. The case study company operates in the global machine manufacturing project business and is a market leader in many segments. Single machines and components are connected, creating large operating lines that produce high-quality products. Global economic changes escalate problems in business. The company’s backyards were full of material waste, which were undelivered and unpaid customers' products worth 15–20 million euros. This resulted in financial problems and ownership changes. Figure 1 shows the historical change in revenue and operating margin. In 2010 the operating margin went way below zero, generating a clear motivation for improvements.

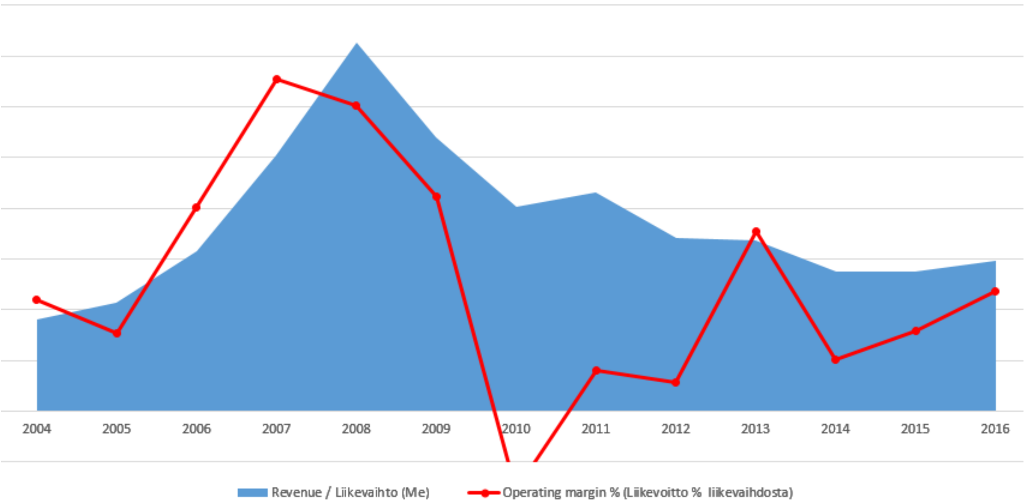


Figure 1: Trend view of changes in revenue M€ (blue area) and operating margin % (red line).

Further motivation for research work arises from studying how carefully selected system models, production methods and concepts are implemented in real field cases in the global project-oriented business environment. The tools used have differed according to need. Some changes have generated new changes and measuring metrics following these. The real work has been mirrored by measured indicators, justifying new changes. The findings have resulted directly in new changes or in the review and revision of previous changes. Based on the nature of the case study project business and total delivery time from quotation into production on the customers' premises resulting from the indicated changes takes a long time. Typically, delivery time from project start to delivery of the products is 6–8 months. Including shipping and transportation to the customer, it easily takes over a year. After installation and commissioning, the answer or result of a successful or unsuccessful project can take at least a year and a half to two years.

It is like turning a large ship if you describe how problematic monitoring and making changes are. First, changes are small indications, and the results come in from far away when the ship starts to turn. You have to rely partly on indicators created for the upcoming future.

1.2 Research work objectives

The objective of the research work was to create an intelligent business co-evolution framework based on scientific studies from systems theory, production theory and information theory. The framework is based on a combination of theories, as the research topic of this dissertation is not dominated by a single theory or discipline.

The case study goal of the research work was to demonstrate how a theory-based framework used in a real-life operative business model evolves into an updated and developed operating model that brings significant company-level operational efficiency. One of the key targets was to take into account customer expectations and fulfil quality requirements while managing to create standard and customer-specific products cost-efficiently in a modern global networked operating environment.

1.3 Research questions and propositions

The problem of seeking improvement in business productivity and profitability in a global customer-driven project business environment raised the following research questions:

Q1. How to manage the business transition from project to product and to life cycle business?

Q2. What are the essential changing business structures and elements?

Q3. How to measure the change and development of business structures and elements?

Q4. What is the integrated system model to manage the changing business?

After a long field study, the research questions raised made visible the following research propositions:

P1. Business transition requires development of business structures in specific order.

P2. Business transition requires co-operatively defined measuring system.

P3. Integration of business structures in changing business needs system model.

Introduced research questions and propositions are from the centre of the research configuration shown in Figure 2.

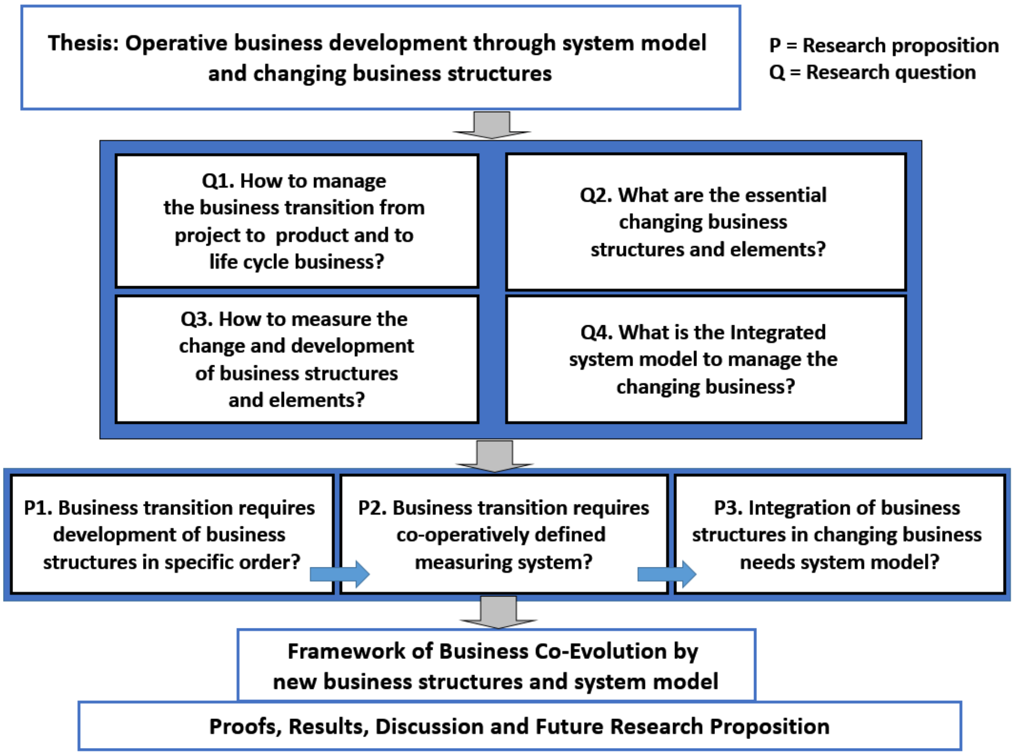


Figure 2: Installation of the research questions and propositions.

2 Theoretical framework

This dissertation has focused on business co-evolution by new business structures and related business model, which gave direction to analysing related theories. As there is no single theory or discipline to master the research topic of this dissertation, several theories have been identified as the framework's base. The theories are systems theory as co-evolution, production theory as managing by operation and information theory as managing by data. The setup of crossing theories is shown in Figure 3.

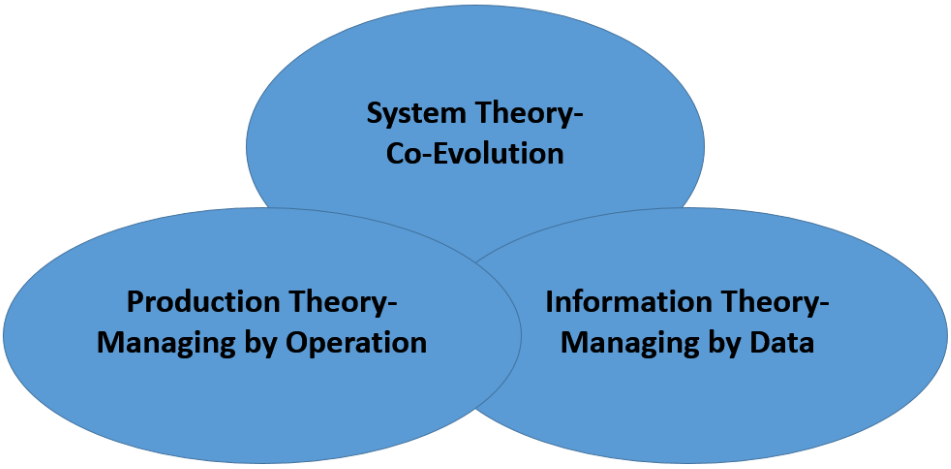


Figure 3: Setup of the theories and their perspective crossing zones.

2.1 Systems theory

System thinking, as a fifth discipline, is the one that looks for wholes. It concentrates on discovering interrelationships and patterns of change rather than things and still pictures. It is a discipline of seeing structures that underlie complex issues and distinguishes significant high-leverage changes from low-leverage ones (Senge, 2006).

Systems thinking has existed for a long time but can be considered founded in optimism before World War II. The great innovations made in the 19^{th} and early 20^{th} centuries can be considered responsible for today’s problems (Skyttner, 1998).

Separating and understanding the origin of regularities and their interaction is crucial to understanding complex systems (Holland, 2000). A Complex adaptive system is a cluster of parts interacting with each other’s and eventually creating system-wide patterns. There are multiple perspectives on which every complex system is dependent. To consider different perspectives and understand patterns created by them, you need to understand how people make meaning of their individual and shared realities (Eoyang & Holladay, 2013).

The balance point where systems somehow stay balanced between chaos and order is usually called the edge of chaos. Where the components of the system are never grounded (Waldrop, 1992)

In the system, dynamic complexity exists because systems typically are; 'constantly changing, tightly coupled, governed by feedback, nonlinear, history-dependent, self-organising, adaptive, characterised by trade-offs, counterintuitive and policy resistant'. Complex systems generate more complexity, and cause and effect are often distant in time and space. The delayed and distant consequences of our own actions are different from and less salient than their proximate effects or are simply unknown. In the system, the most complicated actions typically arise from interactions (feedback) between the components of the system (Sterman, John D., 2000).

There are multiple levels of explanation given a systems perspective to complex situations. At least the following levels of explanation can be recognised, starting with the most common: event (reactive), the pattern of behaviour (responsive) and systemic structure (generative). The last explanation, systemic structure, is the most powerful but least apparent. It answers the second level by asking what generates patterns of behaviour (Senge, 2006).

You can understand some issues by examining how major organisations, like engineering, sales, project management and sourcing, interact. But to have a deeper understanding, one needs to look for critical systemic force issues occurring within functional areas and others caused by the industry dynamics. The interactions that must be examined to solve the issue at hand, regardless of surrounding organisational boundaries, are called the key principles 'principles of the system boundary'. This is often difficult to practice since organisations prevent people from detecting and visualising important interactions (Senge, 2006).

Complexity can be found in different forms. Detail complexity is more easily recognised and focused on rather than dynamic complexity. Dynamic complexity is related to situations where cause and effect are substiles, and consequences are not obvious. Traditional business analysis, planning and forecasting tools are not equipped to manage and cover dynamic complexity. Understanding deeper and choosing dynamic complexity instead of detail complexity is where the real leverage lies in most management situations (Senge, 2006).

System thinking development is a learning process with two loops. The reductionist, limited and static view is replaced by a holistic, broad and dynamic view, followed by change and design policies and functions accordingly (Sterman, John, 2000).

It is recognised that people in the same organisational structure are most likely to behave similarly in complex systems. When to be efficient, system thinking and modelling require an open mind; participants should recognise their limitations in view perspective and defensive actions. Negative feedback means a self-correcting process, and positive feedback means self-reinforcing (Sterman, 2000).

The organisation's core learning dilemma is that 'we learn best from experience, but we never directly experience the consequences of many of our most important decisions'. As Donella Meadows impressed: 'A truly profound and different insight is the way you begin to see that the system causes its own behaviour' (Senge, 2006).

2.1.1 System approach

How to define a system? 'A system is a set of things people, cells, molecules or whatever interconnected in such a way that they produce their own pattern of behaviour over time'. To a large extent, a system generates its own behaviour. A system has the following structure where three different interactively connected components are: elements, interconnections and a function or purpose. The function or purpose can be considered the least obvious part of the system and is the most critical determinant of the system's behaviour. A living example of a system is an ice hockey team, where the elements of the system are the players, coach, field and hockey. The rules of the game, game strategy made by the coach, communication between players, and the laws of physics affecting hockey, ice and the players are interconnections. The team's purpose is usually winning the games, spending time and enjoying exercise or making money for the team (Meadows, 2008).

Systems can have subsystems built-in and different purposes structured in different layers of the system. This makes it even harder to separate the systems' different functions and purposes. Any of the subsystems' purposes can collide with the master system's purpose. A key factor to a successful system is to keep the master system and subsystems in harmony and focused on the same goal (Meadows, 2008).

The foundation of the systems is stocks; they are physical and nonphysical stored elements. Elements which be seen, felt, counted or measured at any time. Generally, changes in stocks set the rhythm of the dynamics of the system. Stocks can absorb inflows and outflows, which are temporarily out of balance. Adjusting the stocks, lowering and increasing is managed by the feedback processes. Feedback loops are balancing or reinforcing. The balancing feedback loops are goal-oriented or stability-oriented as the different reinforcing loops, which are snowballing, amplifying and self-multiplying (Meadows 2008). Flows and stocks are essential elements in the dynamics of complex systems (Sterman, John D., 2000).

2.1.2 Industrial dynamics systems

An industrial system consists of six flows; the flow of money, orders, material, personnel and capital equipment, which are integrated by an information network; the flow of information. The information network is critical in giving the system its own dynamic characteristics. 'An information-feedback system exists whenever the environment leads to a decision that results in action which affects the environment and thereby influences future decisions' (Forrester, 2013).

How to model an industrial system? First, you must identify the business case organisation's problems and goals. The next step is to generate a model which shows the interrelationships of the important factors in the case. This model will show results from interactions between its component parts. These interactions are typically more crucial than the separate component parts. Separate departments like engineering, manufacturing, sales, finance etc., are too often displayed as separate skills, not as a part of a unified system (Forrester, 2013).

In the industrial system development, Forrester described separate steps to follow in enterprise design (Figure 4).

- The first thing is motivation, where there is a clear goal and open questions are to be answered. The important problems are more rewarding to master but often take no more effort than trivial ones.
- The second task is to describe the situation. The factors which are found behind the answers must be visualised, described and connected. The result of the second step should describe the exact factors and their interrelationships.
- The third step is the mathematical model. This model will provide information on the mechanics of the interactions between the parts of the system.
- Simulation is the next step, which can be done in real life or cost efficiently by computer.
- The fifth step is the interpretation of the results of the simulation. Questions to be answered after simulation; Are the results as expected? If not, what is the reason? New questions will arise after deeper analysis.
- The next phase is system revision, making improvements by redesigning the system structures and policies. The results depend on the designer since this is a process of invention and trial.
- The whole process should be reviewed and revised to repeat the experiment. This should be done as needed to obtain an efficiency level where the design can be used in real life.

Management science must look for improvement, not hang on to an optimum and perfection (Forrester, 2013).

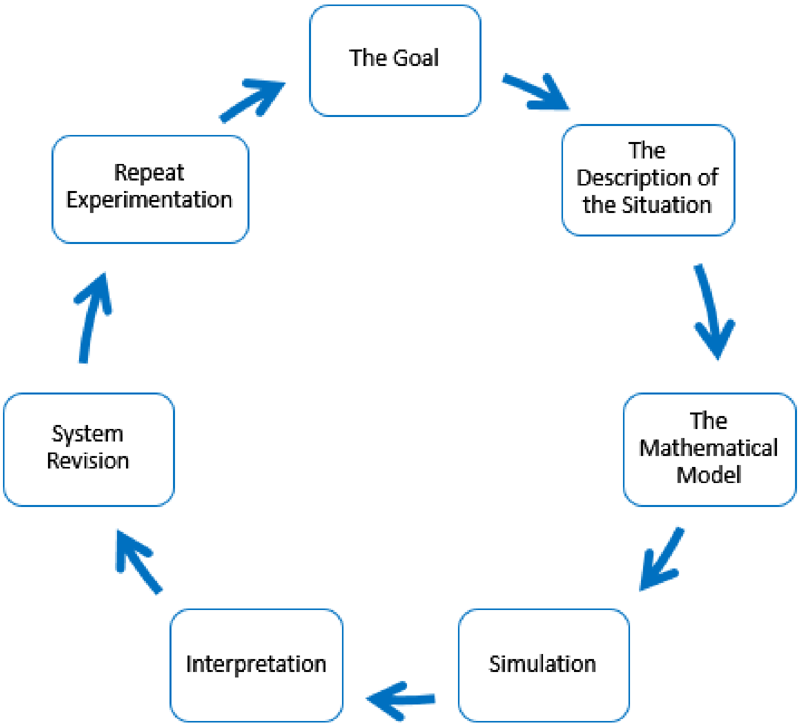


Figure 4: Industrial system development steps.

During the model, the elaborating modelling team gathers information about the issues by interviewing the organisation. Meetings between the core and modelling teams are held where the model is critically reviewed and developed, starting from the early interim phase towards a more sophisticated model (Sterman, John D., 2000).

Sterman wrote about his view on more extended principles for successfully utilising system dynamics. These are the fundamental principles for the successful development and execution of the system dynamics model:

1. Develop a model to solve a particular problem, not to model the system.
2. Modelling should be integrated into a project from the beginning.
3. Be sceptical about the value of modelling and force the 'why do we need it' discussion at the start of a project.
4. System dynamics do not stand alone. Use other tools and methods as appropriate.
5. Focus on implementation from the start of the project.
6. Modelling works best as an iterative process of joint inquiry between the client and the consultant.

7. Avoid black box modelling.
8. Validation is a continuous process of testing and building confidence in the model.
9. Get a preliminary model working as soon as possible. Add detail only as necessary.
10. A board model boundary is more important than a great deal of detail.
11. Use expert modellers, not novices.
12. Implementation does not end with a single project.

System thinking teaches by the principle of leverage that the most obvious solutions to a problem do not work. It may give short-term results in the best case, but in the long run, it makes things worse. System thinking demonstrates that minor well-focused improvements can have significant results. And the biggest results are often found in the least obvious direction. These high-leverage changes are hidden and nonobvious to most of the system participants. The most obvious symptoms are more attractive to choose from than symptoms of high-leverage changes, which are deeply hidden in the system (Senge, 2006).

The concept of hybrid innovation has been introduced in synergy management, consisting of a business space with three axes: business innovation, customer innovation and life cycle innovation. Integrating the concept of hybrid innovation into the life cycle concept and using the management architecture as a reference model for the available service, product and knowledge structures provides an effective system architecture for the synergy management framework of hybrid innovation in the transition phase of the business life cycle. The architecture of complexity and the mapping of interactions between different domains are essential elements of the framework. Figure 5 shows the Dynamic System of Hybrid Innovation (Salminen, 2009).

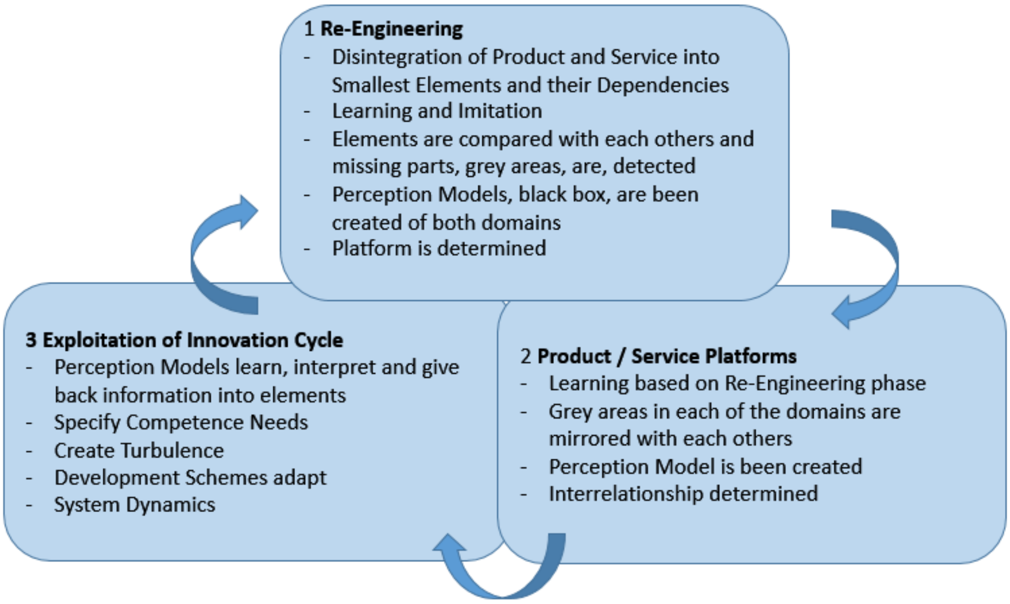


Figure 5: The Dynamic System of Hybrid Innovation (Salminen, 2009).

2.1.3 System of mass customisation

In the systems model of mass production, the interaction between manufacturer and consumer has a feedback loop, which creates and reinforces standard products, mass production techniques and large homogenous markets. In mass production, the ultimate goal is to provide standard goods and services at prices affordable to nearly everyone. This is the opposite of mass customisation, where the goal is to provide products and services in a manner where options and customisation for nearly everyone's demands can be satisfied. Pine proposed five fundamental steps in mass customising products and services:

- Customised services are provided on top of standard products made by marketing and delivery.
- Provide products and services embedded and customisable by the end customer.
- Point of delivery customisation where there is a limited time frame for customisation during the sales phase.
- Enable quick response; products and services are delivered in a short delivery time.
- Modularise standard components to configure various customised end products and services.

Mass customisation, compared to mass production, creates a new logic in the dynamic system model. The new dynamic system feedback loop of mass customisation reverses the old mass production one. Figure 6 presents a mass customisation feedback loop (Pine, 1999).

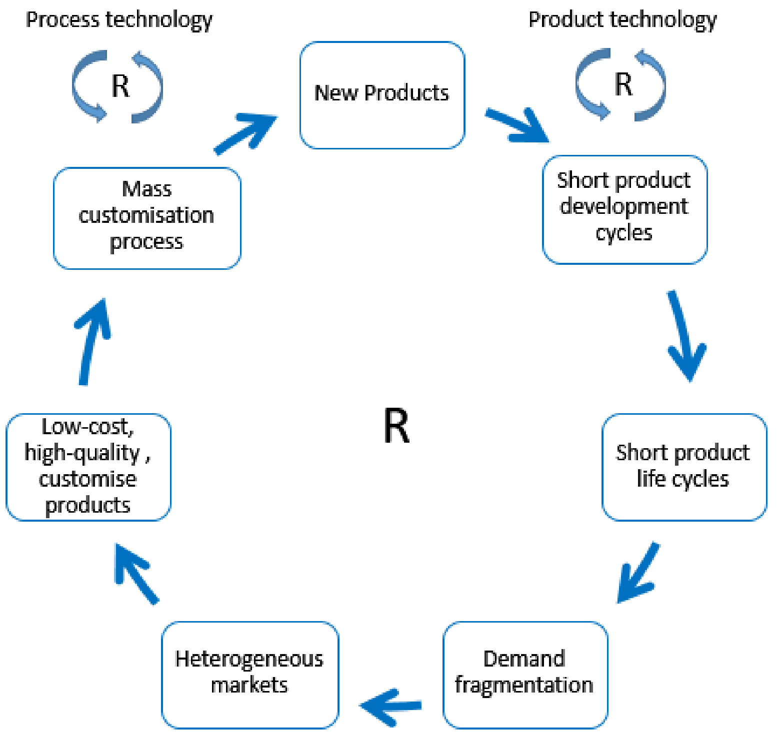


Figure 6: Mass customisation reinforcing (R) dynamic system feedback loop (Pine, 1999).

From the perspective of mass customisation to keep a company successful in the present and the future, four different parallel activities are recommended. The first is the mass customisation process, based on pre-engineered products, where you can produce customer-tailored products almost immediately. Second is incremental platform innovation based on the customer's needs. Third is follow-on platform development to obtain continual technological improvements and increase the value provided to customers. The fourth one is to acquire latent customer information for breakthrough innovation research in the field of new business with new products and services (Pine, 1999).

2.2 Production theory

Historically, advanced approaches to streamlining production have been noted, such as ship hulls equipped in the 15th century as an assembly line. Early high-volume production or mass production can be found in industry segments like automotive, guns, clocks, sewing machines, grain harvesters and bicycles, which drove the development of production theory. The automotive-related industry has played a significant role in developing production theory among other industry segments.

2.2.1 Evolution of different production models

History has shown different approaches to improve productivity in companies' way of doing their business. Many years of studies, innovations, implementations, corrections and readjustments have evolved the efficiency approach to working models. The essence of business or production models, which was stated brilliantly almost three decades ago, can be described as eliminating waste. In the big picture, waste exists in different forms, as concreate and abstractive in companies' business models. The employees have been at the centre of these ideologies, their learning and continuously improving culture.

In the early 1900s, the Ford production methods were adopted by many manufacturers like Morris, Austin, Renault, Citroen, Fiat, Opel and Volkswagen (Wilkins & Hill, 2011).

Ford's first car was road tested on June 4, 1896, which was the beginning of the new era. After Henry Ford was made adjustments and had learned plenty from it, it was sold. This was the first used car sale made in the U.S. The second car was finished by 1898, which was improved from the first one. The first U.S. driver's license was issued to Henry Ford by the mayor of Detroit (Curcio, 2013).

After the huge success of the Model T, Ford and his employees began to experiment with assembly line production in 1908. The very first line was improvised and rope-operated. In earlier history, pyramids were produced, and ship hulls were equipped in the 15th century in an assembly line manner. Ford production's first assembly line was the flywheel magneto's subassembly in 1913. During one year, the line efficiency was improved from 20 minutes to 5 minutes, and workers decreased from 29 to 14 (Curcio, 2013).

Typical Ford mass production features used at that time were interchangeable parts, an in-house press process and a moving assembly line. At the same time, production models in high-volume manufacturing (mass production) can be found in segments other than the automotive industry, like guns, clocks, sewing machines, wagons, grain harvesters and bicycles (Non-Indexed Pages #2.1985).

Ford was an example of the successful mass production of cars and shared production knowledge willingly or unwillingly. The production of cars and trucks in U.S. plants in 1903 was 1,708. In Canada in 1905, 117 vehicles were produced. Ford's different production facilities located in Europe began in 1912. It started in England, where they produced 3,178 cars compared to at the same time, in U.S. plants 170,068 cars and Canada 11,584 cars. In 1931 production began in Germany, and after a few years, in 1935, new production started in France. The number of cars and trucks produced in 1935 was quite significant. In the U.S., 1,120,606 were assembled; in England, 66,605; in France, 9,692; in Germany, 12,768 and in Canada, 80,172 (Wilkins & Hill, 2011).

Ford had its own rubber plantation in the Amazon to ensure the availability of rubber for tyre production, which the company sold to the Brazilian government in 1945. Ford was even urged to participate in the developing Chinese economy by Sun Yat-sen in 1924 (Wilkins & Hill, 2011).

Woollard was educated at the City of London School and Brick College. After college, he took an apprenticeship with the London and South Western Railway. There he gained practical knowledge of flow production. He was also involved in the development of the Clarkson steam-powered omnibus. After getting more experience in car design as a leading draughtsman (Weigel Motors), in 1910, he became chief draughtsman. In 1918 he was promoted to chief engineer and assistant managing director. He experimented with flow production during the war to manufacture axles and gearboxes. As the general manager of Morris Motors Engines Branch, he pioneered flow production and production automation during the 1920s (Church, 1996). From 1924–1925 Woollard published several papers presenting the details of Morris Motor’s flow production methods (Emiliani & Seymour, 2011).

Mr Woollard described in 1925 in his theory of continuous flow production that the target was not mass production; instead, it was the endeavour to secure continuous flow 'so that a relatively small factory may meet the greater overseas plants'. Mass production should be outdated by continuous flow production. Continuous production is not a new invention itself. Different industries (food, newspaper, textile and others) have been practising for many years (Woollard, 1954).

Shingō has significantly influenced different businesses' productivity. The first record of him working on flow production was when he implemented it in 1943 at Amano Manufacturing for torpedo mechanisms and reached a 100% improvement in productivity. Between 1948 and 1954, he held production technology courses in Japanese companies. In 1945 after having taught courses at Toyota, he was hired as the first consultant to Toyota. He widely taught improvement training at Toyota and to its suppliers' employees (Shingo Shigeo & Liker Jeffrey, 2007).

Shingō describes the basics of production as the absolute elimination of waste by improving the four elements of the process: processing, transport, inspection and delay. Of them, the only value-adding one is processing; the remaining three are non-value-adding waste. These three should be eliminated as much as possible (Shingō, 1988).

While making the business turn around at Danaher in the mid-1980s, Art Byrne and George Koenigsaecker called the business development a 'just-in-time' or Toyota production system; this was before the term *Lean* was invented (Byrne & Womack, 2013).

Researcher John Krafcik coined *Lean* during the International Motor Vehicle Program (IMVP). Because the system uses less of everything compared to traditional mass production, it was called *Lean* production. There is a striking difference between mass production and lean production's fundamental goals. Mass production aims for a decent goal, 'good enough', compared to lean production, which aims for perfection (Womack James et al., 1990).

In the book *The Machine that changed the world*, Jones, Roos, and Womack stated the five essential elements of a lean business system. These elements are designing the product, supply chain coordination, dealing with the customers, producing the product from order to delivery and managing the combined enterprise. These five elements must combine in a mutually supporting way to succeed in business (Womack James et al., 1990).

The book review stated in 1989 that the Toyota production system empowers its workers by using them as an autonomic nervous system. In the Toyota production plan, the idea of automatic nerve means lowering bureaucracy and making judgement-based decisions at the lowest possible level. The Toyota production system provides keys to transcend the traditional business limits in different areas 'Managers of finance, marketing, human resources, production and accounting will find it directly relevant to their areas of interest' (Starr, 1989).

Multinational companies develop company-specific production systems. These systems can be called 'company name' Production Systems as XPS. Multinational companies are consolidating their local improvement programs into a whole enterprise-wide production system. As a good example, Toyota shows its case of the TPS way of durable competitive advantage. The value of company-specific production systems XPS competitive advantage can be evaluated in the VRIO model. 'The VRIO model explains that sustained competitive advantage can only be gained from resources that are Valuable (V), Rare (R) and Inimitable (I) and Organisationally (O) exploitable resources'.

The VRIO model analysis of the TPS durable competitive advantage shows that XPS can be the source of durable competitive advantage. Similarly, the Volvo Production System (VPS) can be evaluated. Volvo was a Western pioneer in lean production (Netland & Aspelund, 2013). Figure 7 shows the pyramid production system applied by Volvo.

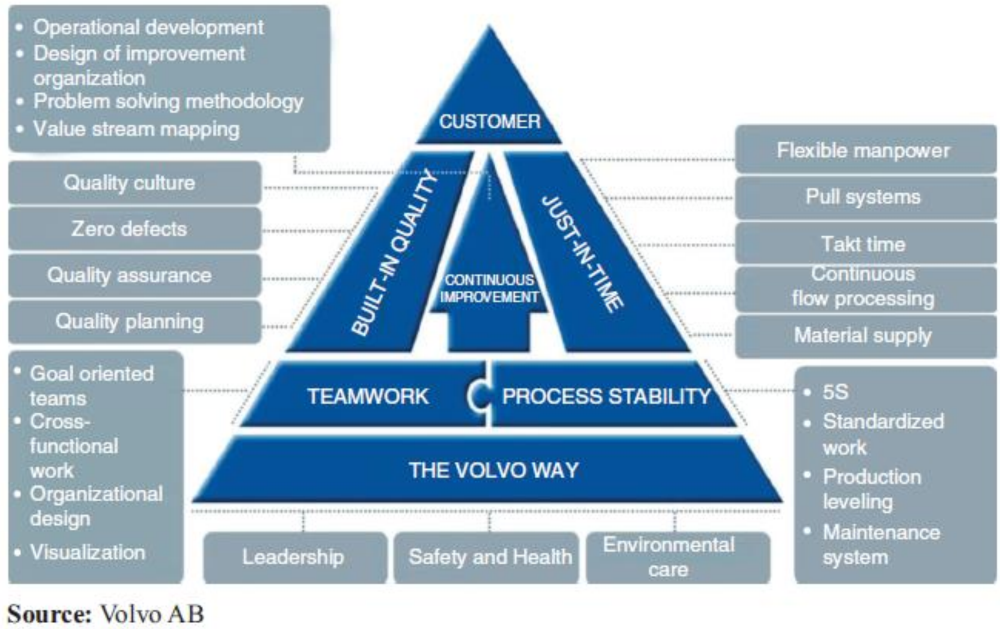


Figure 7: The Volvo Production System Pyramid (Netland & Sanchez, 2014).

Shingō studied the Volvo method in the 1960s and visited Volvo plants several times. He noted the human aspect of work is understood differently by Volvo. The Volvo method tolerated both worker character types, the ones who are indolent by nature (type X) and the ones who are hardworking (type Y). Changing the characteristics of human nature from X to Y cannot be done quickly. The Volvo production system tolerated inventory 'inventory is a necessary evil' (Shingō, 1988).

Sociotechnical systems theory was used at Volvo Cars to attempt to break Taylorism in their Kalmar and Uddevalla factories. They combined efficiency and worker well-being. It became visible that a superior overall system needs the most suitable elements from Lean Production (LP) and Sociotechnical Systems Theory (STS) as a hybrid model. The workers' well-being has been in focus throughout the history of STS. Considering the work organisation's design, workers' natural motivation can be increased. 'Integrated work organisation' where production teams can master diverse tasks following STS principles of multifunctionality. Tasks are connected to production flow and previous indirect functions such as quality, control, maintenance and planning. Implementing lean practices and integrated work organisation together can achieve better productivity than just implementing a lean production model. In the early stages of STS, responsible autonomy was a goal, which generated inventory buffers to protect production. Using integrated work organisations with essential lean methods such as inventory reduction, just-in-time production and a pull system instead of a push system brings positive benefits (Dabhilkar & Åhlström, 2013).

The Volvo business units have the freedom to choose whether or not to implement VPS, a continuum of Volvo's decentralised historical strategy. A central goal seen in Volvo's system is to create a learning organisation with greater change-tact time than the competitors. In global industries, the growth and importance of company-specific production systems (XPS) are indisputable (Netland & Aspelund, 2013).

World Class Manufacturing is another approach to productivity and efficiency originally presented by Hays and Wheelwright in 1984. Later, Schonberger reinterpreted the ideology and presented a new World-Class Manufacturing (WCM) model in 1986. Fiat officially introduced its WCM model in 2006. As in lean production, one of the famous books is *The Machine that Changed the World* (Womack James et al., 1990) Similarly, for WCM, the book *World Class Manufacturing – The lesson of simplicity Applied by Schonberger* (Chiarini & Vagnoni, 2015).

Agile manufacturing (AM) is a 21st-century approach to the manufacturing efficiency model. Different eras of industries and production models can be identified, from the craft industry to mass production to lean manufacturing and now agile manufacturing. The agile concept is a flexible and quick response focused on the customer and customer-designed products. New tools provided by information technology, such as concurrent engineering, virtual manufacturing and information infrastructure, are deployed in agile manufacturing (Gunasekaran, 2001).

The term for the concept of agile manufacturing was coined in 1991 by a team of researchers at the Iacocca Institute, Lehigh university. Agile manufacturing models do not negate earlier manufacturing paradigms. They are more likely synthesising from there to create a new 21st-century approach (Yusuf et al., 1999).

2.2.2 Waste elimination

In the TPS system, Ohno defined that the most vital objective to increasing efficiency is to eliminate waste consistently and thoroughly. Thorough waste elimination has been the starting concept of the Toyota Production System (Ohno, 1988).

Taylor's view of waste, *The Principles of Scientific Management* (Taylor, 1911), in production was the difference between optimal production in the theoretically best way identified and managed by scientific management compared to the current production level. Similarly, Henry Ford also understood that waste is a loss of production potential (Koskela et al., 2012).

Shingō noted that there is nothing wrong with the saying 'eliminate waste'; instead, he proposed an improvement, 'find waste', which serves more the idea of solving specific problems and continuous improvement. He stated, 'There are many examples of waste in workplaces, but not all waste is obvious. It often appears in the guise of useful work. We must see beneath the surface and grasp the essence' (Shingō, 1988).

The concept of waste has been scientifically used for two centuries. The use of waste ideology has continued through different eras. First, it emerged in the 19th century flourished almost totally vanished in the second quarter of the 20th century and saw its revival through lean vocabulary. Over time, the definition of waste has evolved lately to being connected to sustainable values (Koskela et al., 2012). In the World-Class Manufacturing ideology (WCM), Schonberger pointed out the point that: 'accounting time must be spent keeping track of and categorising the contributors to waste and delay' (Chiarini & Vagnoni, 2015; Schonberger, 1996).

2.2.3 Flow production

Woollard understood and had a vision that the production flow starts from the sales department and continues throughout the organisation (Woollard, 1954, p.104). He described the early principles of flow and continuous production in his article *Some notes on British methods of continuous productio*n in 1925 (Woollard, 1954).

The ideology of flow production and production levelling has been mentioned in the TPS production system by Ohno. Shingō stated the importance of flow production and deepened it, defining the flow curve with the statistical approach (Shingō, 1988).

Woollard was already working with flow production issues in the mid-1920s that were later characteristics of the TPS system: work cells, part families, standardised work, just-in-time, supermarkets, automation (jidoka), takt/cycle time, quick change over, multi-skilled workers, arranging layouts and equipment in the phase in which value is added. One of his principles states: 'The production system must benefit everyone; consumer, workers and owners' (Emiliani & Seymour, 2011).

Lord Nuffield (William R. Morris) established technology transfer into Australia at the end of World War II and created a factory for Morris Minor and Oxford cars. The factory opened in March 1950, with flexible manufacturing techniques, including just-in-time supply principles. The manufacturing concept included modern storage and retrieval techniques. A group of UK Longbridge engineers moved to Australia to support technology transfer (National Committee on Engineering Heritage, 1999).

Henry Maudslay was an early machine-tool manufacturer and one father and improver of the screw-cutting lathe in the early 1800s. Before the invention, screws were made essentially by hand. The lathe made possible the standardisation of screws, nuts and bolts vital to parts interchangeability (Gordon, 2015). Screwed bolts were perhaps invented as early as 400 BC by Archytas of Tarentum. But it took several hundred years to get them under mass standardisation and agree on standards with uniform thread sizes (Kelleher, 2002). The standardisation of these basic elements was needed before large volume usage and further development of productivity in production.

The first time Toyota requested Ohno to prepare standard work methods for textile work was in the late 1930s. Since then, the map of proper working procedures has shown its importance in production. The standard worksheet should clearly list these elements: cycle time, work sequence and standard inventory. Later it proved to be the origin of his plant-first principle (Ohno, 1988).

In the production system, the use of standardisation or the opposite as divergence depends on companies' general policy shaped by sales, reported Woollard. He also noted that regularisation better describes standardisation in production ideology (Woollard, 1954).

A measurable base for improvements is created when creating a standard way of doing any value-adding job or work simultaneously. By clearly defining how work proceeds, time, material tools, and the methods to be used, the base for the first work reference standard is done where improvements can be compared and evaluated. Fixing variables of working also gives more consistent quality and productivity (Byrne & Womack, 2013).

In the flow process, just-in-time production is described as follows by Ohno on the TPS, 'the right parts needed in assembly reach the assembly line at the time they are needed and only in the amount needed'. This describes the basic idea of the just-in-time process. If operated accordingly, there would not be a need for inventories. The real world has shown it is not always possible to work without inventories; common sense is also needed (Ohno, 1988).

W. Edgar Deming held quality and productivity seminars in Japan and taught that in the business system, it is everyone’s task in the organisation to meet customers’ requirements. The concept of fulfilling customers' needs is broadened to include internal and external customers. The origin of Deming’s principle was that the next process is the previous customer. This gives significant expression in just-in-time production with a pull system, 'the preceding process must always do what the subsequent process says' (Liker, 2004).

The just-in-time process practically removes all inventories and clears the transparent image of production. The whole system stops when a simple part is missing or of bad quality. According to Ohno's view, this is the power of just-in-time production. It will remove all inventories and safety reservations and focus on lurking problems in the previous production process before they threaten to stop production (Womack James et al., 1990).

In the pull type, production productive actions are based on orders received. These orders are firm orders emerging on actual need. This is fundamentally different from push-type production, where the fundamental premise for actions is speculative need. Products are pushed through production from the source (Shingō, 1988).

This production model has an ideal state when everything is made as ordered and there is no excess inventory. If the downstream process has no demand, the upstream process stops producing. This prevents the build-up of unwanted inventory (Work In Process) between processes (Stoller, 2015).

The implementation of the pull system is complex compared to the principles of the simple idea. Companies often start their lean journey by implementing the pull system instead of establishing one-piece flow, standard work and working operations with the takt time first. In the lean business, the pull system can be seen as a fundamental concept and should be kept in mind when creating a lean business (Byrne & Womack, 2013).

The roots of Kanban go back to 1953 when the first Kanban was applied in Toyota's machine shop. Ohno got the idea for the name Kanban from U.S. supermarket pull systems. The basic idea is that the later process indicates a need for the goods, and the earlier process gets input to produce goods just consumed by the later process. Kanban is the operating method of the Toyota Production System. It is the method of carrying information vertically and horizontally within Toyota (Ohno, 1988).

Kanban means 'tag' or 'ticket' and controls and coordinates the production. The major problem with the Kanban system is that Kanban get lost. This method of controlling production requires short setup times, small lots and short lead times from suppliers. The Kanban is an autonomic nervous system of production control that functions with minimal inventory (Shingō, 1988).

This Kanban system can be seen as a car fuelling process in everyday life. When the fuel level gets low in the gas tank, you get an alarm indicator, and after that, you fuel your car. Normally you do not fuel a car with an almost full gas tank. You keep minimum inventory when filling the gas tank as late as possible (Liker, 2004).

2.2.4 Continuous improvement

The improvement should never end, Ohno claimed in the TPS system. The essential continuous improvement area should be the timeline from when the customer places the order to the point we collect the cash. Improvements are to focus on reducing the timeline by removing non-value-added wastes (Ohno, 1988).

The improvement can be incremental or radical. Companies should adopt an authentic culture of continuous improvement. Japanese adopt a systematic approach to continuous improvement. The Deming Circle or Plan-Do-Check-Act is a cornerstone of the continuous improvement of the Japanese ideology called Kaizen. It is the process of making systematically incremental improvements (Liker, 2004).

Shingō proposed six improvement principles, which were found to be efficient during his time for making improvements. Attitude, Division of labour, Mechanisation, Motorisation, Synchronisation and Standardisation. Standardisation is defined into four subtitles; materials, parts, products and machines, dies and tools. Standardisation is an effective way of improving productivity (Shingō, 1988).

Ohno noted, 'without standards, there can be no Kaizen'. The work process and the management process need to be standardised. Before standardising work or every step in the process, you cannot hope to improve it. When you have a standardised way of working, you can determine what aspects of the process are currently causing the problem. After a clear picture of a better process can be seen. Then the implementation plan can develop, measure the results and adjust the process accordingly, which is the PCDA process (Womack James et al., 1990).

The evolution of PCDA started in the early 1920s. At Bell Laboratories, Walther Shewhart invented the early-stage concept of control charts. W. Edwards Deming revised the Shewhart process control cycle and created a plan-do-check-act cycle. It aimed to reduce variation between desired and delivered performance. The ISO9001 quality management standard recognises the PDCA model as managing processes and creating process-oriented thinking (Gupta, 2006).

2.2.5 Value stream and current state analysis

Value streams are surrounded by different organisational functions. Each function has its own responsibility to create value for customers. The problem is if each function is blindly looking at its tasks and nobody is responsible for the whole value stream (Liker, 2004).

The value stream and process can improve remarkably if the process is analysed from the customers' perspective and proceeds with different identified steps. Recognised steps are to draw a current state map where different waste is identified, then define the future process flow by making a future state map, create an implementation plan, visually measure progress and focus on continuous improvement of the changed map and process (Liker, 2004).

2.2.6 Company-level improvement

Company-level improvement has been studied and identified five useful steps that lean companies have taken (Womack & Jones, 1996) Direct quote:

1. Define value precisely from the end customer's perspective in terms of a specific product with specific capabilities offered at a specific price and time.
2. Identify each product or family's entire value stream and eliminate waste.
3. Make the remaining value-creating steps flow.
4. Design and provide what the customer wants only when the customer wants it.

5. Pursue perfection.

The method of developing organisational processes and flow of work suggested by Liker (Liker, 2004) has been recognised during the study.

1. Identify different customers (internal and external) in the process.
2. Recognise and understand both repetitive and unique processes.
3. Map the flow to define value-added and non-value-added issues.
4. Create a future-state value stream map with process improvements according to lean tools.
5. Implement improvements and use the PDCA cycle to continue development.

Significant improvement in company-level performance has been recorded during companies' work with lean ideology, Table 1.

Table 1: Porsche study (Womack & Jones, 2003).

Porche's Lean Transition - Key Results	1991	1997
Production Cycle Time - Welding to Finished Car	6 weeks	3 days
Inventories - Avg. days stock per part	17 days	3 days
Effort - Assembly hours per car	120 hours	45 hours
Quality (Defects per million for bought parts)	10000	100
Quality (Defects per car post-assembly)	100	25
Concept to New Model Launch	7 years	3 years

2.3 Information Theory

Industrial revolutions are recognised as four revolutions. The first was in the 18th century, the transition from muscle power into mechanical production with water and steam power. The second revolution was in the 19th and 20th centuries during the era of mass production and electricity. The third revolution started in the 1960s from computing through personal computing into the internet era in the 1990s. The fourth revolution is where increased cognitive power is accelerating human production. It is about fundamentally changing the culture of living, working and relating to others (Schwab, 2016).

The Fourth Industrial Revolution is the engaged use of cyber-physical systems in industries, particularly manufacturing sectors (Schwab, 2016; Xu et al., 2018).

Cyber-physical systems are the incorporation of computation and physical processes. Built-in computers and networks monitor and control physical processes through feedback loops. There are interactions in both directions between computing and physical processes (E. A. Lee, 2008).

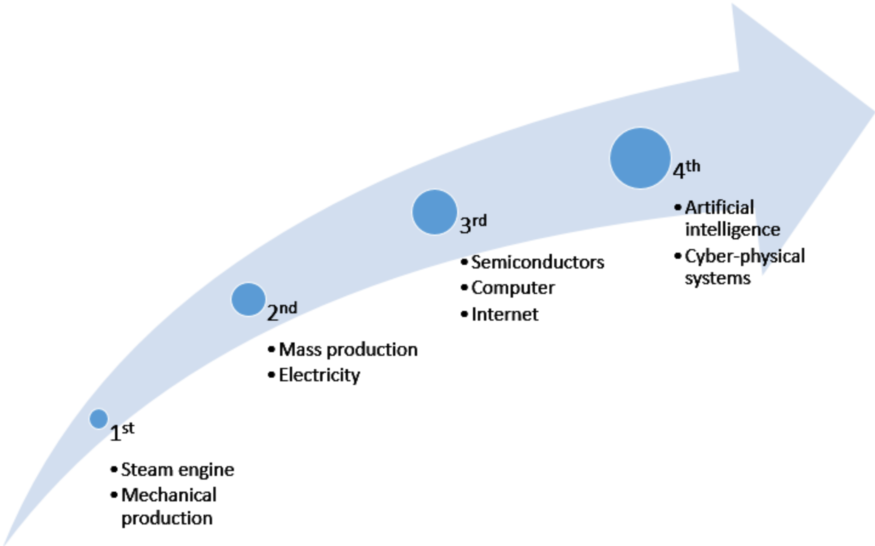


Figure 8: Phases of the Industrial Revolution (Schwab, 2016).

2.3.1 Continuous integration of data

Inside the large frame of the Fourth Industrial Revolution is an essential component of Industry 4.0, which emerged as an initiative in Germany early 2010s, concentrating on the application of digital technologies to manufacturing. Industry 4.0 focuses on the relationship between digitalization, organizational change and productivity improvement in manufacturing and production systems (Philbeck & Davis, 2019).

Germany Trade and Invest describes Industry 4.0 as referring to 'the intelligent networking of machines and processes for the industry with the help of information and communication technology'. Industry 4.0 started as a national strategic initiative by the German government's Ministry of Education and Research. Industry 4.0 was established in 2011. Four major sectors are recognised within industry 4.0, the Automotive and Lightweight Technologies Sector, ICT and Software Sector, Machine and Equipment Sector and the Microelectronics Sector (GTAI, 2018).

Applications from different disciplines, such as cyber-physical systems (CPS), Internet of Things (IoT), cloud computing, industrial integration, enterprise architecture, service-oriented architecture (SOA), business process management (BPM), industrial information integration, among others, are giving rise to the emergence of Industry 4.0, which is also known as smart manufacturing and cognitive manufacturing (Xu et al., 2018).

The development and progress of Industry 4.0 is creating a growing demand for a skilled workforce through the intelligent networking of machines and materials, automated work processes and innovative software solutions in the Internet of Things (GTAI, 2018).

Industry 4.0 is used as business architecture in supporting business-based ecosystem development. The business ecosystems are dynamic networks of entities where participants create value by communicating with each other (Ruohomaa & Salminen, 2019).

2.3.2 Industrial maturity levels

The use of Industry 4.0 data allows different levels of maturity to be identified. The starting point is usable and correct data. Relevant information should be usable and visible in real-time to all necessary internal and external stakeholders. With the foundation in place and reliable and consistent information, more advanced levels of the Industry 4.0 development process can be achieved.

At an early stage, production can be described as using computers, but these are not connected to each other on a network. In the most advanced stage, the system operates autonomously, making decisions and optimising operations independently. Figure 9 shows different maturity levels (Schuh et al., 2020).

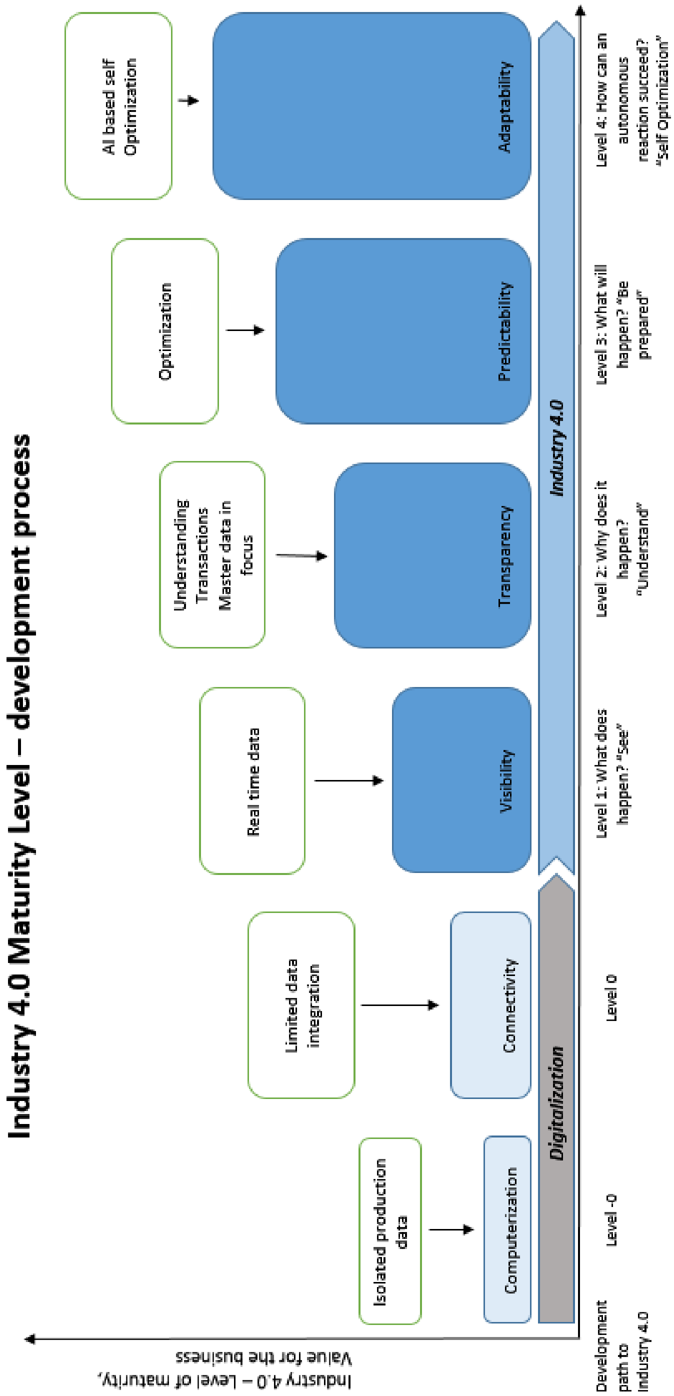


Figure 9: Industry 4.0 Maturity levels in the development process (Schuh et al., 2020).

Almost every object can gather and transmit information through embedded technology in the 'Internet of Things' (IoT). Increased connection of operations technology to information technology (IT) makes available new and unprecedented collaboration across the enterprise, which is able to link processes and facilities to suppliers and customers in new and value-adding ways. Securing data and infrastructure set new challenges in these connections (Rockwell Automation, 2014).

In Enterprise Resource Planning (ERP) systems, data quality is an essential requirement for the proper function of the whole system. Data quality has several definitions, commonly referred to as accuracy, usefulness and timelessness. The business data quality should consider three phases when inputting data, processing data and output. The real data usefulness will only be known once the effects of a decision based on this information are known (Hernes et al., 2020).

Companies with large worldwide operations can suffer impacts of poor data quality resulting in customer and employee dissatisfaction, problems with reputation and additional costs (Glowalla & Sunyaev, 2014).

Defects and improperly captured data can have several root causes, which are invisible to the operator using the data. ERP data integrates and supports various corporate data-related activities like engineering, manufacturing, sales, purchasing, production, finance, accounting, personal management and implementing advanced business processes (Lee et al., 2010).

Challenges are to master products according to the paradigm of mass customisation where the goal is developing, marketing, producing and delivering cost-efficient way products and services with enough options, variations and customisation that nearly every customer finds precisely what they want. The more efficiently a company satisfies individual customer requests and needs, the greater the sales (Pine, 1999).

Toyota has continued improving kaizen using artificial intelligence (AI) and a computer vision platform provided by Toyota's partner Invisible AI. The target for this partnership is to support continuous improvement in safety, quality and operational efficiency leading to an unsupervised computer vision system that learns continuously and, based on that, provides business value (*Invisible AI Partners with Toyota to Install Ground-breaking Computer Vision Platform Across North America.* 2022).

3 Methods

Based on the scientific study of different theories, a business co-evolution framework was created, implemented, tested, and further developed into a proof-of-concept made on an actual case study in a modern customer-driven business environment. The case study has proceeded on the company level focusing on the operating model-related development with daily business life. The long-time findings and progress have had many effects, both radically and incrementally. The research was carried out in the running years 2012–2016. Almost all organisational levels and functions contributed and worked during that time. Long-time information and data were collected through development meetings with many iteration rounds, department meetings, management meetings, management reports, financial reports and the ERP system.

The ethical and ideological goal was to have a neutral organisational view and look out for the best interests of the personnel and company as a whole rather than looking out for the interests of one department or person.

3.1 Research approach and process

The research process is based on business and management research process since the study is closely connected to the evolution of operative business models in a customer-driven project business environment. Methods under different theories and production philosophies have been utilised. Applied theories include systems theory as co-evolution, production theory as managing by operation and information theory as managing by data.

Figure 10 illustrates a schematic view of the research process by Saunders (Saunders et al., 2016). The process is guided by separate stages, which are shown as a straightforward process. In a real-life case, research stages are overlapped and are generally revised in several ways.

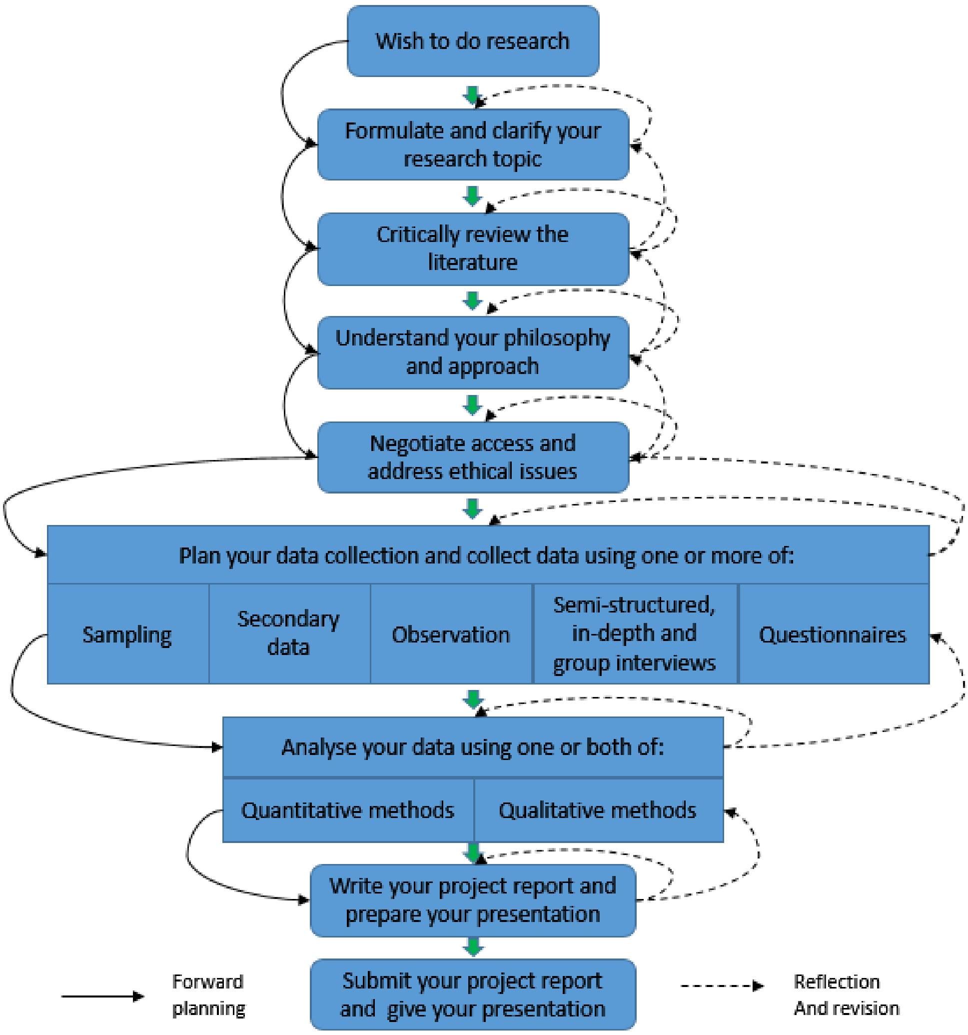


Figure 10: Business and management research process (Saunders et al., 2016).

As the research process suggested, the research topic was defined, and the research questions were designed and formulated. These questions are described in the introduction.

The more profound process of formulating research design can be approached through the research onion presented by Saunders in understanding research philosophy and approaches to theory development (Saunders et al., 2019). It visualises the choice of data-collecting techniques and analysis methods the research onion is shown in Figure 11.

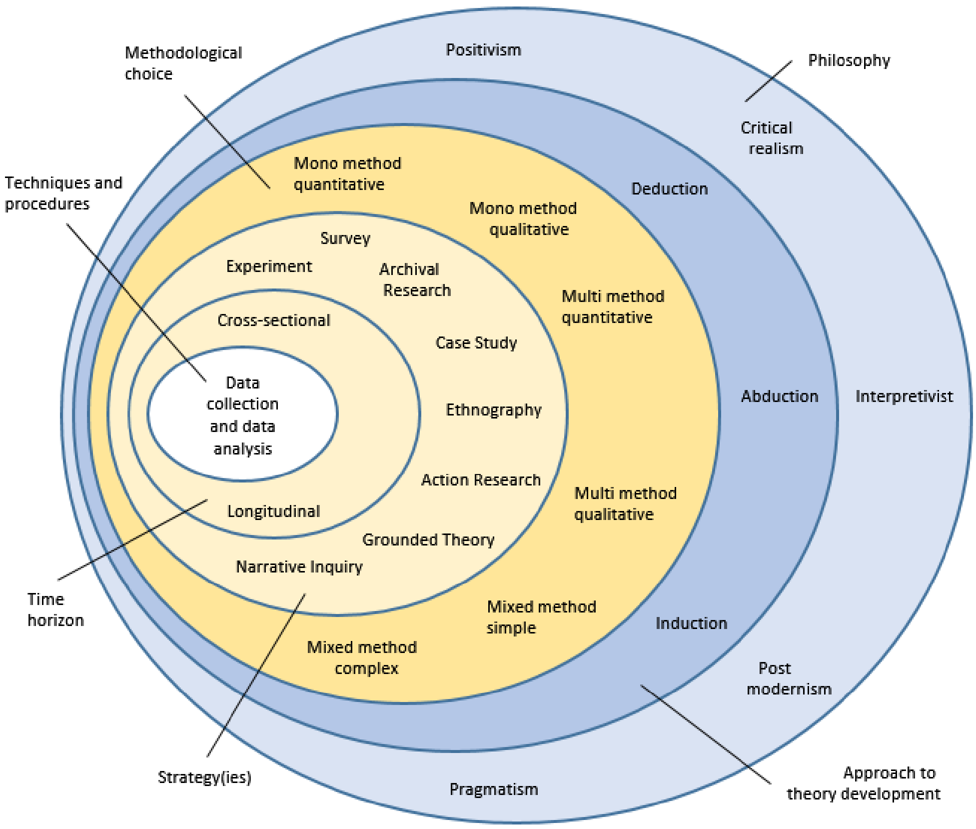


Figure 11: Research onion (Saunders et al., 2019).

3.2 Research design and implementation

There are elements of different philosophies in the study. It cannot solely claim that the philosophical approach is either Positivism or Pragmatism. More likely, the ideology is a combination of these two. In the suggested 'Heightening your Awareness of your Research Philosophy (HARP)' test, the highest scores were achieved by Pragmatism, and the second was Positivism in evaluating this research. 'Pragmatists recognise that there are many different ways of interpreting the world and undertaking research, that no single point of view can ever give the entire picture and that there may be multiple realities' (Saunders et al., 2019).

Theory development status in research is the next phase in the research onion. There are three approaches to theory development: Deductive, Inductive and Abductive. In the deductive approach, the aim is to use data to test the theory. In the inductive approach, the focus is on using data to develop a theory. The last one is abductive, where the approach is that inductive interferences are developed, and deductive interferences are tested iteratively throughout the research. This abductive approach was applied to this research.

In this study, different methods are utilised in mixed order depending on the phase of the research study. The methodological choices used are illustrated in Figure 12.

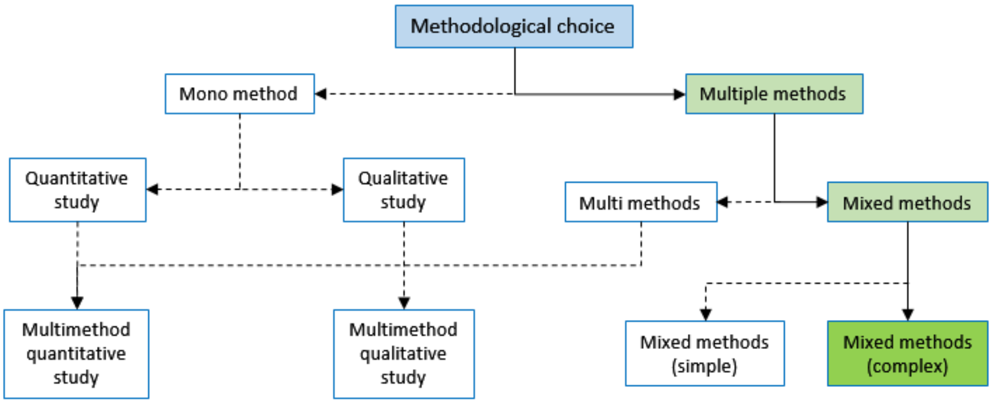


Figure 12: Methodological choices used in research (mod. from Saunders et al., 2019).

In the study, quantitative and qualitative methods were applied during the research process. The numeric data was output from the ERP system and applied management reports. Non-numeric data was recorded in development meetings and transferred into process map revisions. The following results are a combination of applied mixed methods.

A principally qualitative research design was applied, and strategies according to these were applied. Elements of the following primary strategies were identified and applied: action research, case study and grounded theory. The following the strategy process descriptions are defined by Saunders, direct quotes from Saunders (Saunders et al., 2016).

- Action research is an emergent and iterative process of inquiry that is designed to develop solutions to real organisational problems through a participative and collaborative approach, which uses different forms of knowledge, and the organisation beyond the research project.

- Case study strategy has the capacity to generate insights from intensive and in-depth research into the study of a phenomenon in its real-life context, leading to rich, empirical descriptions and the development of theory.
- Grounded theory is a process for analysing, interpreting and explaining the meanings of social actors' conduct to make sense of their everyday experiences in specific situations.

The time horizon was set into the perspective diary of longitudinal studies, focusing on study change and development. Figure 13 shows the research design in this study, highlighted with red ovals in the research onion.

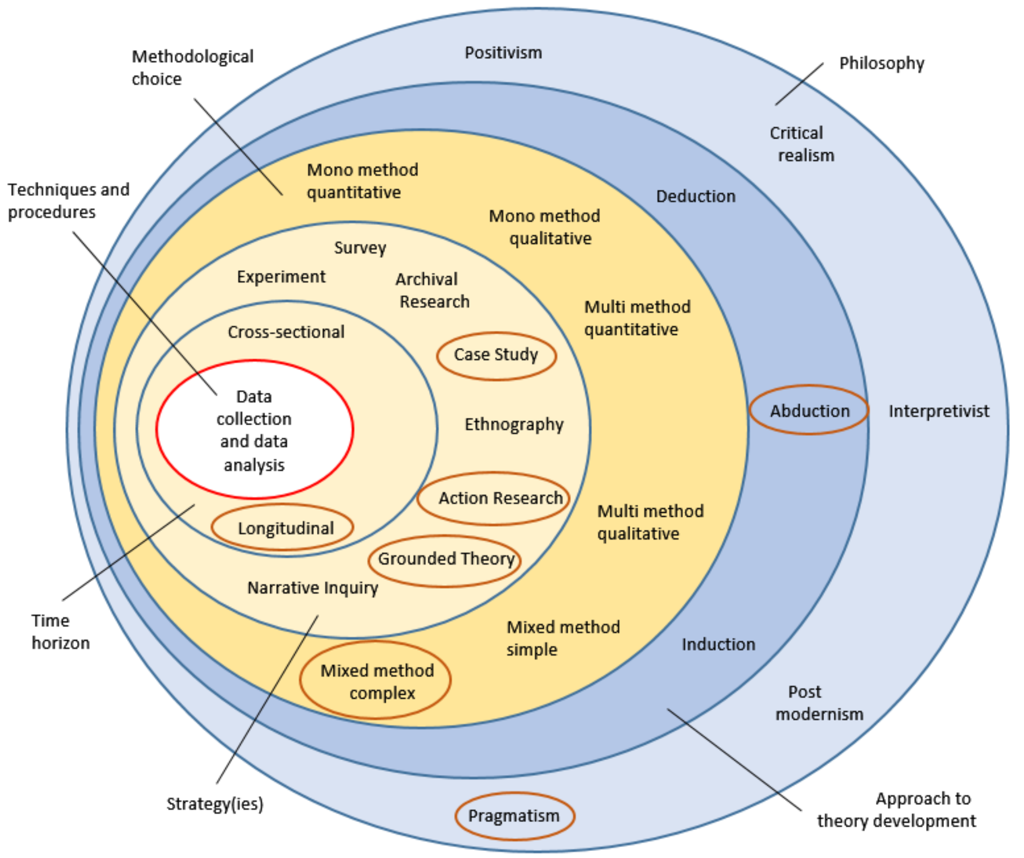


Figure 13: The research design positioned in the research onion (mod. from Saunders et al., 2019).

4 Results

The background to the case study results is based on work carried out in a large multinational project machinery manufacturing company, a global market leader. The results include several years of company-wide collaboration with different departments in the organisation, resources working together in an iterative process and a large amount of collected measurement data.

The results can be broken down into several layers. The integrator is the system model that produced concrete outputs, such as 'Delivery of new production capacity', called the overall process map, which generates new processes and findings of areas for improvement. In order to measure the effectiveness of the system model, it is necessary to understand the processes, their interactions and the results obtained from the whole.

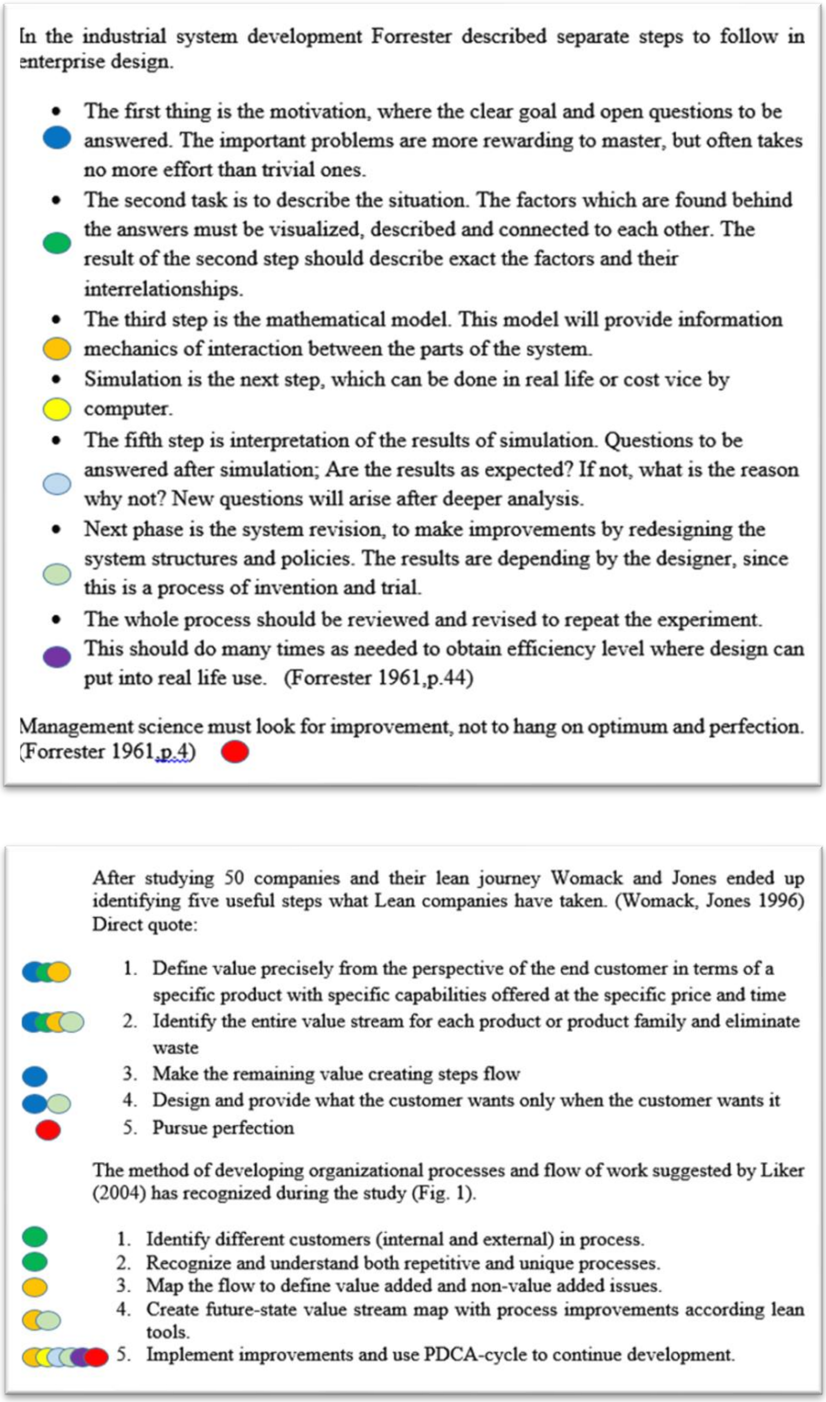
4.1 Case study ideologies used in managing business transition

A combination of the three vital business development tools from systems theory and production theory was mainly utilised with other tools from chosen theories. These chosen methods are more likely to support each other and not be in conflict or exclude themselves.

The key applied and guiding ideologies are the following:

1. Industrial systems development: Steps in enterprise design by Forrester.
2. Five steps lean companies take by Womack and Jones.
3. Method of developing organisational process and flow of work by Liker.

The following Figure 14 demonstrates a combination of three chosen methods that supports the approach to the evolution of the business model. There are marked as coloured dots of crossing and supporting points from the different key methods chosen.



In the industrial system development Forrester described separate steps to follow in enterprise design.

- The first thing is the motivation, where the clear goal and open questions to be answered. The important problems are more rewarding to master, but often takes no more effort than trivial ones.
- The second task is to describe the situation. The factors which are found behind the answers must be visualized, described and connected to each other. The result of the second step should describe exact the factors and their interrelationships.
- The third step is the mathematical model. This model will provide information mechanics of interaction between the parts of the system.
- Simulation is the next step, which can be done in real life or cost vice by computer.
- The fifth step is interpretation of the results of simulation. Questions to be answered after simulation; Are the results as expected? If not, what is the reason why not? New questions will arise after deeper analysis.
- Next phase is the system revision, to make improvements by redesigning the system structures and policies. The results are depending by the designer, since this is a process of invention and trial.
- The whole process should be reviewed and revised to repeat the experiment. This should do many times as needed to obtain efficiency level where design can put into real life use. (Forrester 1961,p.44)

Management science must look for improvement, not to hang on optimum and perfection. (Forrester 1961,p.4)

After studying 50 companies and their lean journey Womack and Jones ended up identifying five useful steps what Lean companies have taken. (Womack, Jones 1996) Direct quote:

1. Define value precisely from the perspective of the end customer in terms of a specific product with specific capabilities offered at the specific price and time
2. Identify the entire value stream for each product or product family and eliminate waste
3. Make the remaining value creating steps flow
4. Design and provide what the customer wants only when the customer wants it
5. Pursue perfection

The method of developing organizational processes and flow of work suggested by Liker (2004) has recognized during the study (Fig. 1).

1. Identify different customers (internal and external) in process.
2. Recognize and understand both repetitive and unique processes.
3. Map the flow to define value added and non-value added issues.
4. Create future-state value stream map with process improvements according lean tools.
5. Implement improvements and use PDCA-cycle to continue development.

Figure 14: New applied combination from different ideologies.

These summarised findings were; a continuous improvement process, identifying the whole value stream and eliminating waste, define the value precisely from the customer perspective.

The starting point goals based on theories were set to be the following:

- Waste elimination is the obvious target. The case study company history showed backyards full of material waste, nearly destroying it. Waste can be material or immaterial.
- Identify the entire value stream, including value-added and non-value-added issues. Based on that, develop a value stream where steps flow. This value stream should serve the company level's best interest and not be made based on one internal organisational player's interest or opinion.
- From the customer's perspective, design and provide a product with specific capabilities at a specific price and delivery time only when the customer wants it and is willing to pay. The critical element is not to tie up project costs to projects before customer commitment until their payment is thoroughly secured.

After continuing to progress, it will make more goals visible; some are more important, and some are trivial.

4.1.1 Identify the situation and model creation

At first, the task is to identify the situation using current state analysis. The task is to reveal the factors found behind the answers. An important task was to identify the whole value stream in the process and clearly define value from the customer's perspective. When clearing out the value stream, you need to identify operators influencing the value stream. Those are found to be different internal and external operators or customers. Because of the company’s outsourced business model, one operator can be internal or external or both simultaneously, Table 2. While analysing, the situation was kept in mind and separated both repetitive and unique processes (Vuorela et al., 2022).

Table 2: Identified process operators.

Swim line	Process operators		
	Operator	Internal	External
1	Customer		x
2	Sales	x	
3	Service	x	
4	Export & Trade Finance	x	
5	Project Management	x	
6	Engineering	x	x
7	Purchasing & Sourcing	x	x
8	Supplier	x	x

At the same time, the current state analysis was made; it was a recorded process map named 'Delivery of new production capacity'. This process describes the system model of the whole business case covering the timeline from starting with the customer quotation phase and ending with the product warranty to the end customer. In the model, each identified operator got their own swim line. Also, the main map includes several sub-processes.

Since the system model is large and complicated with many operators, the model was built in different steps as a model development sub-cycle, Figure 15. The method used to work with task level included the following steps:

- Identify active and non-active swim lanes
- Interview swim lane representatives
- Create the first model according to the interviews
- Start reviewing the model with task-related swim lane operators (1 up/x/1 down)
- Interpretation
- Revision when consensus has been reached
- Repeat or return to the main cycle

Several workshops were kept to identify the current status, and a model was created that described it accordingly. Multiple workshops and interviews are usually needed to cover the information needed for the next new revision of the system model as 'Delivery of new production capacity'. These early revisions represent the current state map and gradually evolved into a developed operating system model.

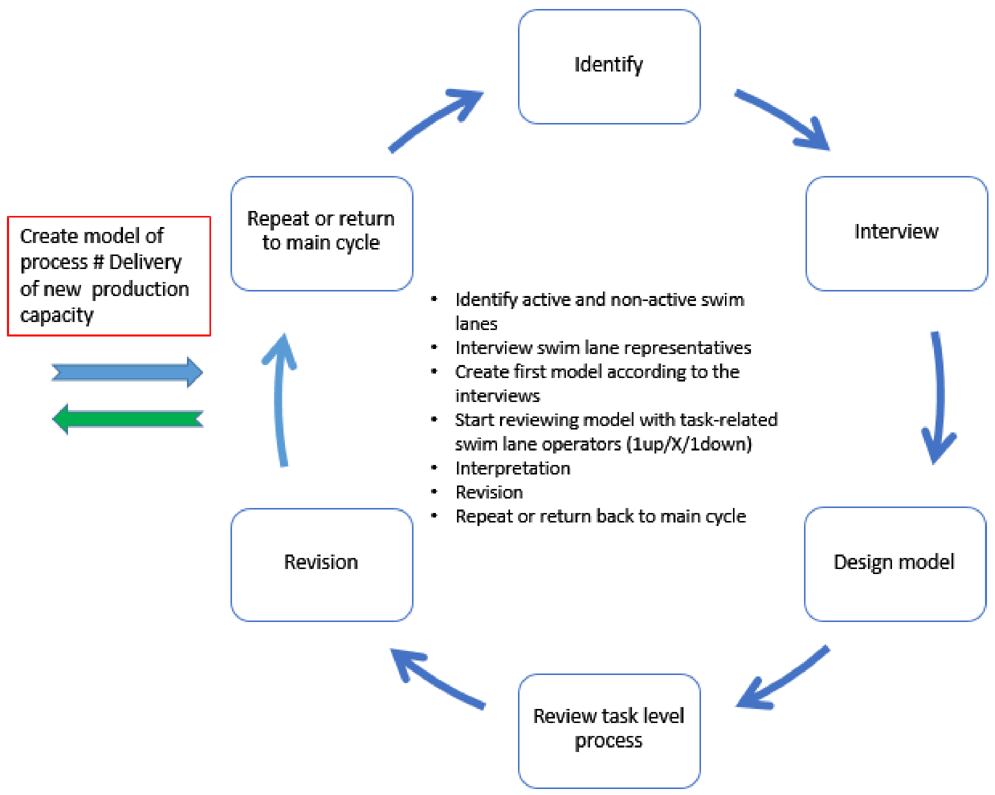


Figure 15: Model development sub-cycle.

4.1.2 Revision based on interpretation of simulation results

The manual simulation was made with all swim lane owners. In the simulation and interpretation workshop, three groups of swim lane owners went through the system model with the actual project and recorded the findings. An interpretation was made based on the results of a real-world simulation. New interpretation-based developments were implemented into the system model with the new revision.

4.2 System steps to manage business development

A new model for business transition management has been created and tested in an extensive case study in a customer-driven project business environment. This model helps to bring the knowledge of the different silos in the organisation as a common interest rather than developing it from the perspective of one silo and the people working there. The version number of the process map of the system model was rev.25 at the end of the study, and since then, it has continued to grow. Since moving to the next revision usually requires several interviews and workshops before a new revision is made, this means that the model has been tested multiple times. Below is an illustration of the 'Systems development model to manage business development' (Figure 16). The process as a whole has shown that the more clearly things are presented, the easier it is for everyone to take a stand and make decisions on the issues at hand.

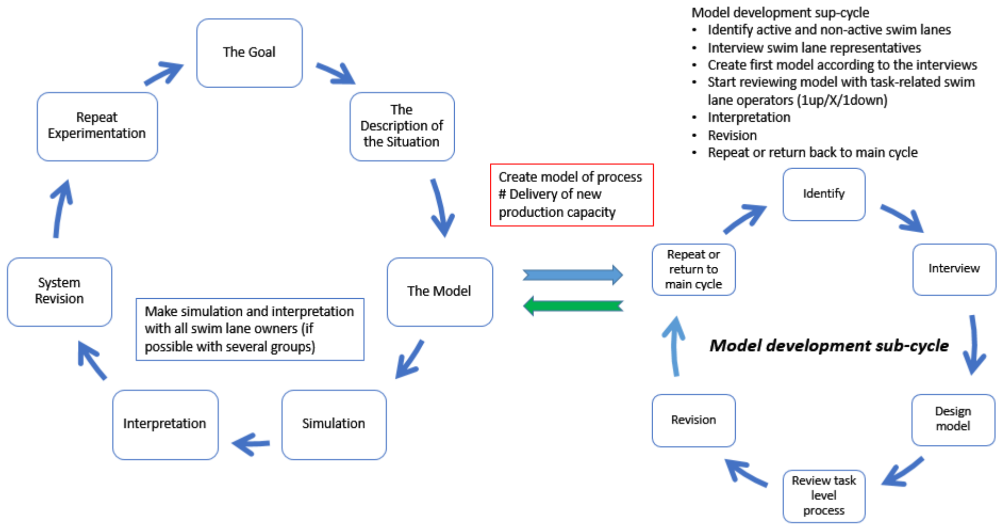


Figure 16: Systems development model to manage business development.

The model is divided into two components, the lower section looks at the task level and the upper section at the overall level. The result is a process map describing the overall picture of the object under consideration (in this case, the company's operational model). If necessary, open issues to re-evaluate are returned from a higher level to a lower one for further consideration.

In the beginning, all swim lane operators, both active and inactive, should be identified. Then interview the swim lane operators and identify their opinions and tasks for the first model process map. The next step is to revise the model and go through the swim lane operator associated with the task and the adjacent swim lane operators (1 up/x/1 down) then interpret and revise until a consensus is reached. The process is repeated with different tasks and operators until the map is ready for the next level. The upper-level interpretation and development cycle is carried out in several groups, with all active operators represented in each group as far as possible.

4.3 Value stream with steps and tack connected to flow

The current state study identified the value stream in the old operating model. It was discovered that the process allowed starting activities and tasks simultaneously before clearly indicating that external customer commitment was done. There were also findings of problems with the internal customers, where undefined and unfinished work was moved forward in the organisation. This generated concrete material waste and immaterial waste. The clear target was to organise and standardise the chain of work so that unwanted work has no room to arise. Certain steps authorise the next phase of the project delivery chain (Vuorela et al., 2022).

The work with the timing model and tack time was also part of the production flow. Different production phases are connected and scheduled differently to ensure a harmonic balance between customer commitment and the delivery process. When the project delivery timeline and critical financial points are defined, it is possible to go deeper into the process and adjust production schedules. Model schedules are connected into product-type structures. Some tasks were discovered to be forward scheduled and some backward scheduled depending on the need in the bigger picture.

According to Womack et al. (1990), Ohno instructed that 'Without standards, there can be no Kaizen'. The actual work and management processes must be standardised before possible real improvements exist. Standardisation needs to cover the whole process with every step in the model (Womack James et al., 1990). In this case, the work of progress at the operative business level needed to cover the whole work chain, including products and the actual delivery process. Below, Figure 17 shows a comparison of simplified process models before and after work.

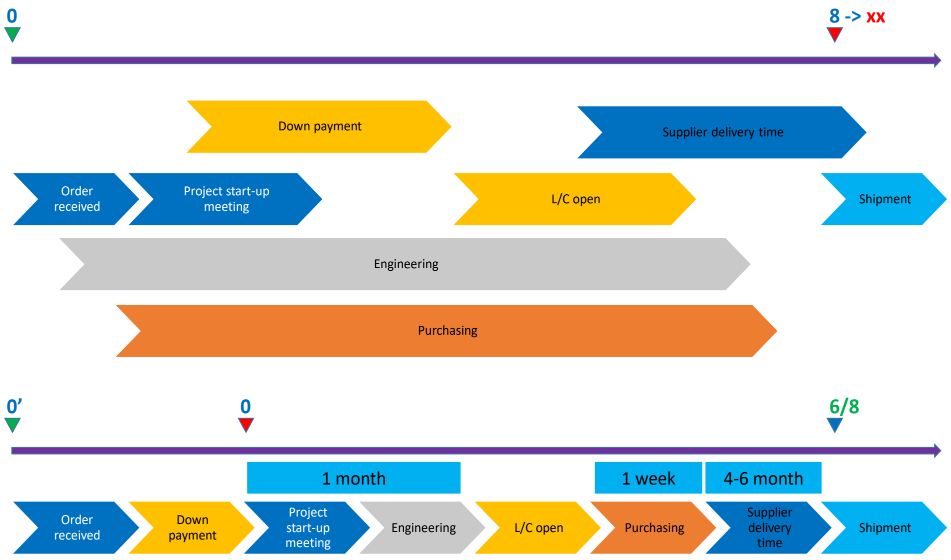


Figure 17: Value flow described before and after (Vuorela et al., 2022).

4.4 The System model

The long development work of the operative system model has been realised into a process map, which describes and standardises the entire delivery process and utilises the organised flow of the value stream. In the map, you can see different operators who can be either internal or external, which gives even more complexity to the process. Eight operator processes were identified and registered in the process map.

This system model connects different sub-issues and processes into a long chain of tasks and activities from the quotation phase to the warranty. It has been a long-time roadmap which has been generating new development needs. These newly developed issues are transferred back into the process map (Figure 18). Reflections between sub-processes and issues between the big road map back and forward have been continuous. This has been a major resource for new development.

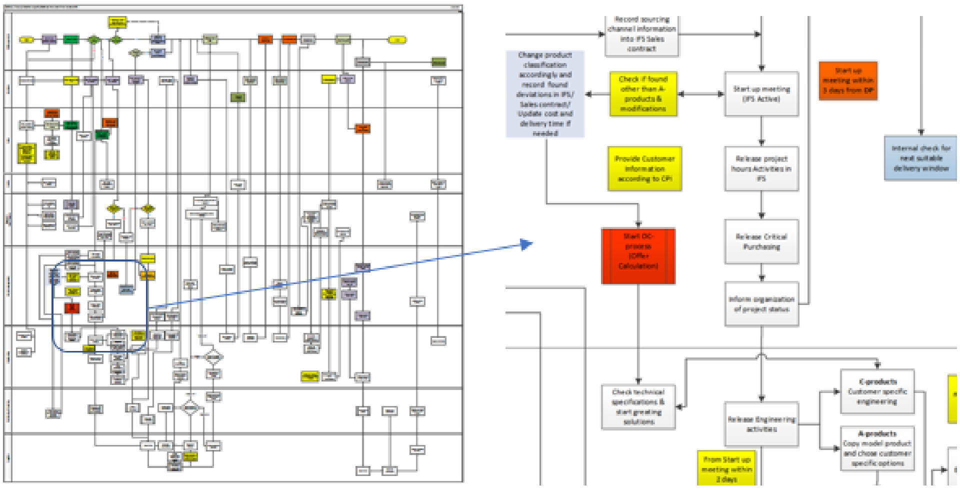


Figure 18: Overall view of the system model and partial magnification from it (Vuorela et al., 2022).

Since the complicated system model is large, the key is needed to visualise the process map and connect sub-positions. In the centre are timeline stages, which need to be reached before described actions are allowed to happen. The connected timeline stage numbers guide to the related sub-position in the following numbers of the following chapters. On the next page, Figure 19 shows the system model.

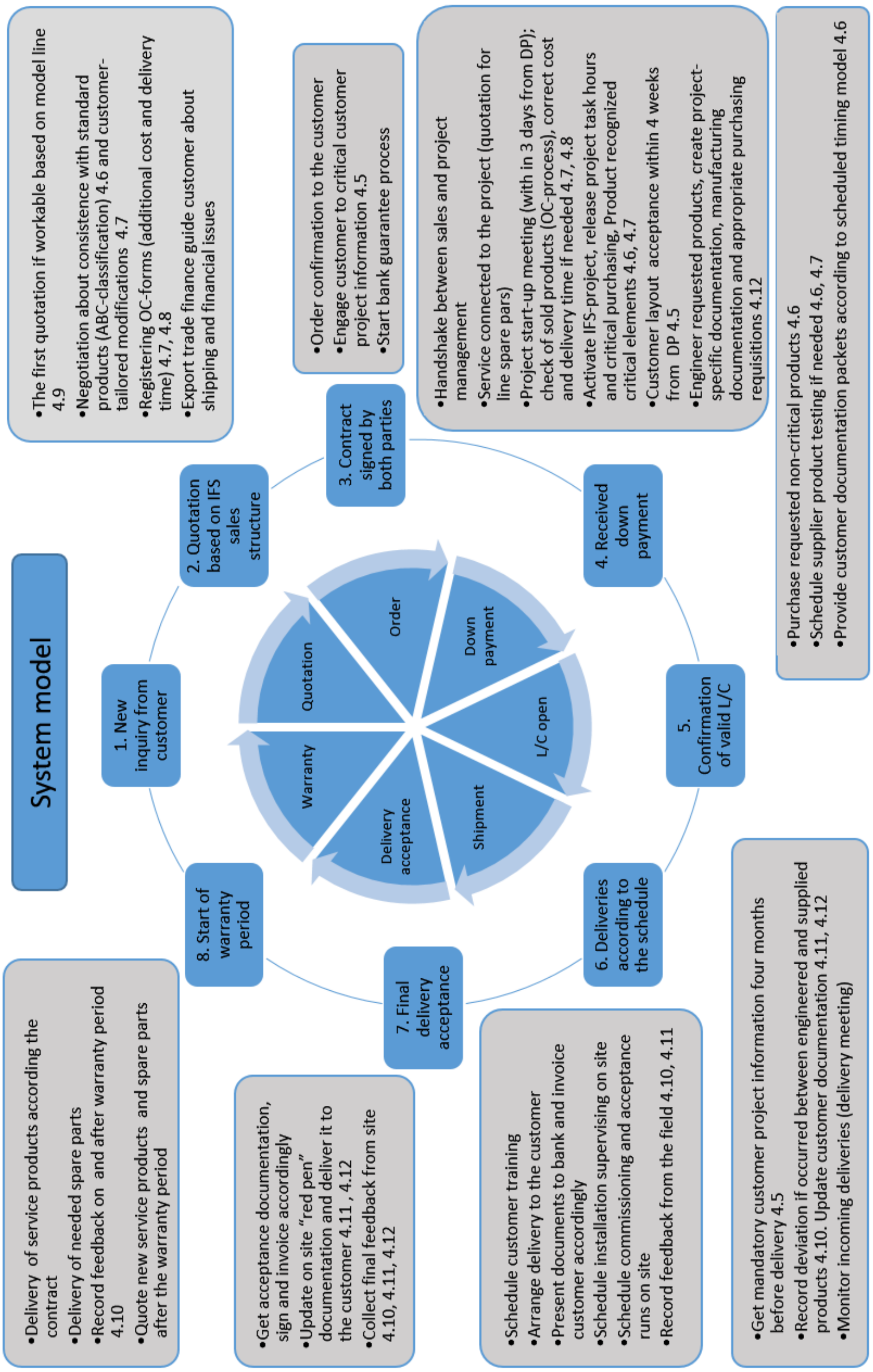


Figure 19: System model (referred to in the following chapters).

4.5 Obligations to customer

Connected system model timeline stage numbers (presented in Figure 19): 3, 4, 5

Customers are responsible for providing payment or necessary information to the seller in a specific time frame to ensure wanted delivery and delivery time. The sales contract template was changed according to the 'big picture' to allow sellers to adjust the delivery time if agreed payments or information is unavailable in a certain timeframe. Critical information for project delivery was recognised and put into timeline of standard delivery. Particularly important were identified as acceptance of layout, defining test cables, reel dimensioning, electrical connections and defining wanted spare parts.

The critical tasks for the organisation and customer are standardised according to the timing model needed to ensure a promised delivery time for the whole project as customer project information (CPI). Customer layout acceptance for engineering is needed within four weeks from the received down payment to get the flow of work running without waiting and the risk of unwanted additional work. Information on acceptance of the product's dimension, material handling and customer supply components electrical connection is needed four months before line delivery.

In most customer cases, spare parts for the line are delivered with the main delivery. The reason for this is typically transportation cost efficiency and customs declaring processes in the destination country. This needs a timing model where the first consistent customer line is engineered and configured. After this list of recommended spare parts is generated and delivered to the customer 3.5 months before delivery. Customers need to give a final list of spare parts three months before delivery to get spare parts with the main line delivery.

There have been cases where one customer's inability to provide requested information or change causes a chain reaction and can even affect other customers' deliveries. In high season the delivery time change is not the same as the amount of delay; rather, it can be the next available production slot. The process of critical customer information is described in Figure 20.

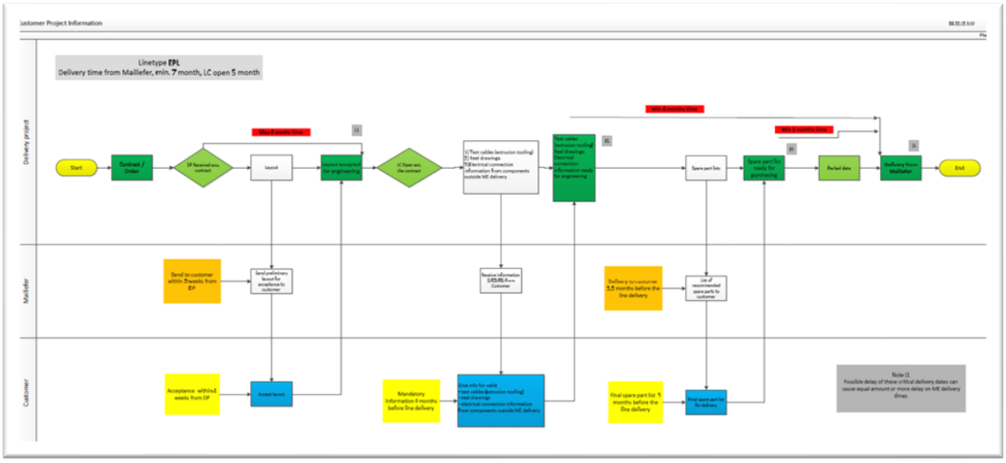


Figure 20: Process of critical customer project information (CPI).

4.6 ABC product classification

Connected system model timeline stage numbers (presented in Figure 19): 2, 4

Working with the system model helped to understand how much additional non-value-adding work was being done on product-related issues. The real problems were the number of products that were being updated and kept alive without a clear need. In addition, standard products could not be easily identified from customised products when needed.

There was a need for standard product recognition to provide benefits for marketing, sales, project management, procurement, suppliers and aftermarket. However, it must be possible to provide customers with customer-tailored products through a separate process.

Typically, there could be more than 450 pcs. of products, with sup-products, options and variation beneath them. Also, each product must have valid electrical and mechanical structures and possible software. There is a needed pre-packing list, cost structure, risk assessment and valid customer documentation like operating instructions. It was an untenable task for personnel to keep all these product structures in shape, updated and with known delivery times. The product classification was divided into the active product as A-products, old after-due date products as B-products that used to be valid A-products and customer-tailored C-products made from A- and B-products. Figure 21 describes the ABC classification hierarchy (Vuorela et al., 2022).

In the new product mastering model, standard and nonstandard products are clearly identified. Standard A-products have proven functionality with locked specifications made from defined parts and components. They constitute the foundation of the product.

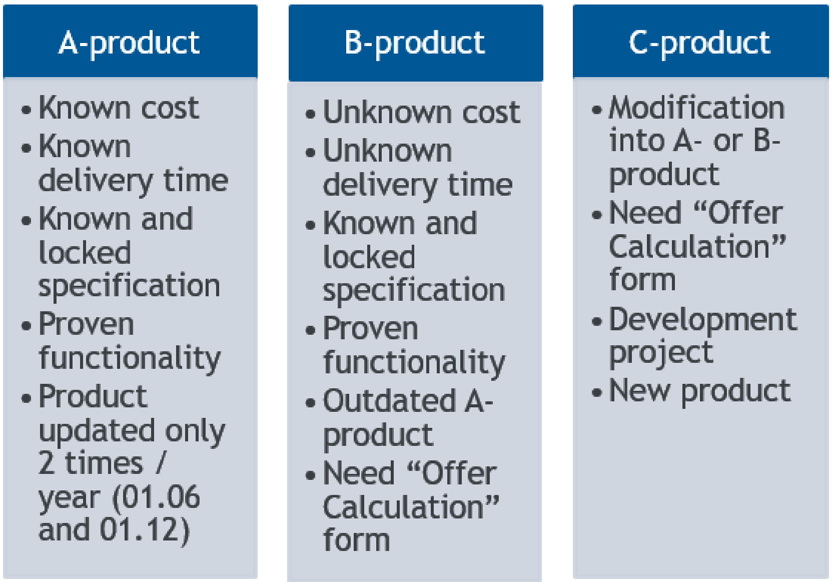


Figure 21: Rules of product ABC classification (Vuorela et al., 2022).

The A-products are updated twice a year to ensure correct components, costs and delivery time. B- and C-products are not updated to save time and effort. You could even state that there is no need to order all the world's newspapers just in case if there is no usage or need for them. Figure 22 shows that the A-product update is scheduled twice a year.

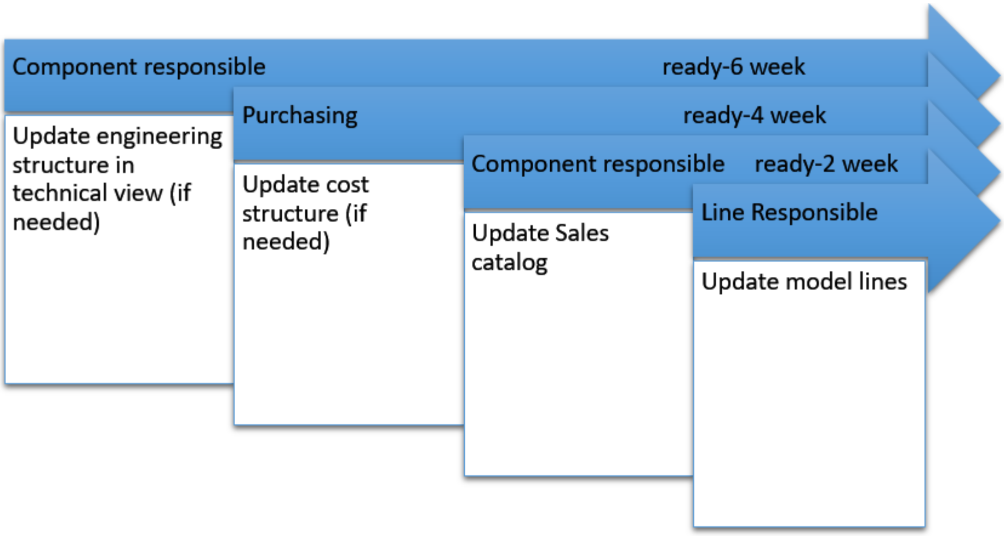


Figure 22: Product update schedule.

The standard A-products have connected pre-defined work hours needed to create a product from order to delivery, which is not available an unknown C-product before the offer calculation has been made

The elimination process of old A-products was together decided so that products which don't have activity in the running year plus two previous years will automatically drop into B-class. The definition of this time frame came from the best knowledge of typical cycles of case business. New products are introduced into the system as B-products to ensure technical and cost structure. When new B-products are a project with warranty status, they can be awarded into A-products in the upcoming twice-a-year product update. The old dropdown B-products can lift back up A-products if they have steady demand and are evaluated case by case.

4.7 The process of managing the offering of both standardised and customised white paper products

Connected system model timeline stage numbers (presented in Figure 19): 2, 4, 5

A large number of required products other than A-products became visible, indicating a need to master B- and C-products. Also, the timeframe from the quotation phase to the realised project forced the systematic recording of component-related modifications. Separate offer calculation processes and tools were created, which ensures a standard way to offer customer-tailored specific products (Vuorela et al., 2022).

These products are in the quotation phase, recorded and evaluated to discover possibilities and limitations to making a customer-requested product. As a result of the process is collected additional delivery time and cost what are needed to build the customer-specific product or find out if the suggested solution is not possible or more suitable product is available as a standard product.

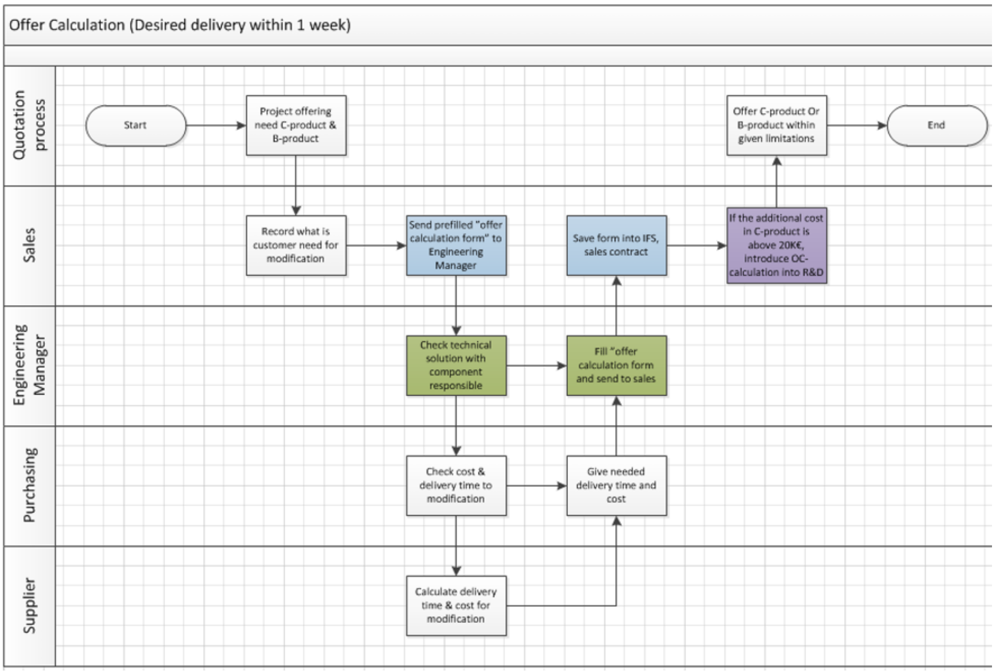


Figure 23: Flow of offer calculation.

The global sales organisation set challenges in the process and the time spent on the offer calculation process. The maximum time to make a requested OC-form (Offer Calculation) is one week, which in many cases is less than targeted. But in more complex requests, there is a change of need for a longer time to collect all the information and solution. Figure 23 shows the flow of offer calculation process. This process enables the next level of mass customisation.

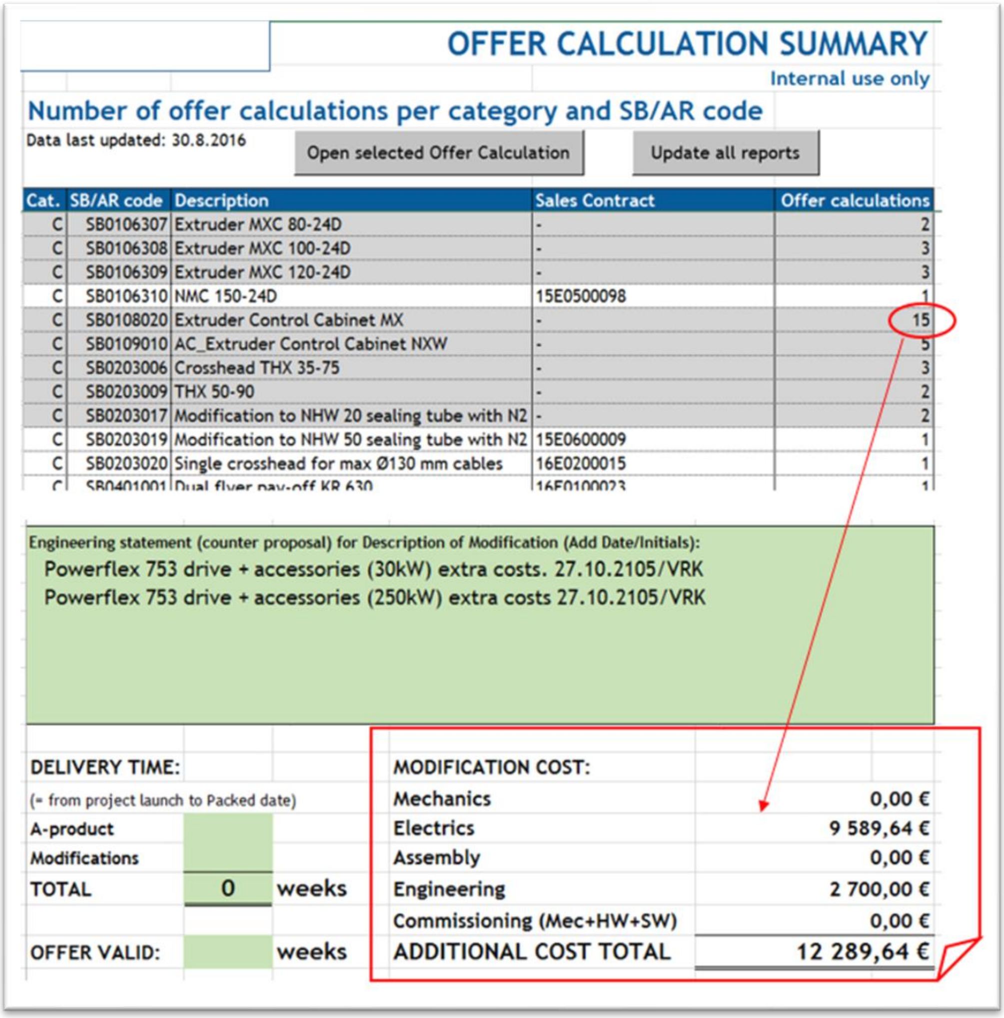
When there are many quoted projects with a broad amount of customer-specific OC products, it is good to view how much extra work is needed in upcoming projects. This requires an estimate of the number of person-hours needed to complete the project. The properly filled OC forms together with standard products estimate workload and give time to react if needed with extra resources. If the customer requests extra product cost on the OC form exceeding €20,000, the project is introduced into R&D (Vuorela et al., 2022).

4.8 Process to improve standard products offering based on customer phase latent information

Connected system model timeline stage number (presented in Figure 19): 2, 4

Collecting the customer base requests/inputs during the running year make it possible to create new offerings based on global customer requests. It is probably needed if customers are willing to pay for the additional feature. New products or product features from the OC database can be ranked according to how many times different requests have been made. When inputs from different types of customer wishes are combined, it is possible to acquire latent information that single customers cannot wish for or describe. The most popular ones are studied and can be made into next year's standard offering (Vuorela et al., 2022).

The benefit of a thoroughly completed OC form is that it can be used as a ready-made budgeting tool for new products or features. Since tasks, hours needed, and cost estimation have already been recorded, there is no need duplicate work when planning a new product or product inputs (Figure 24). This speeds up the evaluation cycle when information needs to be collected for decisions.



OFFER CALCULATION SUMMARY

Internal use only

Number of offer calculations per category and SB/AR code

Data last updated: 30.8.2016

Open selected Offer Calculation | Update all reports

Cat.	SB/AR code	Description	Sales Contract	Offer calculations
C	SB0106307	Extruder MXC 80-24D	-	2
C	SB0106308	Extruder MXC 100-24D	-	3
C	SB0106309	Extruder MXC 120-24D	-	3
C	SB0106310	NMC 150-24D	15E0500098	1
C	SB0108020	Extruder Control Cabinet MX	-	15
C	SB0109010	AC_Extruder Control Cabinet NXW	-	5
C	SB0203006	Crosshead THX 35-75	-	3
C	SB0203009	THX 50-90	-	2
C	SB0203017	Modification to NHW 20 sealing tube with N2	-	2
C	SB0203019	Modification to NHW 50 sealing tube with N2	15E0600009	1
C	SB0203020	Single crosshead for max Ø130 mm cables	16E0200015	1
C	SB0401001	Dual flyer pay-off KR 630	16E0100023	1

Engineering statement (counter proposal) for Description of Modification (Add Date/Initials):

Powerflex 753 drive + accessories (30kW) extra costs. 27.10.2105/VRK

Powerflex 753 drive + accessories (250kW) extra costs 27.10.2105/VRK

DELIVERY TIME:		
(= from project launch to Packed date)		
A-product		
Modifications		
TOTAL	0	weeks
OFFER VALID:		weeks

MODIFICATION COST:	
Mechanics	0,00 €
Electrics	9 589,64 €
Assembly	0,00 €
Engineering	2 700,00 €
Commissioning (Mec+HW+SW)	0,00 €
ADDITIONAL COST TOTAL	12 289,64 €

Figure 24: Offer calculation collection model sheet.

4.9 Model line structure follows product classification

Connected system model timeline stage number (presented in Figure 19): 2

The model line is a ready-figured production line consisting of several machines. The model line should consist only of A-products. It should have been predefined what production capacity is promised to be delivered to the customer. Model line is the next higher level in the product hierarchy, and it should be the type of structure of line level as the single machines have in the product level.

When the model line is thoroughly configured, including details like layout, PI diagram and acceptance products with used raw materials, it is possible to make the first quotation package based on it with little technical line-specific knowledge.

The model line offering was noted to include other than A-products, which was not the desired case. As a result, a tool was created for identifying product consistent in the model lines and delivered lines. The tool was useful when needed to identify development progress because it reveals the current status and level of progress. The target was to remove nonstandard products from model lines but provide customer-tailored products through the OC process. The target is to recognise products and sales options beforehand so that the organisation can profitably provide sold line consistency to the customer in the correct delivery time.

In the long run, it is good to have a balance between standard products and customer-tailored products. It is more resource-consuming to produce a nonstandard product than produce standard products. But correctly budgeted and sold nonstandard products can provide a bigger profit. These need to be considered when balancing products and resource capacity. In this business segment, it is rather mandatory to be capable of providing customer-requested customized products. The case company and business model have targeted the 70%–80% level of standard products from yearly volume.

4.10 Component feedback process

Connected system model timeline stage numbers (presented in Figure 19): all stages

The product and quality issues were found to be problematic areas. Different kinds of information and signals from various sources were recorded in the organisation. The process was created for product-related issues to ensure continuous improvement into valid products. Urgent issues like safety, for example, are handled separately, but valid issues from these also are brought into the ‘component feedback process'.

The business sector operated machinery faces vide range problems. In cable machine manufacturing, single machines called components are put together to form a production line. When different components are connected timely and by production speed in a process, it creates an technically demanding process, which produce in high-quality cable for several kilometres depending on the line type. When operating the line, there can be at least speed, vibration, dynamic, pressure, heating, cooling, process, extrusion, electrical, software and safety-related issues.

All the signals are collected in one place, which is the quality manager. The quality manager keeps on the task list where all these signals are reported and followed. The reason for this was that the in the project business, you can get inputs related to the same issue from different sources; customers, project management, commissioning etc. These inputs are pre-evaluated by the task-related component manager and team manager, who are the owners of the specific component. They can collect background information for the case and prepare a proposal for evaluation and decision meetings, usually held every second month. Figure 25 shows the continuous component feedback process.

These evaluation and decision meetings are kept with the predefine team. There is a learning function since similar kinds of problems can arise from different product families. Normally component (single machine) has different engineering subcategories; mechanical, electrical, software and process. The problem can be pointed to one subcategory, or problem-solving may also need a combination of the usage of these teams. In these meetings, it is evaluated whether the input is valid to proceed or not. In product-related issues, it is critical to understand whether a needed feature is good for the product or is one customer-specific idea. A feature or option not providing customers value is useless to put into production.

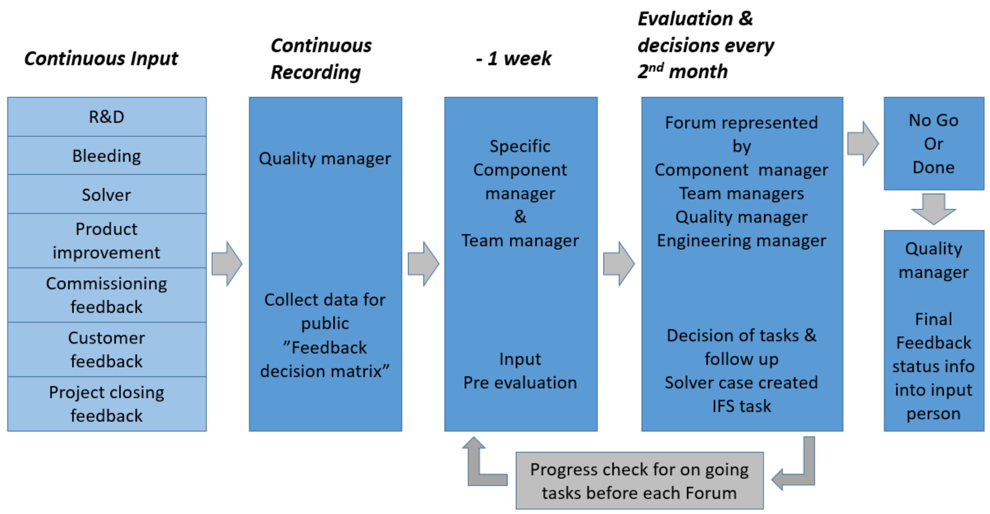


Figure 25: Continuous component feedback process.

It is essential to continue to increase the number of inputs. Motivating is if the person who created the issue gets feedback on the decisions. Also important is to follow up on how accepted inputs are done. The yearly readiness of approved inputs is followed year by year.

4.11 Risk assessment process for products and production lines

Connected system model timeline stage numbers (presented in Figure 19): 5, 6, 7

The risk assessment process needed to be standardised because a major problem was that there was no similar product risk assessment at company level. More likely, assessments were done in a very different style depending on the person doing the work. A similar effect was found in the user manuals.

A standard process ensures the same level and style are used to assess different products. This was based on a separate risk assessment team that worked with the component responsible for the product assessed. A commercial tool was utilised, and personnel were trained to work with it. The assessment can be a part of the new product development, which enables inputs for product design. A template for operation instructions was created to unite style and common elements to be copied into each product's operation instructions. Valid risk assessment is the base for operating instructions (Figure 26).

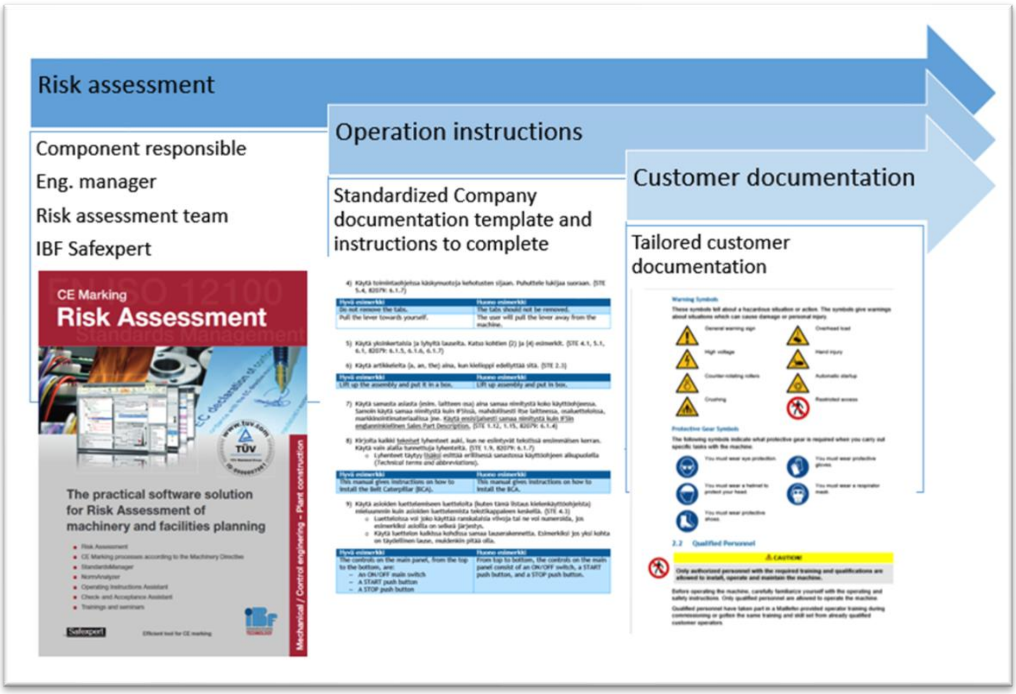


Figure 26: Model structure from risk assessment to customer documentation.

4.12 Standardisation of the document process

Connected system model timeline stage numbers (presented in Figure 19): 4, 5, 7

There were a problem with the usage of project-related documents. Several times documents which were not ready and authorised to pass forward were used by the organisation for different purposes. This caused unwanted costs or delays that are known as waste. The native engineering documents were mixed into the process, and thus wanted to separate them from the process.

A clear hierarchy was created between the ERP and the document management system. The ERP is the master to call needed documents but was only allowed to access a separate pdf vault where released documents have been placed. The native engineering vault was the environment where engineering work was created. The pdf vault is where a document approved for further proceeding is automatically moved after the document has been released in the engineering vault. From the ERP, direct access to the pdf vault was created, where you can view and print the document. Figure 27 shows the documentation hierarchy between different systems.

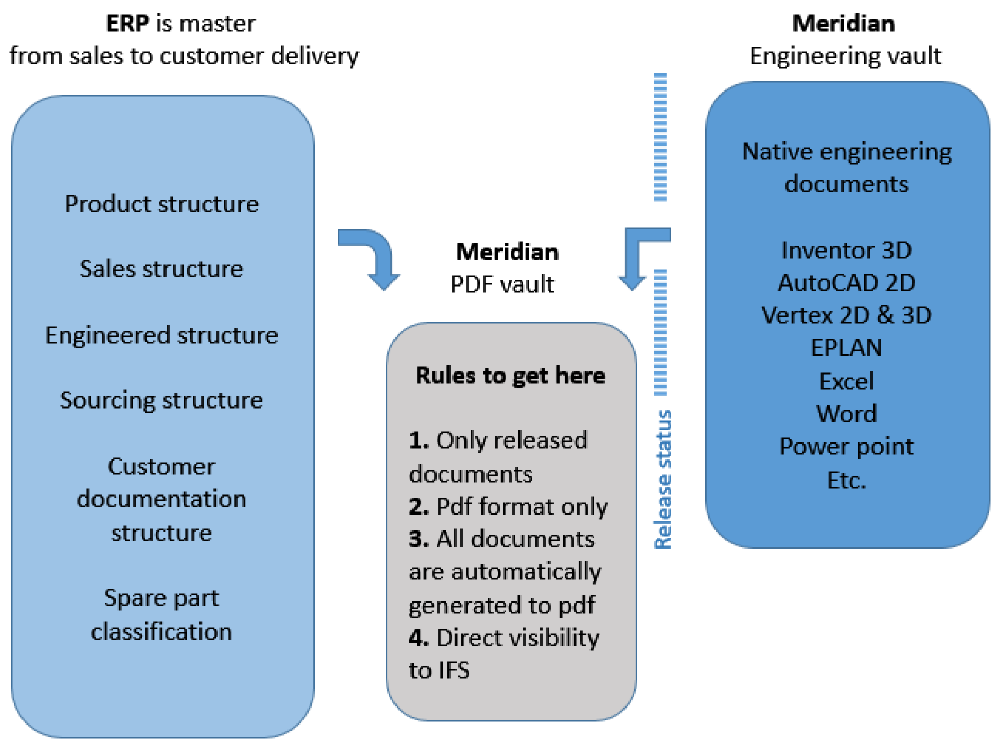


Figure 27: Documentation hierarchy between different systems.

At the next level, the company has created and developed its own system to master a standard way of handling customer and engineering documentation. The system automatically masters documents in a standardized way. This reduces the number of hours needed for different purposes, and when documents are stored and processed by a program, there is little room for human errors.

The program generates customer documentation, a pre-packing list and engineering documentation. Documents are attached to the ERP with different document classes, which are collected by the purpose and the document class attached to this. This covers all the needed document types and is easily adapted according to the needs. For example, customers are provided with different document packages at different stages of the delivery project. In the final phase, all the documents are collected and provided to the customer, where the customer can use the documents with the delivery document program.

It can also be used for the following purposes: collecting a single document or set of documents, gross needs lists, bill of materials and purchasing documents. The purchasing documentation is the same for all suppliers and saved automatically in a specific folder with standard naming, which ensures easy usage by the next organisation.

Pre-packing lists are mastered with the tool from the type structure in the ERP and are generated to customer specific from there with the customer information.

4.13 Long-time change measured on several key business indicators

When choosing measurement indicators to monitor change, the current business model for doing business must be considered. In this case study, operational progress was measured by the following main indicators: On Time Delivery (OTD)/Quality cases/Quality cost.

These three elements are needed to monitor the progress of the operational business. The OTD reflects how several tasks and parameters succeed in the early stages, just before the project delivery is on its way to the customer. Quality cases show how the customer's promises are being fulfilled during the commissioning phase. This gives a picture of the situation that usually prevails a year or a year and a half after delivery. Finally, quality costs provide a perspective on the failure or success of the commissioning and warranty phases. This is usually an indication years after the actual contract with the customer has been signed.

All these indicators are different issues in the process separately and combined together. In the early phases of the development process, when tasks and products were more in unknown grey area, it needed a more extensive effort to solve real root cases in problem-solving. When the process developed further, the problems appeared differently.

4.13.1 Change in On Time Delivery 2012–2016

On Time Delivery (OTD) gives an accurate view of the company's operative capabilities. It reflects how sold goods can execute and deliver to customers on time. The base work for this is in defining product level. There is a need for a defined product hierarchy (Figure 28). First, a valid product structure is needed with specific performance as a known engineering structure. After that, you can have a specific cost structure defining product cost and delivery time. There has to be a valid sales structure based on these two, which is the key to the contract made with the customer. Each product should be able to configure from readymade options and variations or, if needed, customer-tailored features are available through a separate process. This is called the OC process and should be used in the quotation phase with the customer. These are the key elements of the OTD shown.

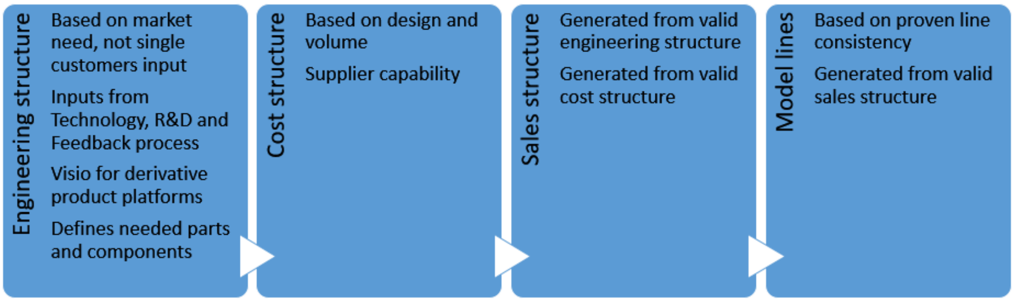


Figure 28: Hierarchy from the engineering structure into the model line.

On Time Delivery has seen steady progress in the measurement timeline. It began at the bottom level at 76%, measured in 2012. After research work, it grew steadily to 93%, measured in 2016, Table 3.

Table 3: On Time Delivery (OTD) development history (Vuorela et al., 2022).

Count of Line No	
Year	OTD
2012	76%
2013	82%
2014	86%
2015	88%
2016	93%

4.13.2 Change history in the amount of quality cases

The amount of quality cases typically shows activity after the main project delivery has been sent to the customer and ends when the warranty period starts. This is called post-delivery, and the amount per month follows them.

Items delivered under post-deliveries are tracked for several reasons. Mainly, corrective actions related to late or missing deliveries from the main delivery can be seen. Often, information coming from the customer is forced to deliver some items under post-delivery. Corrective actions are also delivered here if there is a failure in packaging or transportation. When there is an error in customer handling or onsite installation-related actions, they are seen in the post-delivery. Product quality-caused corrective actions are naturally delivered post-delivery. The deviation between customer process expectations and provided equipment capability may also cause corrective actions seen in post-deliveries. Figure 29 shows the change history in the amount of quality cases (blue column) with trend lines of the six-month running average (the upper red line is the number of missing items, and the black line is the number of projects).

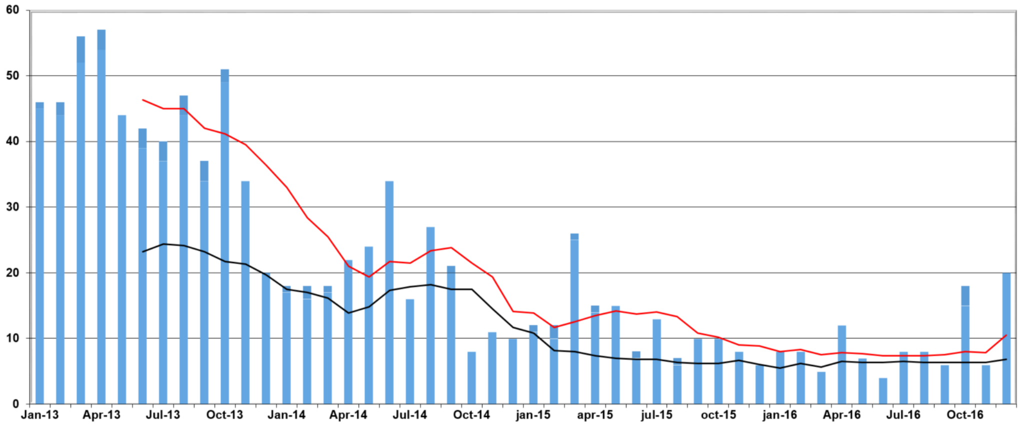


Figure 29: The amount of quality cases with trend lines (as a unit of measure) (Vuorela et al., 2022).

In statistics, in late 2016 and early 2017, old laboratory test lines were delivered with some new products under post deliveries. This needed to be done because conflict caused the transfer from the old ERP into the new system. Several years ago, the old laboratory line materialised in the old ERP, and it was decided to do it this way by cost, labour and vice.

The amount of post-deliveries per month has decreased steadily under the study timeline.

4.13.3 Change history in quality costs

The quality cost has two sub-classes: Cost after closing the project and Guarantee cost. Cost after closing the project reflects how well all items have managed to deliver in the actual shipment. It also reflects how much effort is needed to satisfy contractual promises to customers, both product and process vice. The Guarantee cost indicates the product quality level in specific use. Figure 30 shows the change history in quality cost % of gross sales.

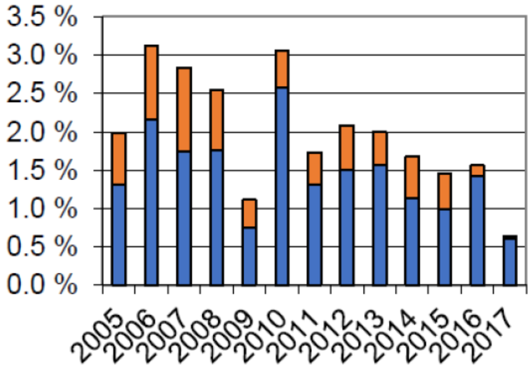


Figure 30: Quality cost % of gross sales (Guarantee cost in orange and Cost after closing project in blue) (Vuorela et al., 2022).

The quality cost percentage of 2017 does not have full information from late projects since project delivery from order to the warranty phase typically takes more than a year. Cost information is included according to the project's original opening date, and costs are updated until the project is closed. There was some statistical interference in late 2016 and early 2017 since the laboratory test line was sold and delivered with additional components to a customer in the project position 'cost after closing project'.

'Guarantee costs' are stable at 0.5%, and 'Costs after closing the project' have a long-term lowering trend reaching 1% of gross sales.

4.14 Supporting measured metrics

Beneath these major indicators comes a second layer of metrics, supporting indicators to achieve the development of major parameters.

4.14.1 Product level change

Since in large organisations, different continuous feedback improvements appear to come in quite a lot; it is essential to follow up on how many continuous product improvements have been done and are ready from the yearly phase.

Remove non-used products from the standard selection. Focus on keeping useful products in shape in all product layers and help free up resources from keeping inactive products up to date.

The product level amount of A-products versus other B- and C-products has been closely followed up on in Table 4. When the appearance of actually delivered projects is followed, it indicates how well the standard product offering reflects customer base needs. Also, an interesting view is to follow up on how well non-standard products are recognised on sold projects. The recognition of product classification on quoted and sold projects is crucial to the data quality used in other metrics.

If the data is studied on the model line consistency of products, there should not be other products than A-products in the model line offering. When model line consistency is found in different product classifications, the cost and delivery time might not be valid.

Table 4: Change history in product class appearance.

Count of Line No		ABC Category				
Year		A	B	C	NULL	Grand Total
2012 Total		2 %	0 %	1 %	97 %	100 %
2013 Total		70 %	2 %	1 %	27 %	100 %
2014 Total		75 %	6 %	2 %	17 %	100 %
2015 Total		70 %	7 %	20 %	3 %	100 %
2016 Total		63 %	17 %	19 %	1 %	100 %

4.14.2 Effects in resourcing

The standard products have a predefined timing model for the different tasks and the hours required to complete them. The scheduling of required tasks makes it possible to monitor if there is a cumulative increase in the number of overdue tasks and react accordingly. The workload chart is presented in Figure 31.

When the OC process has recorded the additional hours needed to create a custom new feature or product, the work required to complete the project is displayed. In delivery projects, these hidden "white paper" change hours often plays a significant role in the overall project workload. As a result, resource requirements are better reflected in the overall projects sold by the company.

Projects in the quotation phase can be reflected in the workload charts. Projects that reach a certain estimation level to move from the quotation stage to the ordered project will appear in the load table, which will help in planning in many areas. The estimated workload of a project is automatically converted into an actual workload when projects change from a quotation to an order.

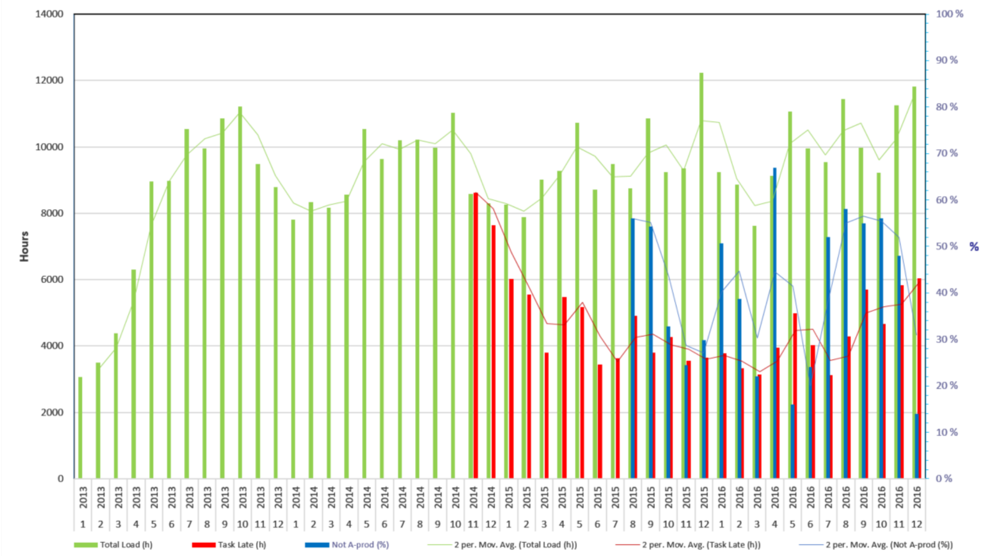


Figure 31: Model of workload chart.

The product classification makes it possible to obtain additional capacity for engineering work during the high season. It is easier to get extra hands on the design of standard A-products than on complex non-standard customer products. Suitable OC projects can also be outsourced based on ready-made calculation forms.

4.15 **Maturity level change**

During the case study, it was found that the company had information that was not clear and visible at the beginning. Most of this information was product information, with a mixture of standard and customised products. Once the view of standard products and the separation from non-standard products became more explicit, the system could be further optimised. The case study company reached level 3 on the Industry 4.0 maturity scale in Figure 32.

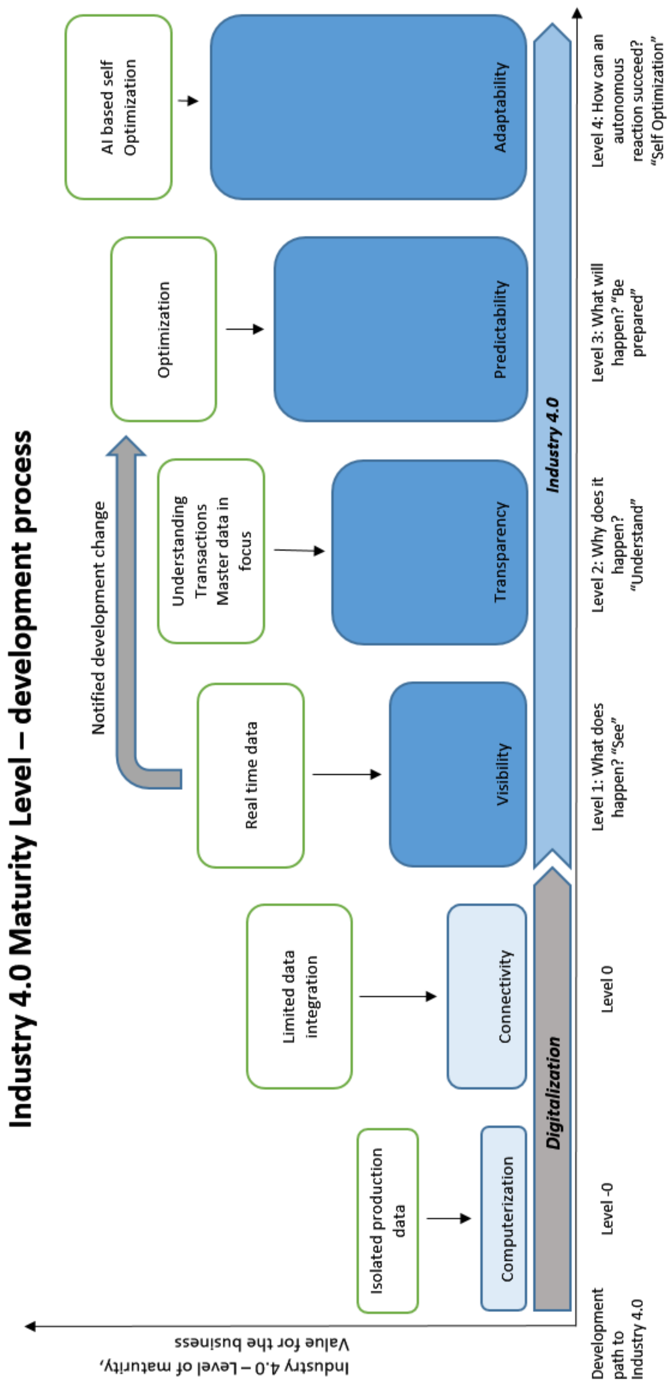


Figure 32: Notified development change on Industry 4.0 maturity level.

5 Analysis and Discussion

There has always been a need to improve the efficiency and profitability of doing business. Co-evolution and continuous development are needed to keep up the phase and improve operative efficiency. History has shown the success of different theories, old valid knowledge and tools when developing different business models. The difficulty is to find and utilise the correct and efficient combination of those in the case-specific business segment.

Even though theories have evolved, single theories do not cover all modern company activities. There are unique theory-specific elements when studying different theories, but common crossing elements with perspective sight differences are found. The main theories applied in the study, and not just limited to these, were systems theory, production theory and information theory, which were mainly contributed as follows; system theory in co-evolution, production theory in managing by operation and information theory in managing by data.

In the case study, the business segment targeted is a large project machine manufacturing business, where there are long lead times from the quotation phase to accepted delivery. This also sets limitations in measuring the change. It is necessary to note that not all the measured change is conducted in development work in the case study. More likely, changes in the world economic situation somehow affect measured results. In the project business, the business model is easily non-standardised and reflects more customer-oriented flexibility. This opens opportunities for conflicts and challenges when one target is standardising the operative model. Still, the key factor identified is maintaining needed project business flexibility towards customers.

The research's one primary goal has been understanding the complex business model and its evolution with change history when applied with updated and developed operation models. At the beginning of the research project, visible research questions are based on the development process and through a better understanding of the open questions, research propositions are formulated.

The following research questions were raised at the beginning of the project:

Q1. How to manage the business transition from project to product and to life cycle business?

Q2. What are the essential changing business structures and elements?

Q3. How to measure the change and development of business structures and elements?

Q4. What is the integrated system model to manage the changing business?

After the study based on the research questions, the following research propositions became clear:

P1. Business transition requires development of business structures in a specific order.

P2. Business transition requires co-operatively defined measuring system.

P3. Integration of business structures in changing business needs system model.

After analysing theories and case study problems, the research questions and research propositions were found to connect in the following ways:

- Proposition 1: Questions Q1, Q2
- Proposition 2: Question Q3
- Proposition 3: Question Q4

The related theories, methodologies and assumptions were reviewed or made from the research and case study framework. The following chapters open each research proposition and related questions one by one.

5.1 Development of business structures in specific order

Proposition P1 (Business transition requires development of business structures in specific order) related questions are:

Q1. How to manage the business transition from project to product and to life cycle business?

A new model to manage business transition has been introduced in Figure 33. This development model brings the knowledge points of the different organisational silos into common understanding and creates development that serves the benefit of the whole organisation, not just one organisational silo. Conceptual continuity has been fixed according to field lab development runs and extensive field tests in the case study.

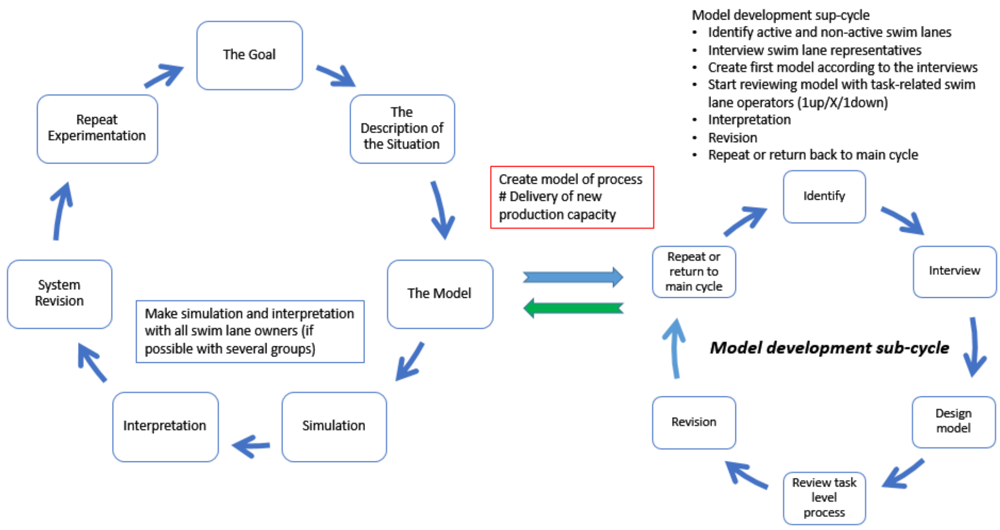


Figure 33: Model of the process of how to manage the business transition.

Q2. What are the essential changing business structures and elements?

The following essential elements to focus on were identified as follows:

- Eliminate waste, which can be material or immaterial. Finding the correct root cause is complex and must be thoroughly resolved.

- Identify the entire value stream, including value-added and non-value-added issues. Then develop a value stream where the steps flow.
- Define value from the customer perspective, design and provide products with specific capabilities at a specific price and delivery time when the customer wants it and is willing to pay for it.
- Manage information through the mass management of product information based on detailed product data validity and accessibility.

5.2 Business transition requires measuring system

Proposition P2 (Business transition requires co-operatively defined measuring system) related question is:

Q3. How to measure the change and development of business structures and elements?

When choosing elements to measure, there is a need to consider the business's specific limitations and company model to operate in the market. In this case, the business segment is connected to the global project business with a long time frame from the quotation phase to final customer acceptance, where the warranty period begins. These three central meters were followed during the operative business model evolution: 1) on time delivery (OTD), 2) amount of quality cases, and 3) quality cost shown in Figure 34. These operational indicators have been selected co-operatively by the company's management team.

- On time delivery (OTD) gives perspective on how promises to the customer can be fulfilled before delivery.
- The amount of Quality cases are typically reflecting activities after the actual delivery.
- Quality cost is divided into two sub-meters cost after closing the project and Guarantee cost.

Count of Line No	
Year	OTD
2012	76%
2013	82%
2014	86%
2015	88%
2016	93%

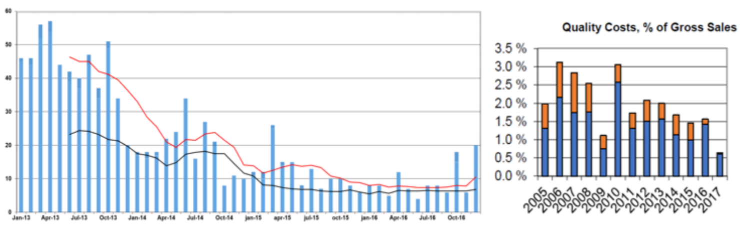


Figure 34: Main measuring elements.

5.3 Need of the system model

Proposition P3 (Integration of business structures in changing business needs system model) related question is:

Q4. What is the integrated system model to manage the changing business?

The system model evolved from the current state analysis through several rounds of revision into an updated operating model. The system model is balanced and dedicated to specific business segments and models with products connected to it in its own era. Changes in these elements likely drive the need to update or fine-tune the system model. Figure 35 shows the whole system model.

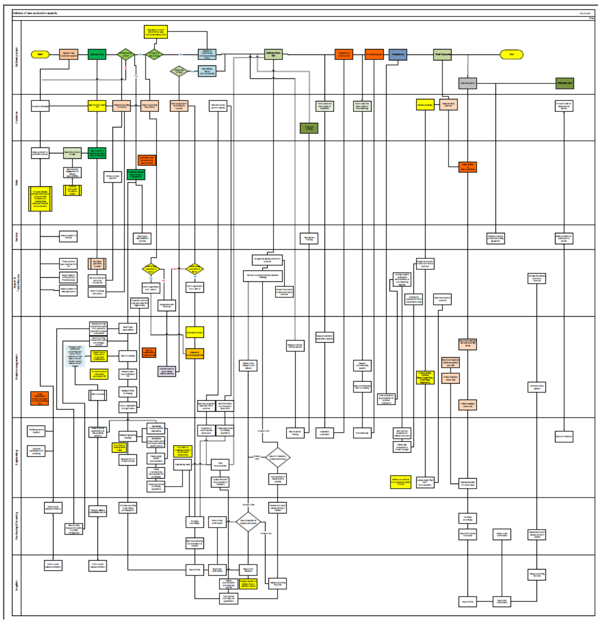


Figure 35: View of the whole system model.

The system model configures and describes the process map 'Delivery of new production capacity', which covers all operational activities from the quotation phase until the customer's product warranty ends. The main process includes several sub-processes, where appropriate.

The same system model can be analysed based on the earlier product model. To work, the system model needs well-managed product structures. The chart shows the product-based angle of view connected to the system model from simplified business elements from quotation to customer delivery (Figure 36). The process is divided into four sections.

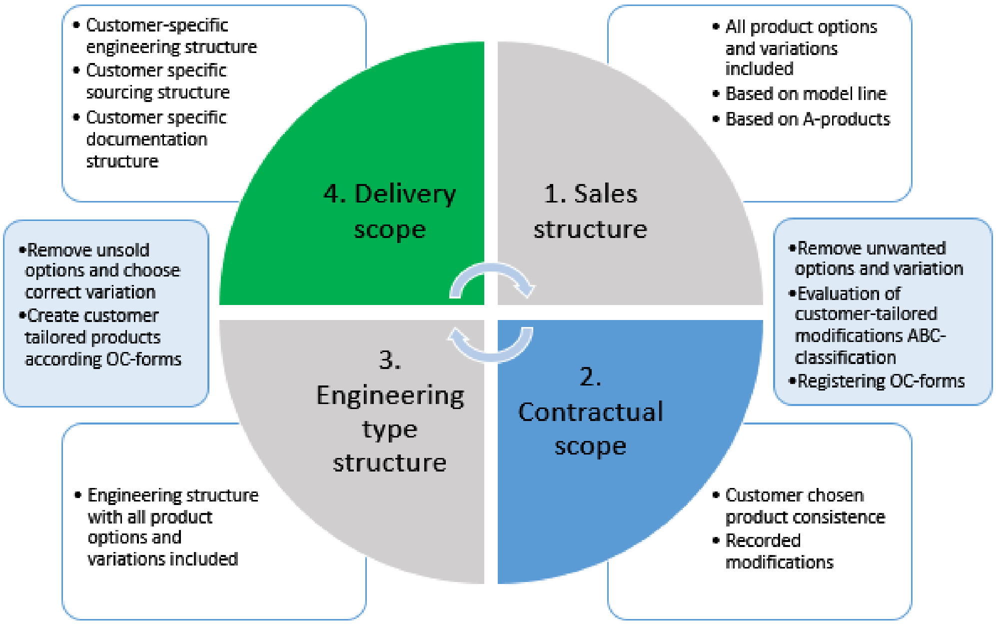


Figure 36: Essential business elements from quotation to customer delivery.

At the quotation phase, the sales structure (no. 1 in Figure 36) is based on a model line of A -products. In addition to the functional characteristics, the cost structure and required delivery time are defined for standard A-products. As the sales negotiations progress, the customer's desired package is refined. Options and variations that the customer does not want are removed from the model products. At the same time, modifications desired by the customer are registered and evaluated by the OC process. This generates the necessary additional cost and delivery time for unknown products if they are executable compared to the standard product.

The contractual scope (no. 2 in Figure 36) phase locks customer-chosen consistency with recorded modifications. This determines the delivery content, cost structure and delivery time clearly.

The engineering type structure (no. 3 in Figure 36) is based on standardised product structures that produce known product characteristics through defined solutions. Options and variations are built into the products. The type structure is modified to match the sold entity by removing options and variations not chosen by the customer. In addition, customer customisations defined on the OC forms are made.

The delivery scope (no. 4 in Figure 36), with a final customer-specific delivery structure, is the basis for creating customer-specific documentation and sourcing structures. Based on the final delivery content, a pre-documentation is built at the initial stage to help the customer move forward with their project. The spare parts quotation to the customer is also based on this content.

5.4 Limitations of the results

The limitations of the results are due to the nature of the business observed. The case study company operates in the global machine manufacturing project business and is a market leader in many segments creating a diverse set of challenges to solve. Changes in the global economy combined with internal and external factors create their own limitations in the problem environment. Variables in the global economy increase or decrease sales in different regions. Customers in each continent and country tend to have different approaches and timing for doing business. The same variation applies to the types of products that customers need. On the production side of the business, operating under an outsourced global model, variations in supplier capabilities can be observed. All these together affect capacity, cost base and delivery times. Changes in the global economy also create challenges in other business segments, which are indirectly reflected in the case study company.

Because each enterprise has to manage its everyday work and not focus on full-time development, the rhythm and timing of development activities must be adapted according to resource constraints and opportunities. This places time constraints on development activities at both organisational and financial levels. Organisational theory and organisational change in the case study company were not studied.

5.5 Future Research Challenges

This study explored the development of operational business through the development of a systems model and integrated business structures. The theory was applied to a case study company, where a streamlined business approach was developed through a systems model. Due to a large amount of data available, the study did not examine the organisational theory and organisational change in the case study company. In this area, interesting future research areas can be found, such as how to use more effectively the global latent information from the customer generated by the process to expand employees' competence and develop the product offering. The case study company has a history of challenges in finding and training new personnel resources due to the highly specialised nature of the business (Figure 37).

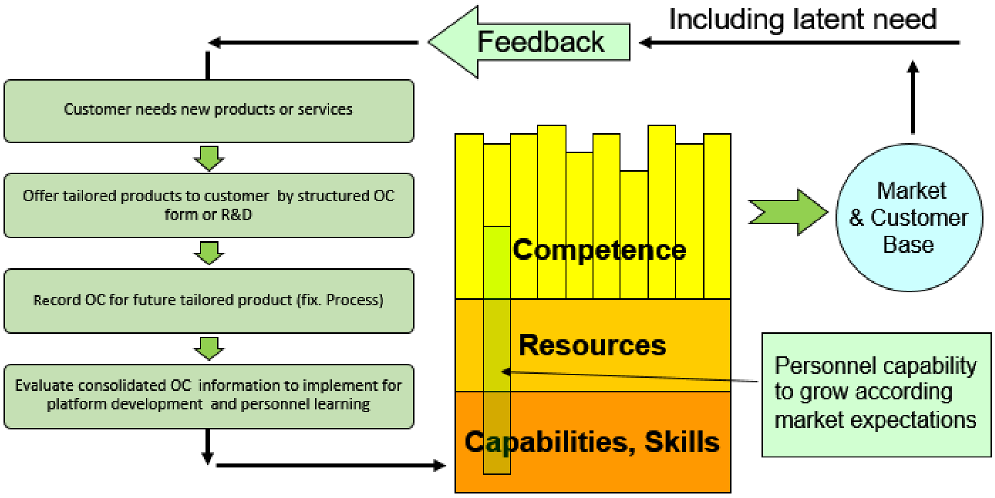


Figure 37: How the process reflected on learning in the company.

The management and accuracy of product information also affect sales and market behaviour. Having the product structures in place at the component level enables the standardisation of model lines. In a case study company, the level of readiness of a model line offering affects the amount of work done per quotation submitted. The completed model lines also drive the market for ready-made production solutions and the specifications of the products that can be manufactured with them. This works to some extent but requires further development and more in-depth theoretical analysis.

Enlarging Life Cycle Care and Management Services knowledge and offerings is possible through the right data and learning curve. This future opportunity for business expansion should be further explored as it has excellent potential to be realised.

An interesting area of future research is to pursue the next level in Industry 4.0: adaptability. Here AI-based self-optimisation takes place within the constraints of human-made boundaries. This also requires the availability of relevant information from design, production, logistics, sales and other relevant business operators.

6 Theoretical contribution

Research areas such as systems theory, production theory and information theory are not new. However, these, as a whole, integrated into the global project business, are less frequently seen in scientific research. Therefore, this integrated whole creates a new theoretical contribution.

In the customer-oriented global project business, it has been studied how the development of the company's operational functions and new operating models have affected the company's efficiency with selected indicators. At the same time, the overall functional picture of continuous change management and the new business structures required for its operation to work as a whole have been created.

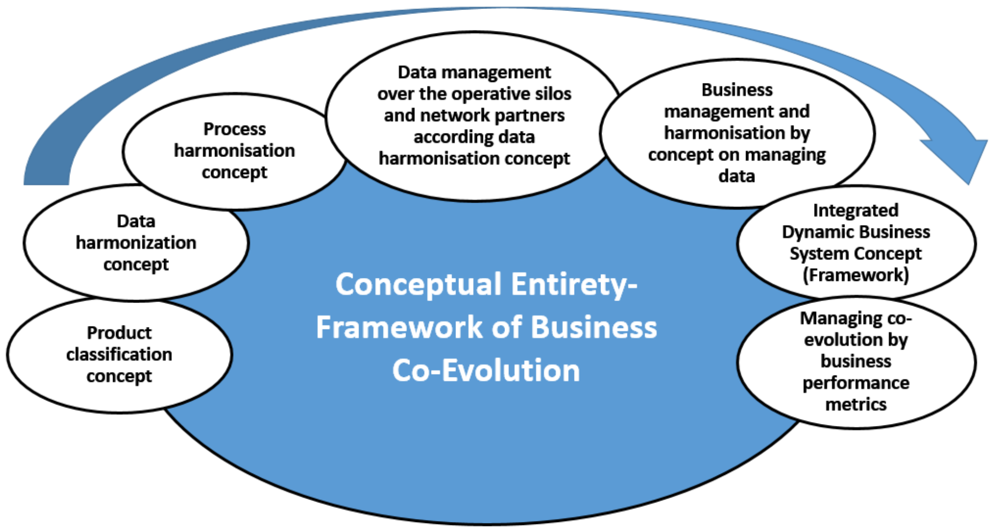


Figure 38: Setup of the conceptual framework.

The overall conceptual framework provides a view of the whole, which is then used to integrate the individual concepts to form a functioning overall (Figure 38). The concepts of 'Product Classification' and 'Data Harmonisation' provide product knowledge and a database for development. The concept of 'Process Harmonisation' is needed for operational development. By building on these sub-concepts, the overall system concept, and framework, can be created and further developed to manage the whole. The above enable data management between different stage holders and operational business development, which is monitored and controlled by continuous measurement.

These concepts are adapted from theory to fit the case study business model, working not as a single entity but as an integrated whole.

The main contribution of this study is that an intelligent business co-evolution framework has been created according to scientific studies and novel proof-of-concept case study on the case business environment. Conceptual continuity has been fixed according to field lab (case study business) test runs and implemented in real practice.

7 Managerial Implications

The study approached the problem through four research questions and aimed to verify three propositions. As the research progressed, the need for three theories was identified: systems theory, production theory and information theory. The knowledge generated by these was tested over five years in a case study in a real environment. The extensive case study found the answers to the questions identified, and the propositions were verified.

The objective is operational business efficiency while cost-effectively providing the customer with the requested product with the desired features at a known price and delivery time.

The extensive numerical data in the study is drawn from a case study of a company's ERP system and its management reports. Over several years, the non-numerical data has been captured from development meetings and transferred to the various revisions of the process map and the functional business structures. The results are a combination of an applied mixed methods research model validated in a real global project business environment. Cooperatively selected business indicators have verified the direction of change and development. These have demonstrated the right trend over several years and have continued to move in the right direction.

A limitation of the study is the volume of material and the long period of observation during which the world economy and markets fluctuate. The case study company's global project business is strongly linked to developing the infrastructure of countries and continents, which is reflected in the market. Organisation theory and organisational changes in the case study company were not studied.

Development projects are challenged by the business of the company's day-to-day operations and the resource challenges they pose. These often take priority, and development projects have to take their place in the queue. Also, different organisational silos may have their own objectives and those of individuals, which may conflict with a neutral understanding of the common good, creating friction. It can be argued that the more clearly a problem can be described, the easier it is to understand and decide on it. The challenge to be taken into account as a result of resource limitations will be the ability to identify the right and most productive development objectives and prioritize between them.

The study's theory and results apply to business development in the manufacturing industry, especially in a global project business like the case study. In these, the open problem domain can be approached by understanding the system model using the following components (presented earlier): item-based data validity, master data, information harmonisation, managing by data, network management and life cycle management.

8 Conclusions

The challenges presented by global markets and related operational activities are constantly changing. Global economic changes and customer demands create dynamic challenges that the company should be able to overcome effectively. In a project business, where lead times are long, operational efficiency is essential while maintaining customer-oriented capability.

The objective of the research work was to create an intelligent business co-evolution framework with integrated individual concepts to form an overall functioning framework based on scientific studies from systems theory, production theory and information theory. These concepts were cooperatively proof tested in a case study on the global project business environment for five years implementing various methodologies based on three theoretical areas.

The goal of the case study was to prove how a theory-based framework used to develop a real-life operational business model into an updated and refined operating model brings significant operational improvement at the enterprise level. One main objective was to consider customer expectations and meet quality requirements while creating standard and customised products cost-effectively while operating in a modern global networked environment.

The study approached the problem through four research questions and targeted the verification of three statements. As the research progressed, the need for three theories was encountered. The knowledge produced by these was tested over five years in a case study in a real environment.

The case study approaches the topic through a system model, which evolved to include optimised business structures. The integrated components of system develop the operational business, particularly in the following sectors: product and item data management, safety, quality and the delivery of a new project, including its complexity management. The system as a whole has various system elements built in that act actively to gather information for subsequent elements, or passive elements that are activated when necessary and controlling elements that give direction or permission to act. The interaction of business structures in a system built in this way enables an integrated whole with greater efficiency than the sum of its individual elements.

The study answered the questions raised and confirmed the research propositions presented. At the same time, a system model was created in which the business elements work together in an integrated manner to form a streamlined operational framework.

The key contribution is that the Intelligent Business Co-evolution Framework has been created based on scientific research and novel proof-of-concept case studies in a project business environment. The conceptual continuity has been validated through field laboratory tests and implemented in real-world practice through organisational collaboration, shown in the research approach outline, starting with the theories, proceeding from the inner frame and opening towards the proven case study setting of the outer frame in Figure 39.

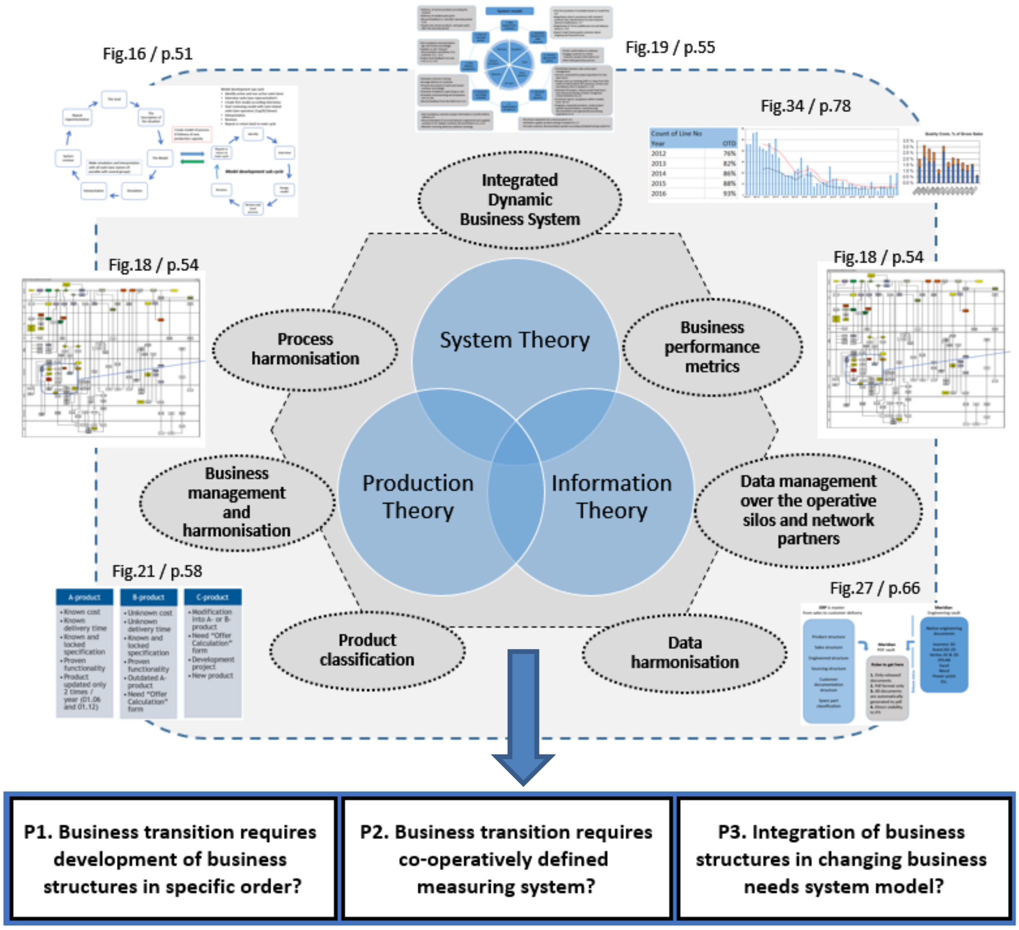


Figure 39: An outline of the research approach

The second significant contribution is the long-term development of the successful case study company's operational efficiency, monitored using several metrics.

References

Byrne, A., & Womack, J. P. (2013). *The lean turnaround*. McGraw-Hill.

Chiarini, A., & Vagnoni, E. (2015). World-class manufacturing by Fiat. Comparison with Toyota Production System from a Strategic Management, Management Accounting, Operations Management and Performance Measurement dimension. *International Journal of Production Research, 53*(2), 590-606. 10.1080/00207543.2014.958596

Curcio, V. (2013). *Henry Ford*. Oxford University Press.

Dabhilkar, M., & Åhlström, P. (2013). Converging production models: the STS versus lean production debate revisited. *International Journal of Operations & Production Management, 33*(8), 1019-1039. http://dx.doi.org.ezproxy.cc.lut.fi/10.1108/IJOPM-08-2012-0316

E. A. Lee. (2008). Cyber Physical Systems: Design Challenges. Paper presented at the - *2008 11th IEEE International Symposium on Object and Component-Oriented Real-Time Distributed Computing (ISORC),* 363-369. 10.1109/ISORC.2008.25

Emiliani, M. L., & Seymour, P. J. (2011). Frank George Woollard: forgotten pioneer of flow production. *Journal of Management History, 17*(1), 66-87. 10.1108/17511341111099538

Eoyang, G. H., & Holladay, R. J. (2013). *Adaptive Action*. Stanford University Press.

Forrester, J. W. (2013). *Industrial Dynamics*. Martino Publishing.

Glowalla, P., & Sunyaev, A. (2014). ERP system fit - an explorative task and data quality perspective. *Journal of Enterprise Information Management, 27*(5), 668-686. 10.1108/JEIM-08-2013-0062

Gordon, J. (2015). *Machines That Drove the Revolution*

GTAI. (2018). *Industrie 4.0 Germany Market Report and Outlook.* (). https://www.gtai.de/en/invest/service/publications/industrie-4-0-germany-market-report-and-outlook-64602

Gunasekaran, A. (2001). *Agile Manufacturing* (1st ed.). Elsevier. 10.1604/9780080526881

Gupta, P. (2006, Beyond PDCA-A New Process Management Model. *Quality Progress, 39*, 45-52. https://ezproxy.cc.lut.fi/docview/214765105?accountid=27292

Hernes, M., Bytniewski, A., Mateńczuk, K., Rot, A., Dziuba, S., Fojcik, M., Nguyet, T. L., Golec, P., & Kozina, A. (2020). Data Quality Management in ERP Systems – Accounting Case. Paper presented at the *Advances in Computational Collective,* 353-362.

Holland, J. H. (2000). *Emergence*. Oxford Univ. Press.

Invisible AI Partners with Toyota to Install Ground-breaking Computer Vision Platform Across North America. (2022). https://www.invisible.ai/news/invisible-ai-partners-with-toyota-to-install-ground-breaking-computer-vision-platform-across-north-america. Retrieved 26.07.2022, from

Kelleher, T. (2002). *Nuts and bolts*. Early American Industries Association.

Koskela, L., Sacks, R., & Rooke, J. (2012). A brief history of the concept of waste in production. *IGLC 2012 - 20th Conference of the International Group for Lean Construction,*

Lee, C., Leem, C. S., & Hwang, I. (2010). PDM and ERP integration methodology using digital manufacturing to support global manufacturing. *International Journal of Advanced Manufacturing Technology, 53*(1-4), 399-409. 10.1007/s00170-010-2833-x

Liker, J. K. (2004). *The Toyota way : 14 management principles from the world's greatest manufacturer*. McGraw-Hill.

Meadows, D. H. (2008). *Thinking in systems: A primer*. chelsea green publishing.

National Committee on Engineering Heritage. (1999). *BMC Plant Nomination . ()*.

Netland, T. H., & Aspelund, A. (2013). Company-specific production systems and competitive advantage: A resource-based view on the Volvo production system. *International Journal of Operations & Production Management, 33*(11/12), 1511-1531. http://dx.doi.org.ezproxy.cc.lut.fi/10.1108/IJOPM-07-2010-0171

Netland, T. H., & Sanchez, E. (2014). Effects of a production improvement programme on global quality performance: The case of the Volvo Production System. *TQM Journal, 26*(2), 188-201. http://dx.doi.org.ezproxy.cc.lut.fi/10.1108/TQM-03-2012-0023

Non-Indexed Pages #2. (1985). *Business History Review (Pre-1986), 59*(000002), 299. https://ezproxy.cc.lut.fi/scholarly-journals/non-indexed-pages-2/docview/205501266/se-2?accountid=27292

Ohno, T. (1988). *Toyota production system : beyond large-scale production*. Productivity Press.

Philbeck, T., & Davis, N. (2019). THE FOURTH INDUSTRIAL REVOLUTION: SHAPING A NEW ERA. *Journal of International Affairs (New York), 72*(1), 17-22.

Pine, B. J. (1999). *Mass customization*. Harvard Business School Press.

Rockwell Automation. (2014). *The Connected Enterprise Maturity Model*

.

https://literature.rockwellautomation.com/idc/groups/literature/documents/wp/cie-wp002_-en-p.pdf. Retrieved 17.05.2022, from

Ruohomaa, H., & Salminen, V. (2019). Ecosystem-Based Development on Managing Digital Transformation. (pp. 132-140). Springer International Publishing. 10.1007/978-3-030-20154-8_13

Salminen, V. (2009). *Synergy management by hybrid innovation* SSN 1459-2045;859

Saunders, M., Lewis, P., & Thornhill, A. (2016). *Research methods for business students: 7. ed*. Pearson.

Saunders, M., Lewis, P., Thornhill, A., & Bristow, A. (2019). "Research Methods for Business Students" Chapter 4: Understanding research philosophy and approaches to theory development. (pp. 128-171)

Schonberger, R. J. (1996). World-class manufacturing: The next decade. *Industry Week, 245*(6), 21. https://ezproxy.cc.lut.fi/docview/219731505?accountid=27292

Schuh, G., Anderl, R., Dumitrescu, R., Krüger, A., ten Hompel, M. (2020). Industrie 4.0 Maturity Index. Managing the Digital Transformation of Companies – UPDATE 2020 – (acatech STUDY). www.acatech.de

Schwab, K. (2016). *Theœ fourth industrial revolution*. World Economic Forum.

Senge, P. M. (2006). *Theœ fifth discipline* (Rev. and updated with 100 new pages, [2. ed.] ed.). Random House, Business Books.

Shingo Shigeo, & Liker Jeffrey, K. (Eds.). (2007). *Idea wo Nigasuna / Kaizen And The Art of Creative Thinking* (English Translation ed.). Hakuto-Shopo Publishing company / Enna Products Corporation.

Shingō, S. (1988). *Non-stock production*. Productivity Press.

Skyttner, L. (1998). The Future of Systems Thinking. *Systemic Practice and Action Research, 11*(2), 193-205. 10.1023/A:1022933619528

Starr, M. K. (1989). Book Review; Toytota Production System: Beond Large-Scale Production
. *Columpia Journal of World Business,* (Summer 1989), 73-74.

Sterman, J. (2000). Business Dynamics, System Thinking and Modeling for a Complex World. *Http://Lst-Iiep.Iiep-Unesco.Org/Cgi-Bin/Wwwi32.Exe/In=epidoc1.in]/?T2000=013598/(100), 19*

Sterman, J. D. (2000). *Business dynamics*. McGraw-Hill.

Stoller, J. (2015). *The lean CEO*. McGraw-Hill.

Vuorela, J., Ollikainen, M., Salminen, V., & Varis, J. (2022). Utilisation of Production Knowledge in Developing a Modern Customer-Oriented Project Business Environment. *Management and Production Engineering Review, 13* 10.24425/mper.2022.142393

Waldrop, M. M. (1992). *Complexity*. Simon & Schuster.

Wilkins, M., & Hill, F. E. (2011). *American business abroad Ford on six continents*. Cambridge University Press.

Womack, J. P., & Jones, D. T. (2003). *Lean Thinking*
. Free Press.

Womack James, P., Jones Daniel, T., & Roos Daniel. (1990). *The Machine That Changed The World*
(2007th ed.). Free Press.

Womack, J. P., & Jones, D. T. (1996, Beyond Toyota: How to root out waste and pursue perfection. *Harvard Business Review, 74*, 140. https://ezproxy.cc.lut.fi/docview/227798105?accountid=27292

Woollard, F. G. (1954). *Principles of mass and flow production*. Published for Mechanical Handling [by] Iliffe.

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *Null, 56*(8), 2941-2962. 10.1080/00207543.2018.1444806

Yusuf, Y. Y., Sarhadi, M., & Gunasekaran, A. (1999). Agile manufacturing:: The drivers, concepts and attributes. *International Journal of Production Economics, 62*(1), 33-43. 10.1016/S0925-5273(98)00219-9

ACTA UNIVERSITATIS LAPPEENRANTAENSIS

1058. KHAN, MUSHAROF. Environmental impacts of the utilisation of challenging plastic-containing waste. 2022. Diss.

1059. RINTALA, VILLE. Coupling Monte Carlo neutronics with thermal hydraulics and fuel thermo-mechanics. 2022. Diss.

1060. LÄHDEAHO, OSKARI. Competitiveness through sustainability: Drivers for logistics industry transformation. 2022. Diss.

1061. ESKOLA, ROOPE. Value creation in manufacturing industry based on the simulation. 2022. Diss.

1062. MAKARAVA, IRYNA. Electrochemical recovery of rare-earth elements from NdFeB magnets. 2022. Diss.

1063. LUHAS, JUKKA. The interconnections of lock-in mechanisms in the forest-based bioeconomy transition towards sustainability. 2022. Diss.

1064. QIN, GUODONG. Research on key technologies of snake arm maintainers in extreme environments. 2022. Diss.

1065. TAMMINEN, JUSSI. Fast contact copper extraction. 2022. Diss.

1066. JANTUNEN, NIKLAS. Development of liquid–liquid extraction processes for concentrated hydrometallurgical solutions. 2023. Diss.

1067. GULAGI, ASHISH. South Asia's Energy [R]evolution – Transition towards defossilised power systems by 2050 with special focus on India. 2023. Diss.

1068. OBREZKOV LEONID. Development of continuum beam elements for the Achilles tendon modeling. 2023. Diss.

1069. KASEVA, JANNE. Assessing the climate resilience of plant-soil systems through response diversity. 2023. Diss.

1070. HYNNINEN, TIMO. Development directions in software testing and quality assurance. 2023. Diss.

1071. AGHAHOSSEINI, ARMAN. Analyses and comparison of energy systems and scenarios for carbon neutrality - Focus on the Americas, the MENA region, and the role of geo-technologies. 2023. Diss.

1072. LAKANEN, LAURA. Developing handprints to enhance the environmental performance of other actors. 2023. Diss.

1073. ABRAMENKO, VALERII. Synchronous reluctance motor with an axially laminated anisotropic rotor in high-speed applications. 2023. Diss.

1074. GUTIERREZ ROJAS, DANIEL. Anomaly detection in cyber-physical applications. 2023. Diss.

1075. ESANOV, BAKHTIYOR. Adaptive user-controlled personalization for virtual journey applications. 2023. Diss.

1076. SILTANEN, JUKKA. Laser and hybrid welding of high-strength structural steels. 2023. Diss.

1077. NOUSIAINEN, JALO. Model-based reinforcement learning and inverse problems in extreme adaptive optics control. 2023. Diss.

1078. USTINOV, STANISLAV. Fast and accurate simulation of fluid power circuits in the presence of small volumes using advanced methods and models for numerical stiffness elimination. 2023. Diss.

1079. HUSSAIN, HAFIZ MAJID. Heuristic-based packetized energy management for residential electricity demand. 2023. Diss.

1080. HÄMÄLÄINEN, MINNA. Principals managing entrepreneurship education in schools. 2023. Diss.

1081. WANG, ZHAO. Photocatalytic degradation of pharmaceutical and person care products (PPCPs) by commercial and synthesized catalysts under UV irradiation. 2023. Diss.

1082. LOHRMANN, ALENA. The water footprint of the global power sector: Status quo, challenges, and opportunities for tackling the global water crisis. 2023. Diss.

1083. PONOMAREV, NIKOLAI. A salt and alkali synergy for synthesising active carbons from lignin: porosity development and techno-economic assessment. 2023. Diss.

1084. AFANASYEVA, SVETLANA. Wind farm layout optimization: project economics and risk. 2023. Diss.

1085. VOSTROV, KONSTANTIN. Reduction of non-circulating bearing currents by electrical machine design. 2023. Diss.

1086. CARILLO MELGAREJO, DICK. Improving the design of cellular networks beyond 5G for smart grids. 2023. Diss.

1087. MALACINA, IRYNA. Zooming in and out: The strategic management of innovation across multiple levels of complex supply networks. 2023. Diss.

1088. SORE, SARISEELIA. Impact of information system capabilities on business value creation: Aspects of IT-producing and IT-consuming companies. 2023. Diss.

1089. IMMONEN, EERO. Advances in optimal design of shapes and processes by computational fluid dynamics. 2023. Diss.

1090. LAVOYE, VIRGINIE. Augmented reality in consumer retail: a presence theory approach. 2023. Diss.

1091. HÄRKÖNEN, KALEVI. Smart buildings in the green energy transition. 2023. Diss.

1092. TSYTSYNA, EVGENIYA. Motives, uncertainties, and imbalances in the evolution of a sustainable business ecosystem. 2023. Diss.

1093. JÄÄSKELÄINEN, ATTE. Business model innovation opportunities when news has become a public good. 2023. Diss.

1094. ADEDIPE, TAIWO. Atmospheric boundary-layer characteristics and their significance in wind energy and urban air quality assessment. 2023. Diss.

1095. SOSUNOVA, INNA. Model and guidelines for designing Internet-of-Things-enabled smart waste management system in smart cities. 2023. Diss.

ISBN 978-952-335-985-7
ISBN 978-952-335-986-4 (PDF)
ISSN 1456-4491 (Print)
ISSN 2814-5518 (Online)
Lappeenranta 2023