Money talks while volume and value should run the show

An evaluation of financial parameters for decision making during manufacturing system acquisition

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Marknadsekonomiska värden har under de senaste decennierna fått en allt viktigare roll med etablering av finansinstitut och globala organisationer som följd. Dessa har tagit kontroll över och till stora delar styrt utvecklingen på marknaden. Som en motreaktion har begrepp som hållbar utveckling uppstått för att komplettera och bredda utvecklingen med miljömässiga och sociala aspekter. Men det finns fortfarande stora utmaningar i hur ett balanserat beslut, baserat på alla tre synvinklarna, kan tas. Beslutsfattarna lutar sig fortfarande i första hand mot de etablerade konkreta finansiella aspekterna.


Abstract

Title: **Money talks while volume and value should run the show**
An evaluation of financial parameters for decision making during manufacturing system acquisition.

Keywords: Value chain; Manufacturing system; Investment process; Economical decision support; Production

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Market economic values have for the last decades been given an increasing role with the establishment of financial institutes and global organisations with a capitalistic focus as a consequence. As a counter reaction, the concept of sustainable development has emerged complementing the economic focus with environmental and social aspects. However, there are still challenges on how to make balanced decisions based on all three viewpoints and consequently the decision makers still primarily reside to the established tangible financial data.

Within the industrial setting there is no difference. The manufacturing system design is based on multiple criteria and requirements, but commonly the final investment decision is primarily based on what can be financially justified. Long term solutions probably lies in combining the tangible economy with the less tangible soft values that cannot be valued in monetary means. Therefore, to find this sweet spot, the purpose of this research is to in-depth investigate the world of economy, but from an engineers’ point of view. A financial analysis is done to understand the economical components and how these are related to the manufacturing system. Furthermore, to connect cost with contributed value of the manufacturing system, a holistic business value chain analysis is done to ensure that less tangible aspects can be understood and utilised.

The result of this research, highlights for example that sales volume has a larger impact on the manufacturing profitability, than that of the initial investment cost. Therefore, manufacturing systems should also be evaluated on the bases of how well it can meet the volatility in market demands. Another result presented is a portfolio of new graphical representation used as a support tool for investment decisions. Furthermore, to be able to invest in manufacturing systems that contribute to a more competitive company, the wider business value with manufacturing is discussed.
Appended Publications

**Paper A.** Consideration of market demand volatility risks, when making manufacturing system investments


Authors’ contribution: Johansson initiated the study, collected the data, conducted the main analytical work, as well as being the principal and corresponding author of the paper. Pejryd and G. Christiernin contributed with constructive analytical discussions, reviewed the manuscript and carried out quality assurance of both the research methodology and final paper.

**Paper B.** Production support model to manage market demand volatility risks


Authors’ contribution: Johansson initiated the study, collected the data, conducted the main analytical work, as well as being the principal and corresponding author of the paper. Pejryd and G. Christiernin contributed with constructive analytical discussions, reviewed the manuscript and carried out quality assurance of both the research methodology and final paper.

**Paper C.** Manufacturing system design for business value, a holistic design approach


Authors’ contribution: Johansson initiated the study, collected the data, conducted the main analytical work, as well as being the principal and corresponding author of the paper. Pejryd and G. Christiernin contributed with constructive analytical discussions, reviewed the manuscript and carried out quality assurance of both the research methodology and final paper.
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Costs do not exist to be calculated. Costs exist to be reduced.

Taiichi Ohno
1 Introduction

Most developed businesses of the world have for the last decades been giving more and more attention to the financial systems, in particular the objectives of reducing cost and maximising profit. This has lately been driven by the ever increasing global market at which the competition is fierce. Instead of making the best possible product, good-enough has been balanced by the cost and calculated profit, and the speed of return on capital employed is at the top of the agendas for the investors. However, steering too hard towards spreadsheet numbers, financial optimisation and mathematical calculations might risk missing the value that was initially tried to be achieved. Products with reduced life time and service issues are causing frustration in many product segments and markets, and less tangible objectives like knowledge development and synergy effects are overlooked. Furthermore, and most importantly, the business financially optimised approach is causing an unsustainable business environment in which the economic aspects often are outweighing the social and environmental aspects within the classical three-legged sustainability model.

In the work for this thesis, during the initial exploration of the industrial investment process for manufacturing systems, it became clear that the processes of acquiring new manufacturing equipment is complex with many interesting aspects. The large project organisation with communication challenges, the interaction with the suppliers, the way a standard process are communicated across the company or the technical details in the actual manufacturing system were just a few aspects all worth the research attention. The investment project organisation also spent time on aspects not related to controlling the physical output of the investment, but the non-physical financial output. From the concept design of the manufacturing system, the operational cost is predicted based on investments size, automation level, tooling, energy and more. From all of these financial calculations, a decision support documentation was put together as requested by financial control departments and management.

Understandably, not everyone is interested in the financial profession with spreadsheets filled with black and white numbers. Within the manufacturing community there still seems to be a higher interest in the technical systems and the physical products, rather than the non-physical financial prediction. However, when not fully understanding the world of economy it can sometimes become a certain bit of disconnect when different languages are being spoken between the
two departments. The financial side conveys the message “reduce cost”, while the technical side asks for “more money” to be able to acquire a system more suitable for the purpose. Somewhere in between lies the solutions perhaps, but to find this spot it requires both the technical and financial appreciation to link these two aspects together. From a manufacturing engineering standpoint it requires a deeper understanding in economy, to be able to understand and meet these increasing financial expectations with sometimes contradicting requirements. The focus of this licentiate thesis will therefore be around building a bridge that closes the gap between engineering and finance. The investment process will be financially studied, but with a technical point of view.

1.1 Research Question

Improvements to the manufacturing investment process are continuously implemented to ensure that better manufacturing systems are acquired. However, even though long term, sustainable and profitable investment options are identified, sometimes, there still seems to be a financial resistance to pursue these options. So, how can the manufacturing investment process be improved so that these long term investments align with the financial corporate strategy for high profitability?

To investigate this broad question, the following three sub-questions have been investigated:

a. Which financial element has the largest influence on the manufacturing operational profit?

b. How should this financial element be considered during the manufacturing system investment process?

c. What other non-physical objectives, apart from profit, are important in a manufacturing system investment?

1.2 Scope and limitations

This licentiate research focuses on the non-physical output of a manufacturing system (i.e. not the manufactured product) and how these can be improved through the investment process. In particular, the financial output has been given most attention at this point. The manufacturing systems studied are mainly related to engine component manufacturing at Scania CV AB in Södertälje, Sweden. This comprises of 17 individual manufacturing systems from which the main set of data has been collected. However, due to the data to a large extend is confidential, the raw data cannot be presented.
1.3 Thesis outline

Chapter 2 comprises of the theoretical frame of reference, mostly around manufacturing systems, investments, decision theory, some fundamental financial models and the chapter is concluded with a section around sustainability.

Chapter 3 introduces the reader to the industrial reality in regards to manufacturing system investment process and how this is conducted today.

Chapter 4 outlines the research approach, how the data has been collected and what type of data has been collected.

Chapter 5 summarises the results and analysis, mainly based on the appended publications. However, chapter 5.1 contains previously unpublished materials around financial model analyses that was considered important to introduce the non-economic reader to why investors, economists and other financially oriented people make the decisions they make.

Chapter 6 concludes all the results and discusses the impact of this work.
2 Frame of reference

The frame of reference comprises of some basic theoretical background to certain key areas of relevance for this thesis. It starts with theory around manufacturing systems including manufacturing system development and investments. As manufacturing system investments are a key component, there is also theory presented around financial models and sustainability.

2.1 Manufacturing system

The words production and manufacturing are often used within similar context and considered synonyms [1]. However, a manufacturing system is defined in different ways by different authors. Cochran et al. include the whole manufacturing enterprise, including all required functions, activities, processes and resources required to produce the product [2]. A key part of the product realisation is the production processes. However, according to Womack and Jones the processes within the manufacturing system are not only about the transformation of physical material, but also include processes like problem solving and information management [3]. According to Hubka and Eder, the manufacturing system is classified as a transformation system, with the elements humans, active environment, technical system and the transformation process, see Figure 1 [4].

Transformation System

![Figure 1. The production system seen as a transformation system, figure based on Hubka and Eder [4].](image-url)
In this thesis the word manufacturing system is defined as Hubka and Eder’s technical system, and does not refer to the other business functions like design, sales, marketing of the product being made. Furthermore, the term manufacturing production system (or simply production system) is referring to the whole transformation system including all four elements as per Figure 1.

2.1.1 Manufacturing system development challenges

The intention with production system development is to increase competitiveness by introducing novel processes, technologies and products [5]. Using the Hubka and Eder system theory, the system could be divided into four areas for development, i.e. humans, active environment, technical system and the transformation process [4]. Regarding the technical system, apart from the continuous improvement of the existing equipment, the industrial activity largely related to the development of this area is through the manufacturing equipment investment process. However, one challenge that the manufacturing system development faces is that the traditional functional organisation is strong [6]. Each function has their individual strategies and goals that aim at improving the specific function [6]. For the whole company to be competitive by utilising the production system to its full capability, more than simplified models and departmental financial aspects need to be considered during the development projects [7]. To organise the company in a process orientation instead, indicates to have a positive impact on quality, lead-time and customer satisfaction [8].

The most widely used standard today that deals with process orientation is ISO 9001, Quality Management System [9]. Even though many companies today are ISO 9001 certified with the clear process orientation as a requirement, the companies are still often functionally organised. To overcome some of the challenges with this functional orientation, additional temporary cross functional teams and projects are introduced rather than completely reengineering the whole company structure. The organisational structure can also have an effect on how decisions can be made as managers have responsibility over people rather than process delivery. However, these forms of organisational challenges and downfalls have been covered extensively since the emerge of Business Process Orientation (BPO) [10]. BPO was developed by Porter in 1985 but further developed by Deming, even though many other authors have contributed to the framework that exists today [11]–[14].
2.2 Manufacturing system investment

To start on a more generic level, an investment process can be seen as the traditional SIPOC process diagram (Supplier – Input – Process – Output – Customer), see Figure 2 [15].

The supplier to the process would be the machining system companies, who would provide the physical machining material as input which through the process becomes the output in form of a manufacturing system. Earlier in the process there will also be an information input to the process in form of quotations. There will also be some company internal suppliers that feed the process with non-physical information around the investment requirements. This could be for example product designs, manufacturing requirements around technical details and ergonomic regulations for the wellbeing of the operators, but also analyses for predicting the required capacity and financial constraints from the business.

The more apparent output of the investment process is the technical system itself, i.e. the machines and other equipment that have been acquired through the process. The quality of these physical items can be measured in terms of design properties like durability, tolerances, fulfilment of laws and regulations [4]. However, there will also be less tangible outputs more difficult to evaluate. One of these non-physical outputs is that the manufacturing system will determine the pre-requisite for the operational performance, i.e. product quality, cost, delivery and health, safety and environment (HS&E). There will clearly be a link between the physical design properties of the manufacturing system and these non-physical pre-requisite for the operational properties, but it is not always that easy to find these relationships. Another example of this non-physical output is the manufacturing system’s ability to continuously develop and improve, which will be depending on the design of the manufacturing system, but also the obtained understanding of the manufacturing system throughout the investment process. If the manufacturing system is bought as a complete turn-key solution and the investment project is more of a project management task, less understanding of
the details will be obtained by the investing company than if the system is collaboratively developed with the system supplier. This approach to buy a finish solution would consequently make it more difficult to continuously improve the manufacturing system and introduce future improvements.

Determining who the customers of the process are is related to which school of quality is used to define “the customer”. The end customer will always be important for the business. However, another important customer for an industrial investment process is the operational department, with the operators as the key individuals. It is their workplace so the system would hopefully be designed with their needs in mind. The design engineers of the product can also be considered a customer, and has requirements on things like the product quality. Furthermore, there are also less obvious process customers, for example the politicians in the society. They might have a large interest in the environmental impact the manufacturing system will have, often regulated through laws and legislations. However, they will also be interested in employment of people and the tax revenue from the company profit. It could also have a positive effect on the local educational system, for example through supporting student projects, thesis work and study visits.

### 2.2.1 Evaluation and decision models

When any type of system is being designed, many aspects require consideration to ensure that the intended system functions are fulfilled while it does not cause any other unintentional harmful functions. Some aspects are regulated by law and commonly related to health, safety and environment (HS&E). Identified at industry, during manufacturing development the operational targets have an important steer of the requirements, such as cost, capacity, quality and flexibility [16]. However, within the academic literature different authors have different focus areas for evaluating the manufacturing system [6], [17]–[19]. One reason for this is that different industries have been studied, at which different challenges are dominating [16]. High volume manufacturing will often focus on the Toyota inspired flow system that requires a reliable and predictable system, whereas low volume and high value manufacturing will be more inclined to look at the product integrity through quality assurance and part handling to not damage the products [20]. During the manufacturing development all this is boiling down to a number of decisions being made, narrowing down the solution space to the final system. Due to the number of aspects that require consideration as well as the large organisation involved, this decision process can be considered a complex process [17]. Additionally, these decisions can either be structured or unstructured, or a combination of approaches can be used for a single decision [21]–[23]. To aid in these complex decisions, a number of different support tools can be used. These
tools have been developed over a long period of time, but the term “decision support” has its roots back to early 70s and the management information system (MIS) [24].

The different decision support models found in academia have different scope. Some more comprehensive multi-attribute support models take into consideration many different aspects and give a single weighted optimal solution [16], [25], [26]. Other models are more specific to a certain aspect, for example environment, economy, technology and innovation. When it comes to economy, financial oriented decisions have been studied since at least the 18th century [27]. Since the growth and increasing popularity in financial evaluation, more and more of the other aspects are being valued in financial terms for the possibility to include them in the financial models. Many cost models have been developed on both micro level looking at the details of what drives the cost, but also on a macro level that covers more a system level. Kaplan and Anderson [28] developed a macro level framework for allocating cost in relation to time, to improve the traditional ABC method [29]. Ståhl [30] has developed a cost-per-part model, which to a large extent also uses time as a cost driver, but includes other aspects such as material cost. This model has also been further developed by Jönsson et al. [31].

Ultimately, investment decisions are based on financial models and bottom line operational performance is measured in financial terms. However, many researchers and practitioners have for quite some time tried to develop more comprehensive evaluation methods, both for evaluating an ongoing operation but also as a decision support tool for manufacturing production system development. One reason for developing new methods is because the existing financial models are not good enough as they give a short term view and do not cover all aspects of importance. In specific regards to investments in Advanced Manufacturing Technologies (AMT), Chan et al. [32] have conducted a comprehensive literature review on the shortfalls of the investment appraisal techniques.

2.3 Financial models

Manufacturing companies are capital intense industries, in comparison to shoestring operations with little tied up capital, such as software development. Large and long-term investments are resulting in fixed assets such as property, plant and equipment, which are key figures in the company’s balance sheet [33]. Because these financial figures are used by analysts to evaluate the company performance, there is an expectation that the right investment decisions are being made that give good financial results. The analysts and investors have different
methodologies and models to evaluate company performance based on historical data and predictions and Return on Investment (ROI), Return on Equity (ROE) and Return on Capital Employed (ROCE), Payback (PB), Net Present Value (NPV) and Internal Rate of Return (IRR) are just a few common terminologies used [34]–[37]. There are some differences between the common financial models and all highlight different areas of interest. However, as they all are financial models they are to a large degree fundamentally the same with similar including elements, i.e. cost, revenue and tied up capital.

2.3.1 Return on Investment

The background to the ROI model origins back to the early 1900s and it represents the classical financial model for evaluating investment performance [38]. The company DuPont de Nemours & Company developed the ROI model with the intention to analyse the profitability of the different decentralised parts of the company, using traditional financial performance figures [38]. A classical representation of the model is from Davis, Figure 3.

![Figure 3. Representation of the ROI equation inspired by T.C. Davis 1950 [5].](image)

The ROI is a product of two percentage ratios, investment turnover and earnings as a percentage of sales. The reason for this is that both the effect of turnover and earnings as a percentage of sales can be traced and monitored separately. This results in that sales (comprising of volume and price) will occur in both branches of the model. In addition, to better understand the source of the ROI score, Davis has broken down the model further into more detailed parts. Earnings and sales can be found
in the company income statement. Furthermore, investment turnover comes out of sales divided by total investment, which can be found on the balance sheet and shows how efficient the investment is to generate sales. The model has been broken down to even more specific details, which allows a more detailed analysis to be conducted. It is for example possible to see where changes occur, but also where improvements can be made to increase the ROI score. As the input to the model is typically taken from a financial report that is on a period basis, the performance will be an average value over that particular period. Davis describes the ROI as:

“...the ultimate measure of the financial success of an established business...” [38].

However, today the issues with using only financial evaluation models are well recognised, at least in the academia. This will be explored in the following chapter.

2.3.2 The current criticism of financial models

Hill expresses the concern that excessive use of Return on Investment (ROI) would undermine the long-term strategy, as the focus for investments is inclined to be short-term payback [6]. Demmel and Askin state that it oversimplifies an investment decision and has an inability to include intangible benefits, like flexibility, knowledge and shorter lead time [39]. Dornan also suggests that it is difficult to accurately value important aspects like flexibility, quality, customer service and other synergy effects [40]. Early entry to the market, perceived market leadership, possibility to offer customised products, etc. are other aspects often mentioned, which are difficult to translate into direct cash flow [41], [42]. Another issue is that the financial methods assume a static environment for the option of not doing anything [39]. This is also what Canada and Sullivan put forward as part of their three pitfalls during usage of traditional economic decision models [43]. They further explain that if these advanced manufacturing technology investments are compared with status quo, companies are ignoring to see the costs associated with the risks and also the opportunities with these decisions. The other two pitfalls that Canada and Sullivan bring forward are firstly that for high capital intense investments with moderate to high risks, high hurdle rates are applied with short expectancy of return on investment [43]. Secondly, the benefit analyses are also insufficient, similarly to what previously mentioned authors are saying. Ordooobi and Mulvaney also conclude that these advanced manufacturing system investments give a greater system wide benefit, but of which managers, accountants and other decision makers often are not even aware of [44]. Most of the mentioned deficiencies are around the limitation of the model and that it only includes financial tangible aspects. However, another aspect and purpose in a decision situation is that the model is expected to predict the future,
often based on assumptions and historical data. However, according to Christensen et al. it can be rather difficult to do this by determining trends and making predictions [45]. It can work pretty well under the circumstances that the future conditions resemble the conditions of the past. Nevertheless, many aspects influence the future for example technological innovations, governmental interference, individual decisions of influential companies and people, which makes it unlikely that the future will resemble the present or the past in an enough extent for the financial evaluation to be valid.

2.4 Sustainability, the financial counter reaction

The term sustainability was a counter reaction to the economic development that had a dominant position since the Second World War and caused an increasing pressure on the environment and social inequality [46]. When writing about sustainability, credit must be given to the Brundtland Commission and their report from 1987, *Our common future* [46]. However, the first time “Sustainable Development” was used in this context was already in 1972 during the United Nations Conference on the Human Environment, also known as the Stockholm Conference [47]. Nevertheless, it was not until the Brundtland report it gained a strong foothold and wide spread acknowledgement. Sustainable development consists of the three pillars (1) Economic growth, (2) Environmental protection and (3) Social equality, where all three aspects need to be considered and balanced to achieve a development that does not jeopardise the need of future generations [48]. However, the three areas are not completely unrelated as focusing on the environmental aspects, in particular the efficient use of resources, will also normally have a positive effect on the economic growth [49].
3 Industrial context

This research is mainly based on studies at the company Scania, a large Swedish manufacturer of transport solutions, such as heavy trucks, heavy busses but also stand-alone engines. The company comprises of approximately 44 400 employees and is present in most areas of the world, but with manufacturing focused in Latin America and Europe. The net sales for 2015 were over 94.9 billion SEK (approximate 10 billion Euro), which is predominantly through the heavy trucks business. However, some data through interviews, observations and experience have been gathered at other industrial companies. Scania is part of the Volkswagen group and the Volkswagen Commercial Vehicles subsidiary together with the German company MAN and the U.S. company Navistar.

3.1 Manufacturing systems

The manufacturing systems studied are producing different parts of the engine component, including parts like cylinder block, cylinder head, crankshaft, camshaft and other key components, see Figure 4. The total manufacturing volume of engines is about 85 000 units according to the company annual report of 2015, spread across trucks, busses, coaches and standalone engines for industrial and marine applications [50].

![Manufacturing Systems](image)

- Cylinder head
- Cylinder Liners
- Cylinder Block
- Crankshaft
- Camshaft
- Balance shaft
- Bearing cap
- Connection rod

Production volume: ~ 85 000 / year

Figure 4. Engine component and the included manufactured parts.
For some parts, like the engine’s cylinder block, this equals the same number of manufactured units. However, for cylinder head, cylinder liners and other components which are related to the number of cylinders in the engine, there will be five, six or eight manufactured units per complete engine set, making the total manufacturing volume for these manufacturing systems equal multiple times larger. The raw material going into the systems is mainly cast or forged iron of different alloys, which is then predominantly processed through traditional machining processes like milling, turning, grinding, boring and such. However, some operations are of other character such as laser identity part marking, cleaning operations, quality control and smaller assembly cells for plugs, bearing, bearing caps and other minor items.

The automotive industry is predominantly characterised by flow oriented manufacturing systems, with dedicated manufacturing lines for each type of part, as contrary to functionally oriented manufacturing cells typically seen in low volume manufacturing companies. The Toyota Production System (TPS) and Lean theories have been applied for many years, which is reflected in most areas of the company, such as the focus on flow, factory layouts, workplace organisation and operation management with the continuous strive to reduce waste and increase value. Simple visual systems are used across the factories, from follow up of key performance indicators, track deviations to logistical control of material flow. Another observation is that the manufacturing systems are to a large extent automated with just a few operators serving whole systems. The operators’ role is characterised by tool preparation, simple maintenance tasks, troubleshooting and corrective actions to get the system up and running when minor errors and stops occur.

The studied manufacturing systems have been commissioned at different times with some being older than 20 years, while some others are newly acquired in the last five years. The older manufacturing systems have a more traditional mass production design, with dedicated machine tools with little product flexibility, whereas newer manufacturing systems have more flexibility built into the design. One example of this difference is for the cylinder block manufacturing, where the 20 year old system is a transfer line where each machine has a unique design to produce the unique specific feature at a specific operation. Here, hole drilling operations have large drill rigs with as many as 25 drills fixed in their location machining all holes in one machine motion. The more recent acquired manufacturing system producing the same family of components has instead many more standard multi-axle machining centres, with a single tool spindle producing one hole at the time. To achieve the same system throughput of parts, parallel machines work simultaneously with the same operation, which also results in manufacturing system less sensitive to disturbances [51].
3.2 Manufacturing equipment investment process

At the studied company, an investment process is being executed when acquiring large manufacturing systems. Even though this chapter is outlining the investment process at the studied company, similar observations have been made at different manufacturing companies. The investment process consists of different phases that has described as a linear stage-gate process, see Figure 5. The process originates from a company process initiative, merging the project management process with the technical activities related to the investment. The investment process’ phases are (1) Initialisation, (2) Pre-study, (3) Project start-up and requirement specification, (4) Quotation work, (5) Tendering, (6) Projecting, (7) Pre delivery test, (8) Installation and takeover, (9) Project conclusion and finally (10) Warranty follow-up. Each phase has a primary objective to be achieved before continuing to the consecutive phase. However, there exists a number of activities that stretch across several phases, in particular those not directly related to the technicality of the manufacturing system acquired.

Figure 5. Investment process for manufacturing equipment at the studied company.

Within the investment project organisation there are participants from many different functions with different sets of skills. Generally there will be a project leader from the manufacturing engineering department who also will be responsible, but the industrial maintenance department plays an important and active role as well with their deep technical understanding of manufacturing systems. Other participating functions are purchasing, operations, health, safety & environment (HS&E), logistics, finance and automation & IT. In relation to the project there will also be a steering group overseeing the progress and responsible for key decisions. However, large investments in manufacturing systems that ties up a lot of capital will be financially controlled by the company executive board, as well as by the owning parent company.
Initialisation phase establishes the conditions and prerequisites for the project. The reason for the investment is defined, which can be things like cost rationalisation, required improvements in quality, health, safety and environment, new product introduction [52]. At the end an assignment directive will be issued to the project leader.

A Pre-study will be done at large investment projects to start understanding the consequences of the investment, timings, and start obtaining an organisational buy-in with required resources secured. Finances are also estimated and initial investment plans are submitted to secure the funding. At the end of this phase a project definition will be written, outlining the whole project including aspects like the background, objectives, scope, organisation, finance and risks.

Project start-up and requirement specification consist of more direct investment activities, rather than preparation and planning as in previous phases. Functional requirements are captured and documented, and potential suppliers are identified. The phase concludes with a request for quotation (RFQ) being sent to the identified suppliers.

Quotation work comprises of reviewing received quotes and if necessary further develop the submitted requirement specification. The quotes are reviewed in respect to technical aspects for the proposed solution, but also financially. This phase concludes with a shortlist of suppliers brought to final negotiations during the tendering phase.

Tendering is mainly a commercial phase, in which the purchasing organisation is the main actor. The final commercial details are discussed, negotiations are held and the phase normally concludes with an order. At this stage all remaining suppliers fulfils the minimum requirements of the investment, and therefore the supplier with the lowest investment cost is selected.

Projecting is the phase at which the ordered technical system is realised by the supplier, at the supplier facility. The main activity from the investing company is to project manage, mitigate arising risks, but also prepare the receiving factory for the delivery of the system. This include among other things to prepare the machine foundation, ensure relevant media system is appropriately sized, communication and training.

Pre delivery test is carried out at the supplier of the manufacturing system, to ensure as many flaws and issues as possible are identified while the system is still at the supplier. Functional tests are carried out as well as health and safety assessments. Several functions from the investing company with the relevant skill set are participating, for example operations, maintenance, manufacturing engineering,
health and safety to ensure that as many aspects of the investment as possible are covered.

Installation and takeover of the technical system is done in similar way as the previous phase, but now it will be carried out at the factory where it will operate. Functional test, health and safety assessment and other checks are done to ensure that the investment functions as intended. This also includes full training of the related organisation, for example operators, maintenance, logistic and supporting engineers.

Project conclusion is a phase when all relevant documentation is archived, but the performance of the investment is also continuously monitored to ensure that it keeps on working over a period of time, and not only during the one-off installation tests. All points in the initial project assignment are checked and followed up and lesson learned logs are updated.

Warranty follow-up is an activity done before the end of the warranty period, to ensure all issues are corrected or financially compensated for. It does not only cover mechanical issues, but also that the investment fulfils the functional requirements such as capacity, cycle times, quality.

3.2.1 Investment process control

To control the output of the investment process, different aspects are approached and managed. The purchasing department at the company is constantly evaluating the machine tool suppliers to ensure a minimum standard is met on aspects such as business moral and financial stability. There will also be commercial agreements enclosed with the order to control the supplier's and investor's legal obligations. The investment process execution is controlled through trained project managers, and the documented process itself as a tool to ensure all aspects are covered and lessons are learnt. Looking at the evaluation and final decision in the investment process, the control is categorised into two main aspects, technical and financial.

The technical control is specified in the requirement specification document, with enclosed appendices. These aspects can be divided further into two main areas; base requirements, controlled through policies, standards, regulations and law and top requirements, controlled specifically by the project and could be for example related to the product being made in the manufacturing system. The base requirements do normally not need to be justified internally for each investment. Example of these requirements are what control systems to accommodate the machining centres to ensure ability to integrate with existing automation system, or ease of maintenance and spare parts rational, or maximum allowed noise levels
for health, safety and environmental reasons. These requirements have sometimes to some degree already been financially justified. Top requirements however are more functional related and specific to the project. These are often related to manufacturing targets on quality and delivery performance. Generally, all requirements are specified as a desired function, to give a certain design freedom for the supplier designing the systems. However, when experiences have given best practices on a certain solution, this solution can be specified as a requirement in the technical specification. Generally speaking, this seems not to be desired by the purchasing organisation as it tends to limit the number of possible suppliers to negotiate with and give the supplier the opportunity to keep price up.

As the final investment decision is financial, economic analysis becomes one key investment activity throughout the project that also effects the process output. Initially the investment costs of the manufacturing system are predicted, which determines certain project directions and limitations. Later in the process the supplier quotes are compared both technically and financially. However, if one supplier is technically preferable but at the same time more expensive, the technical advantage requires conversion into monetary value to make it possible to include it in the financial decision model. The less tangible aspects like competence development, possibility for further development and flexibility are through this strict financially oriented decisions being left outside the formal decision process. Financial models used are versions of Return on Investment (ROI), Net Present Value (NPV) and similar traditional models [34]–[37]. There are project discussions on Life Cycle Analyses (LCA), Life Cycle Cost (LCC), Total Cost of Ownership (TCO) and such evaluations looking over a longer period of time [53]–[57]. However, looking at the formal decision points there are nowhere these are used as base for financial decisions. To some degree it can be found in the technical control, for example where a certain technical solution has previously demonstrated as robust and requiring less maintenance, it would then be included as a technical minimum requirement for all suppliers to fulfil.

3.2.2 Investment financial decisions

Throughout the investment process as part of the financial control, there are recurring financial decisions being made. Depending on the size of the investment different decision makers are involved, stretching from factory local group managers the whole way to the parent company for large investments. Normally the first decision is a strategic make-or-buy decision, but this really occurs before the initiation of the investment process. This is a strategic decision based on the criticality of the component, protection of intellectual property, etc. For example, at the studied company the powertrain and driver cabin are considered core
components and are therefore to a large degree made in-house. If these analysis result in a make-decision, the investment process is initiated.

The second decision is made after the pre-study phase, which is both technical and financial but on a conceptual level. The financial size of the investment is estimated by the technical community based on rough estimates and experience. Rough budget quotes can be obtained by potential suppliers as input, but they are not guaranteed and no order can be made on these quotes. Depending on the size of the investment, different decision makers are involved, but anything above €500 000 goes minimum to the executive board of the company. A one-pager describing the technical aspect is presented together with a rough financial business case. Recently, also sustainable aspect is specified separately as the company aspires to become leader in sustainable transport systems.

After that the requirements of the future manufacturing system are identified and formalised in the requirement specification document, there is a purchasing decision being made. Once again this is depending on the size of the investment, but any project larger than €250 000 will go for approval to the purchasing managers across the sister companies within the corporate family. The decision is not related to the technical or financial aspects, but to which suppliers are considered appropriate for the project and will receive the request for quotation.

When the quotations have been received from the suppliers and the technical evaluation is completed, the final decision is being made. This decision is wholly financially oriented, given that the minimum technical requirements are fulfilled. If the final quotation cost for the investment is higher than the initial estimates after the pre-study, the second decision then requires a revisit to ensure funds are available and allocated. The main financial focus lies in the one-off investment cost, and not the long term costs, like Life Cycle Cost (LCC) as popularly found in literature.

Once the order is made to one supplier, the projecting phase of the investment process commences and the detailed design of the solution will be developed. If during this phase additional cost follows through e.g. unforeseen circumstances or that further functionality is introduced, the second financial decision requires a revisit again.
4 Research approach

To answer the research question it was decided to look at existing manufacturing systems using a qualitative and empirical approach. The industrial reality was explored through observations, interviews and review of solid quantitative financial data. The main research interest has been the process of manufacturing system acquisition, or simply investments for production. The results of previous investments have been used as study objects, i.e. existing operational manufacturing systems. In the investment process there are two main aspects which are evaluated; (1) technical and (2) financial. Traditionally in the engineering profession, the technical requirements get plenty of attention as this is the core competence of most involved people in the investment projects. The financial aspects do also get the attention, but generally economy is an area that is secondary over the technical aspects within the manufacturing engineering skill set. This is instead covered by financially oriented functions, like industrial control, purchasing, management and alike. Moreover, the final decision is also financially oriented and is controlling the outcome of the investment. Therefore, the work in this study has been to bridge the gap between these two areas, by conducting a deep dive into the finances of manufacturing system, with a technical perspective and mind-set.

4.1 Source of data

The source of data has to a large degree been collected from the existing administrative systems at the studied industrial company. Additionally has interviews and observations been conducted, mainly with key individuals at the studied company. However, there are also influences from other manufacturing companies through interviews, observations and previous industrial experiences by the author and supervisors.

4.1.1 Financially related data

A large amount of solid and comprehensive real manufacturing data has been collected for the studied manufacturing systems. It has been collected from different reporting systems already in place, used and managed by different company functions. In particular, the cost reporting system has been a key source of data, which is updated and reviewed on a monthly basis. Other database
systems for consumable inventories but also the assets register have been used to find the details around the permanent investment and working capital.

The simple DuPont’s Return on Investment (ROI) model has been selected as the core model to be used in the studies, as it is well recognised financial model and includes the typical parameters evaluated [38]. In Figure 6, the original ROI model (previously presented in chapter 2.3) has been further extended and detailed. This has been done to better visualise the technical related level, clarifying what elements of the manufacturing systems contributes to the different parts of ROI. The dashed line in Figure 6 indicates where the original model stops and the extended detailing continues. Additionally, some slight rephrasing has been done compared to the original model from Davis in Figure 3. For clarity, Cost of Sales has been renamed to only Cost, but would include similar elements as the original model. Additionally, instead of looking directly at the total cost of sales, the volume of produced parts is multiplied by cost per product to achieve the same total cost. The reason is that the company representatives often referred to cost per part, rather than total cost. Also included in the model in Figure 6 is a plus or minus symbol to illustrate how the element affects the overall ROI score. A plus sign means that a higher value contributes to a higher and better ROI, whereas the elements with a minus sign should be reduced to increase the ROI score.

Figure 6. Extension of DuPont’s Return on Investment model, detailed to a typical manufacturing level.
In the following chapters the origin of some data will be clarified. Some data will be used in the raw format extracted from the administrative system at the company. However, in some instances the data has been challenging to trace specifically to a unique manufacturing system. Instead of excluding these areas completely from the model, they have instead been estimated and simplified in accordance with general recommendations for those types of elements. This gives a better ground for comparison between the manufacturing systems, even though the result is not completely accurate to the true performance of the systems.

4.1.1.1 Inventories

Figure 7 illustrates where inventories are located within the ROI model (Figure 6). When it comes to the storage facility of consumables, such as tools, machine spare parts and consumed parts assembled on the components manufactured, it is a shared facility that provides material to a number of different manufacturing systems. The consequence of this is that for most inventory items there is no way to truly trace items to a specific manufacturing system. Instead, the storage inventory value has been distributed between the manufacturing systems in direct proportion to historically how much it has used of each item. For example, out of all cutting tools used for all the engine related manufacturing systems, one system stands for 10.2 percent of the reported cost of cutting tools. Therefore, this system is then also given 10.2 percent of the cutting tool inventory value. This logic was done for all storage inventories of which no system traceability exists. Fortunately, for machine spare parts, over 90 percent of the inventory value of the items is traceable to an individual machine and consequently also the related manufacturing system. The machine spare parts represent almost 60 percent of total inventory value, so being able to trace almost all of this was important to be able to do more accurate financial analysis.
4.1.1.2 Accounts receivable and cash

Within the asset branch of the model, more specifically within working capital, the accounts receivable and cash were difficult to specify for a specific manufacturing system as it is the same financial organisation who is responsible for all engine related manufacturing systems. Figure 8 illustrates where accounts receivable and cash are located within the ROI model (Figure 6). However, practitioners suggest that in manufacturing industry, the cash reserves should cover at least two months’ worth of cost [58]. Therefore, this variable was defined and calculated as twice the amount of the collected cost data.

Accounts receivable is the money the customer own the company when products and services are payed for on credit. This product is not sold to an external customer and there is no accounts receivable. However, to still give this variable some value the company annual report was used. It is from this document possible to calculate the whole company’s days sales outstanding (DSO), which adds up to approximate three months’ worth of sales [50], [59]. Therefore, the Accounts receivable was defined and calculated as three times the sales.

![Figure 8. Location of accounts receivable and cash in ROI model.](image)

4.1.1.3 Permanent investments

Figure 9 illustrates where permanent investment is located within the ROI model (Figure 6). The studied manufacturing systems have been acquired at different years but also additional investments have been done after initial commissioning, resulting in different financial value of the money spent due to for example inflation. To take this into consideration, the permanent investments throughout the years have been converted into 2014 value through Edison and Söderberg consumer price index (CPI) for Sweden [60]. The CPI for years after 2012 has been based on projection as this index was established in 2011. The items included
under the *permanent investment* element are only equipment found in the assets register database. Generally, property, plant and equipment (PP&E) would all be included as assets, but have in this research been simplified to focus only on equipment.

**Figure 9. Location of permanent investment in ROI model.**

### 4.1.1.4 *Price per product*

Figure 10 illustrates the *price per product* being located within the sales branch of the ROI model (Figure 6). No data for this has been available, as these products are part of a larger assembly and mainly sold internally between manufacturing departments. There are also some business sensitivity aspects in publishing profit margins on component level. Therefore, when calculating and comparing ROI scores, the *price per product* was instead set to a figure higher than the *cost per product* to ensure no negative ROI score would be obtained.

**Figure 10. Location of price per product in ROI model.**
4.1.1.5 Cost per product

Within the earnings side of the model and specifically the cost per product, as visualised in ROI model Figure 11, the following cost drivers were included; scrap, stop time losses, operators, transportation, consumables (tools, cutting fluid, safety equipment, etc), maintenance (labour and spare parts), capital (depreciation) and overhead. These are the cost drivers that are currently systematically collected and used within the engine manufacturing departments studied. In regards to the capital cost, i.e. the depreciation of investment value over time, it is not fair to compare different systems with more than 20 years between the time of commissioning. Most equipment of the old systems has been considered to have no more value, and therefore give no capital cost for the product going through these old systems. To be able to make a fair comparable analysis, all equipment is instead considered to have its original financial value, re-evaluated to present monetary value, and with a depreciation time of 15 years.

Figure 11. Location of cost per product in ROI model.

4.1.2 Business core process and value analysis

To be able to identify and analyse value, it is important to start with understanding the customer of the value. This research proposes that the manufacturing system within large industrial companies can contribute with much more value to the rest of the business. The customers in this context is the business and in particular its core process. 15 out of the 100 largest Swedish companies were externally analysed to identify these industrial businesses’ core processes [61]. Rosemann (2006) suggests that there is an issue with business process modeller competence, therefore the review was conducted on a higher level [62]. One of the key principles within the ISO 9001 quality management system standard is process orientation, therefore the ISO certificates issued specifies the businesses core
processes [63], [64]. Furthermore, the companies’ annual reports were carefully read to verify the core process identified. Sometimes the company structure reflects the ISO 9001 core process, and at other times it is rather ambiguously found in the text.

For each of the identified core processes, potential manufacturing system value was discussed and reasoned among the industrial experienced individuals. In addition to the ISO 9001 certificate review, one company was also visited and an interview was conducted with the company marketing director. As one of their recent TV commercial circled around the manufacturing production system, the main topic of the interview was how the manufacturing function can contribute with value for the marketing function.

### 4.1.3 Industrial experience

The author’s technical frame of reference has been an important input to this research. It has guided the financial analytical work from a technical point of view and made it possible to see beyond the economic numbers and understand what drives the figures. The technical background starts with a Master of Science degree in mechanical engineering. After the studies the author were employed as a manufacturing engineer within the aerospace industry for six years, to then continue in the automotive industry for another six years. The experience stretches across different manufacturing engineering fields, including things as production planning, process quality assurance, shop floor IT, investments in manufacturing equipment and continues involvement in root cause analysis and development groups. During the research for this thesis the experience has also been complemented with a number of observational studies at the manufacturing systems producing the relevant engine components specified in Figure 4.

Another important source of information is other people’s industrial experience. Continuously throughout the research there has been different forms of industrial meetings to discuss a wide range of topics, both within the main studied company but also with other manufacturing companies. The topics stretch from things like design features of engine components, design challenges, corporate finance, sustainability, purchasing and how large manufacturing system investments are controlled and managed. Some meetings have been structured interviews to collect specific data, while others have been less formal discussions. There has also been direct involvement in the company development meetings for the investment process, which also gives access to a network of senior individuals which collectively have many years of experience.
5 Results and analysis

To be able to improve the investment process of manufacturing systems and thereby answer the research questions, it is important to understand the existing operational manufacturing systems. The output of the operational process is in the foundational and simple level a manufactured product, like the engine components that have been the main focus of this study. However, there will also be other outputs like waste products and non-physical items such as knowledge, information and the financial result. This chapter is to a large extent focusing on the financial output and the system properties that is controlling this output. The last section is widening the output perspective to more non-physical outputs that are of interest for other key functions within the company.

The following chapters are mainly summarising the key points of the appended papers. However, chapter 5.1 presents new and complementary information, which clarifies the ROI model, and an analysis of the individual elements. Chapter 5.2 summaries appended Paper A and brings out the importance of considering the volume dependencies of manufacturing systems. Chapter 5.3 summaries the appended Paper B and present how this dependency can be considered and analysed, both during a manufacturing system investment process but also on how to mitigate risks with the existing operational systems. Chapter 5.4 summarises the appended Paper C and moves away from the pure financial aspect and presents a wider business holistic approach on what value the manufacturing systems can contribute with to other business value chains.

5.1 Analyses of ROI model and company profitability

To be able to analyse and understand the financial result from a manufacturing operation, it is important to look closer and understand some of the basic financial models. The Return of Investment (ROI) equation is one classical model that contains much of the financial aspects of importance. In the model, to obtain the ROI value, the investment turnover is multiplied by earnings as a percentage of sales. The model is constructed in this way to be able to track what is contributing to a good or bad ROI score. Half of the model origins from the company balance sheet, while the other half can be found on the income statement. However, as a few elements are repeated on both halves it can mathematically be simplified
through a number of transformational steps. Starting with the original model presented in Equation (1), transformed can be done as per Equations (2), (3) and (4), to obtain the simplified Equation (5).

\[
ROI = Investment\ turnover \times Earnings\ as\ a\ %\ of\ sales
\]

\[
\frac{Sales}{Total\ investment} \times \frac{Earnings}{Sales} = \frac{Earnings}{Total\ investment}
\]

\[
= \frac{Volume \times Price - Volume \times Cost}{Total\ investment}
\]

\[
= \frac{Volume}{Total\ investment} \times (Price - Cost)
\]

Equation (5) clearly shows four variables within two distinct factors that need to be considered. The first factor is the ratio \( \frac{volume}{total\ investment} \) and the second factor \( price\ minus\ cost \) (specified per product). To be more profitable, the ROI value should be increased. From a mathematical point of view, this is achieved by increasing \( volume \) and \( price \) and by reducing \( total\ investment \) and \( cost \). This corresponds well with the typical push received from the financial departments within companies. And even though this looks mathematically like a simple straightforward task, in reality this is more complicated to achieve. There are strong and complex relationships between all variables, and changing one would potentially affect the others. Further analysis in demonstrating these relationships will be conducted in the following chapters.

### 5.1.1 Analyses of first factor, volume per total investment

To achieve a better Return on Investment (ROI) score, \( volume \) should be increased while \( total\ investment \) reduced. Moreover, as per the ROI model in Figure 6, the variable \( total\ investment \) also comprises of two other variables, i.e. (1) \( permanent\ investment \) and (2) \( working\ capital \). So with increasing \( volume \) the \( total\ investment \) would also increase. Not because of the variable \( permanent\ investment \), as long as no further investments are required, but because \( working\ capital \) would increase. \( Working\ capital \) is comprised of another three elements; (1) \( inventories \), (2) \( cash \) and (3) \( accounts\ receivable \). The recommendation of holding \( cash \) is normally related to the \( cost \), and with increased volume the total cost will also increase, and more \( cash \) should be
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Accounts receivable is how much money the company’s customers own and yet have to pay, which relates to the invoice payable time. This varies from industry to industry, but it is however directly related to sales volume as well. Therefore, by increasing sales volume, the accounts receivable will then also increase proportionally.

Inventories would also potentially increase but probably not in direct proportion to the volume. This is because inventories comprise of elements which are more or less related to manufacturing volume. Items such as machine spare parts, employee clothes and work in progress (WIP) would potentially be unchanged or just changed slightly with increased volume. However, other elements such as consumables and part storage have a direct proportion to volume as these are often related to inventory buffer coverage.

These are all effects caused by an increased volume, but not how the volume could be increased to start with. One common way to boost sales (to increase volume) is to reduce the price, as seen every time a company has reduced price offers. However, exactly how much volume would increase with reduced price is difficult to predict as the human factor of the customers play a big role. Some companies who strive to achieve a strong brand value even experience that reduced price even reduce sales over a longer period of time, as for example the customers’ perceived relationship between quality and price comes to play. For example, the Swedish bed manufacturer Hästen is protective of their brand, and by reducing price there is a risk that the high valued brand is damage causing an overall reduced sales figures [65]. Then similarly, increasing price could also be a way to drive sales volume up, which then gives double positive effect on the ROI score.

Another way to increase volume could be to increase the quality of the product to become better than the competitors and through this take market shares. However, the attempt to increase quality could also increase the cost in different ways. Similarly, but conversely, in a financial strive to chase cost reduction without further understanding of the cost drivers, it could lead to reduced quality that could, among other things, hurt the company reputation and in turn reduce volume drastically as customers turn their back. It is however difficult to predict these consequences with any accuracy. The South Korean electronics company Samsung experienced this recently as they seem to have pushed the limit a bit too far. Reaching the market before the competing U.S. company Apple was important to obtain an increased market share and boost sales volume. However, as they later had to recall their flagship phablet smartphone model Galaxy Note 7, due to batteries catching fire, the reputation of the brand became damaged [66]. This could potentially cause ripple effects across the whole company with reduced volume on many other Samsung products as a consequence. This could never
have been predicted with certainty and would be difficult to include in a financial model, but the risk could have been identified and preventative actions undertaken.

5.1.2 Second factor analyses, price minus cost

Within the second factor of Equation (5), price minus cost per product, both price and cost are related to volume. The price volume relationship was discussed in previous chapter as part of how to increase volume. Cost is also related to volume but not as a mean to increase volume. Instead, with increased volume the cost would be reduced, resulting in a double positive effect on the Return on Investment (ROI) score. This is due to cost being composed of elements that are volume dependent. Cost is in essence composed of fixed costs and variable costs. The total fixed costs would not change with increased volume, but it would be diluted on more parts and consequently the cost per product would be reduced. Generally, in low volume manufacturing the fixed cost would stand for a larger part of the cost per product, while in high volume this would be the opposite and known as economies of scale [67]. However, with continuously increasing volume, the fixed cost could at some point also be increased through the diseconomies of scale [68]–[70]. It is therefore difficult to generalise the effect of volume changes on cost, which additionally is also very different between different industries.

5.1.3 Conclusion from evaluating the financial model

With the deeper analysis of the Return on Investment (ROI) profitability model, it becomes easier to realise that there are interrelated dependencies between most variables, making it difficult to predict consequences of changes in the variables. However, what can be realised is that changes in volume has a far larger influence on the result that initially indicated from just looking at the equation. Apart from the direct relationship between volume and ROI as per the Equation (5), most of the other variables are also functions of volume. Some relationships are easier to calculate and predict, while other are more manufacturing system related. A deeper understanding of the volume dependencies is therefore the next step in this research. As cost often is in focus for a manufacturing facility, the volume to cost relationship has been targeted for further analysis.
5.2 Consideration of market demand volatility risks

Looking at the world today, financial evaluation can be found in most situations where some kind of financial transaction occurs. In a decision process, two basic fundamental questions are normally asked; “is it worth the cost?” and “what are the alternatives?”. To be able to answer these questions, decision models have been developed over time, of which many are mathematically based, hence the input also needs to be quantifiable and often valued in terms of money. However, all inputs to these financially oriented decision models are estimates, assumptions, predictions with different degree of uncertainty. For example, the initial purchase cost can be pretty certain, but even so during large manufacturing development investments these tend to increase along with the project as unknown factors present themselves, new requirements come in and the prerequisite changes. Whereas long term cost and revenues are strongly relying on for example promises from the investment providers and historical data, with a far higher degree of uncertainty. Either way, one strong influencing factor in a manufacturing investment decision is the ever so difficult question on future market demand and sales volumes, that obviously solely dictates the revenues but also a large part of the cost. Therefore, when making an investment decision it would be wise to understand the volume dependencies related to cost, as this differs from one manufacturing system to another.

5.2.1 Cost composition

Cost can simply be divided into fixed cost and variable cost. Fixed cost has in theory no relation to the sales volume. This can be contractual committed cost, capital cost, labour cost (for permanent employees) and other similar items. Variable cost is directly related to the volume produced, for example consumables, consumed parts, energy and transportation of parts. Most reported and tangible cost drivers at companies have elements of both fixed and variable cost, making it difficult to easily separate the two. For example, typically reported maintenance cost can be composed of both wear related spare parts, which is more related to manufacturing volume, but also the overhead organisational cost, which would be paid irrespectively of how much the machines are used. Moreover, there is also a reporting time delay on several cost drivers, which makes it even more difficult to structurally separate the two cost elements to relate it to the correct manufacturing volume. This sometimes relates to how cost is internally reported, for example when consumables are taken from the storage unit, it might not be reported as a cost in the company financial books until an order is placed to the storage item suppliers. Depending on the item buffer level,
this can be as rare as a few times per year, making it difficult to see on a daily basis the actual costs incurred of manufacturing. Another example is again the wear related machine spare parts, which might last for years before breaking and only then causing a cost in the books.

### 5.2.2 Identification of fixed and variable cost

There are different ways to determine the fixed cost and variable cost. One way to do this time-efficiently is to look on a high statistical level over a longer period of time. This will not reveal exactly what is driving the different cost elements but will statistically and mathematically reveal how cost is effected by volume. With the classical linear best fit line, Equation (6), where \( y \) represent cost and \( x \) represent volume as seen in Equation (7), all variation is taken out and gives a system level estimate of the two cost elements.

\[
y = kx + m
\]

\[
\downarrow
\]

\[
\text{cost} = k \times \text{volume} + m
\]

The constant \( k \) to \( x \) will be the volume variable cost, and the free constant \( m \) being the fixed cost. The example displayed in Figure 12 is based on anonymised cost data from one of the studied engine components. Here the volume related cost is 4 SEK per manufactured part, while the total fixed cost is about 37 000 SEK per month.

![Figure 12. Extraction of fixed and variable cost parameters through linear best fit line.](image-url)
Due to the reasons presented in chapter 5.2.1, this is not completely accurate for each month, but will still give a good enough indication of the cost distribution between fixed and variable costs.

By knowing the cost structure and relationship to volume, it is then possible to better understand what will happen to the profitability if the volume changes. Typically, when calculating cost for an investment project, one or a few single volume points are used to obtain static conditions required by the financial evaluation model. To instead represent this in a visual graph as a decision support tool seen in the fictive example in Figure 13, the cost per part can be plotted against a volume line. Rather than only considering a single volume point, the decision maker can now see the consequence of when the sales volume is increased or reduced. A system with high fixed cost and low variable cost will be a favourable investment option as long as the sales volume stays high, which is above 10 manufactured pieces per month in the example in Figure 13. Meanwhile, a system with low fixed cost and high variable cost will instead be more favourable in a low volume situation. Clearly, a system with both a low fixed cost as well as a low variable cost will always be financially an even better system. This is all due to the differences in the cost structure, in particular the proportion between fixed and variable cost between the two investment options. During a manufacturing investment project, there is a risk that the evaluation is based on a single high volume point, with the assumption that this is a representation across the whole volume span. However, this is not always the case, so it is of importance to understand the increased product cost with reduced volume for all investment options.

![Diagram of two manufacturing systems with different cost structures](image)

Figure 13. Deciding on a single point gives a different answer than looking across a volume line.
5.3 Managing market demand volatility risks

A portfolio of visual support tools has been developed to support both in investment projects, but can also be used on a risk mitigation initiative on existing manufacturing systems. The effect of cost per product in relation to volume has been the focal point as this has demonstrated to be different for every manufacturing system and an important aspect to consider. However, change in volume is also having a significant effect on the financial result in complex interrelated ways. All proposed support tools require financial data around fixed cost and variable cost, as well as a volume range of interest. The financial data for existing manufacturing systems can be obtained from financial control systems. However, to not get lost in the details, a linear cost line as per Figure 12 and Equation (7) can be used as a good enough method, giving an approximation of the two important parameters; fixed cost and variable cost.

In the following sections the graphs are based on collected data from the manufacturing system at the studied company. However, due to the sensitivity of the data it has been anonymised. This is one reason why the volume axis in some of the graph are presented in percentage instead of the actual volume. However, in Figure 15 where multiple of different manufacturing systems are compared, the volume must be presented in percentage as the volume differs between the systems.

5.3.1 Actual cost per product

The first support tool in the proposed portfolio is a graph displaying the actual cost per product over volume reduction in percentage, seen in Figure 14. To use the actual cost has been considered to be a less ambiguous representation, and therefore easier to adapt in an industrial context. The volume axis can also be displayed in real figures rather than a percentage, but as the next graph requires percentage on the volume axis, both are for consistency. The zero volume point in this case is the maximum capacity of the manufacturing systems, but the expected normal monthly volume would be less than this. The graph will visualise which system is stronger at what part of the volume interval, but also the actual expected cost per product. Figure 14 shows that system A is financially better at higher volumes, i.e. with little volume reduction as the axis present. Once the volume has been reduced with more than about 40 percent, system B becomes more profitable. For an investment comparison the market demand needs to be understood to be able to evaluate which system would become most profitable.
Even though the initial intention with the graph was to compare investment options, it can be used for exist manufacturing systems producing the same family of components with comparable volume and cost structures. However, one limitation with this visual support tool is that it displays actual costs and therefore cannot easily be used to compare different manufacturing systems producing different products. For this it is better to use normalised values giving a better graph for comparison, which will be presented in the following section.

### 5.3.2 Change of cost per product

To be able to obtain an overview of multiple manufacturing systems that are producing different products with different volume and product cost structure, the data that goes into the graphical representation requires normalisation. One way is to work with percentages, therefore the second graphical support tool Figure 15 displays the increased cost per product over a sales volume interval, both axes in percentage unit. In the example displayed in Figure 15, the volume axis starts at the zero reference point with the calculated capacity for each system, but the volume interval can be configured as desired.
In the graph (Figure 15) is a number of completely different manufacturing systems displayed, making completely different products, but all are related to the studied engine manufacturing systems. A supervisor who perhaps is responsible for all of these systems, can now see that the most volume sensitive system is system A. The product cost in this system will have almost a 120 percent increase with a 60 percent reduced volume. This can be compared to the system with lowest sensitivity at which the product cost would increase about 60 percent for the same volume reduction. Some might say that a 60 percentage drop in sales volume is not that common and does not need consideration. However, the zero reference point here is the calculated maximum capacity of the systems, therefore a 60 percent utilisation of the system maximum capacity is suddenly not as irrelevant or unrealistic. From the information obtained from the graph, the business can decide if actions are required to mitigate some of the financial risks that the systems A impose on the total profitability. The actual cost per product will also play an important role here and needs to be considered complementary. If the most sensitive systems are producing one of the cheaper components with low total cost, it might not impose a high financial challenge to the business. Even though the cost per product increases the most, the total actual cost might not represent a large proportion of the business total cost. Nevertheless, this tool gives a list of priority for further investigation in the details.

Figure 15. Change of cost per product in relation to volume reduction from maximum capacity of the manufacturing systems.
5.3.3 Proportion of fixed cost per variable cost

The reason for different manufacturing systems having different cost behaviours with reduced volume is solely due to the proportion of fixed cost per variable cost. Therefore, to better understand and clarify this ratio relationship, would give the business and investment decision makers a better insight and ground for decision. The graphical support tool in Figure 16 displays how this proportion changes over a volume interval. For example, in the graph it shows that system B has a lower proportion of fixed cost than system A. This explains the reason for how system B is financially better at lower volume than system A seen in the initial graph Figure 14. However, a low proportion of fixed cost is in its own not necessarily a good system, as this also can affect the actual cost per product. Seen in the graph Figure 14 is that even though system A has a higher proportion of fixed cost than system B, it also has a lower cost per product at high volume. So as long as the market demand remains high, system A will be the financially preferred system even though it has a higher proportion of fixed cost. In this example, it is only when the volume is reduced by more than 40 percent that system B becomes financially better. Hypothetically, if system A had both a lower cost per product and also a lower proportion of fixed cost compared to system B, it would be financially preferred across the whole sales volume range.

Figure 16. Ratio between fixed cost and variable cost with reduced volume.
5.3.4 Cost sensitivity index ($I_s$)

As identified in previous chapter 5.3.3, the ratio fixed cost over variable cost determines the manufacturing system cost sensitivity to volume. This proportion can be considered as a neutral cost sensitivity index ($I_s$), and would help in both determining the cost risk associated to existing manufacturing systems, but also aid in an investment decision in new manufacturing systems. This sensitivity has also been recognised previously by Porter, but only briefly mentioned [10]. A manufacturing system with a higher $I_s$ value indicates that the cost will raise more rapidly with reduced volume, than a manufacturing system with a lower $I_s$. It is not possible to generalise what is considered a high or low value of the $I_s$ as different industries have different profit margins and expectations to absorb the increasing cost. This needs to be determined for each business separately. Additionally, businesses that operate in a volatile and uncertain market would perhaps favour a more predictable cost structure, and a low $I_s$ would then be preferred. However, to have large part of variable cost elements could at the same time mean that the overall cost is higher, as sometimes seen through leasing contracts. So the overall cost vs. value must be considered.

If this sensitivity index is known for a particular manufacturing system at a certain manufacturing volume, the cost increase can be predicted with accuracy with reduced volume through the Equation (8). This also means that two manufacturing systems with the same fixed and variable cost ratio, will have identical product cost increase measured in percentage, irrespectively of the actual cost. $PF$ in Equation (8) is the percentage of initial volume, expressed in decimal form.

$$\text{Cost increase} = \frac{I_s + PF}{PF(I_s + 1)} - 1$$

From the relationship between this ratio and the volume and cost increase, a table can be constructed to support in cost risk mitigation activities, see Table 1. A reduction of volume with 10% gives a $PF$ of 0.9, volume reduction of 20% gives a $PF$ of 0.8 and so forth.
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Table 1. Cost increase through known Sensitivity Index (I\textsubscript{S}) and reduction in volume.

<table>
<thead>
<tr>
<th>Reduced Volume</th>
<th>-10%</th>
<th>-20%</th>
<th>-30%</th>
<th>-40%</th>
<th>-50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I\textsubscript{S})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>5.6%</td>
<td>12.5%</td>
<td>21.4%</td>
<td>33.3%</td>
<td>50.0%</td>
</tr>
<tr>
<td>2</td>
<td>7.4%</td>
<td>16.7%</td>
<td>28.6%</td>
<td>44.4%</td>
<td>66.7%</td>
</tr>
<tr>
<td>3</td>
<td>8.3%</td>
<td>18.8%</td>
<td>32.1%</td>
<td>50.0%</td>
<td>75.0%</td>
</tr>
<tr>
<td>4</td>
<td>8.9%</td>
<td>20.0%</td>
<td>34.3%</td>
<td>53.3%</td>
<td>80.0%</td>
</tr>
<tr>
<td>5</td>
<td>9.3%</td>
<td>20.8%</td>
<td>35.7%</td>
<td>55.6%</td>
<td>83.3%</td>
</tr>
<tr>
<td>6</td>
<td>9.5%</td>
<td>21.4%</td>
<td>36.7%</td>
<td>57.1%</td>
<td>85.7%</td>
</tr>
<tr>
<td>7</td>
<td>9.7%</td>
<td>21.9%</td>
<td>37.5%</td>
<td>58.3%</td>
<td>87.5%</td>
</tr>
<tr>
<td>8</td>
<td>9.9%</td>
<td>22.2%</td>
<td>38.1%</td>
<td>59.3%</td>
<td>88.9%</td>
</tr>
<tr>
<td>9</td>
<td>10.0%</td>
<td>22.5%</td>
<td>38.6%</td>
<td>60.0%</td>
<td>90.0%</td>
</tr>
<tr>
<td>10</td>
<td>10.1%</td>
<td>22.7%</td>
<td>39.0%</td>
<td>60.6%</td>
<td>90.9%</td>
</tr>
</tbody>
</table>

If all sensitivity indexes for all manufacturing systems at a company were mapped, it would be easy to see which part of the company that would struggle the most during a dip in market demand. And as already suggested, this can be done fairly quickly by looking on a higher statistical level by calculating a straight best fit line through historical cost data, see Equation (7). With an increased understanding on how cost per product would be affected by reduced or increased market demand, the business can mitigate risks and design the manufacturing system accordingly. For example, the business is probably very well aware of a pain threshold for how much a product can increase in cost to still be profitable. So if the curve in the graph is too steep and the cost per product is increasing too much with reduced volume, the fixed cost can be addressed proactively. Depending on what is driving the fixed cost different actions can be carried out. Capital cost due to large amounts of fixed assets is often perceived as a heavy rucksack of fixed cost for the company to carry, in particular within manufacturing industries with large manufacturing facilities. This can be managed with other forms of business models, where more fixed assets are moved to leasing types of contracts, or manufacturing value bought through other business models. This is only possible where the asset and cost model is volume flexible and the system can be scaled in relation to the market demand. And even if manufacturing systems are not designed with high degree of volume flexibility, as this was perhaps not part of the specification, it can be considered for future investments. If for example the business knows that there is a high uncertainty in market demand, instead of building one manufacturing system with a top capacity, smaller parallel systems would potentially be more financially beneficial, in which the machineries are leased with the possibility to return them to the supplier if volume is reduced. However, leasing can also contribute to additional costs and other risks, which need to be considered appropriately.
5.4 Holistic manufacturing system design for business value

While chapters 5.1, 5.2 and 5.3 address financial challenges during an investment project, the purpose of this chapter is to widen the perspective that should be considered during manufacturing system development. Traditionally, the requirements specified for a manufacturing system revolve around fulfilment of manufacturing needs, i.e. quality, capacity and cost, as well as fulfilments of legal requirements. However, apart from making parts, at large companies the manufacturing systems contribute with value in many different respect. These other aspects should also be considered during the investment process to ensure that the manufacturing system can strengthen the company’s competitiveness. It is therefore proposed that a holistic design approach should be applied to support the other value chains across the company.

As the main players involved in a manufacturing related investment are somehow related to the manufacturing function within the company, the requirements and focus will mainly be manufacturing. However, to gain a competitive advantage and fulfil other less obvious objectives, many other company functions should be considered which would give more strategic and company holistic benefits. This research shows that the other functions are typically product design and development, purchasing, sales, marketing and service, see Figure 17. Some companies also see the recycling of the company products as a core process to start embracing the complete product life cycle perspective.

Figure 17. Manufacturing companies’ core processes.
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One example of increasing the holistic value would be an extension to the cross-functional collaboration between product development function and manufacturing, which already exists at most companies today. During a manufacturing system investment, the related product development team would most likely be involved in the discussions, but from experiences these discussions are rather on how to design the manufacturing system to fulfil quality requirements but also to meet future product changes. Therefore, the proposed extension to these discussions would be for manufacturing function to additionally ask how the manufacturing system can help the product developer in developing the next generation products. Interviews with product developers indicate a high interest in using the manufacturing systems to make development parts, additionally to the series production. This puts requirements on the system to hold extra capacity for this purpose, but also to be flexible enough. Making prototype products in the series production system would give for example the product developer a valuable insight in the producability of the new products in a much quicker way.

Another example that would benefit not only the product developer, but also many other areas within the company, is to make the manufacturing facilities easier to enter and visit. This would put additional requirements on safety design of the manufacturing system outside the normal scope. Currently the factories are mainly restricting external visitors to stay in walking aisles, together with a guide who knows the area and the associated risks. If the factory was designed with the purpose of receiving guests completely untrained in the manufacturing risks, it would be designed differently. Examples of this can be found in isolation, where gangways are available in the ceiling, away from dangerous trucks and machineries. More transparent covers and larger safe zones around the machines would also bring the interested individuals close to the manufacturing process. This could be enough for the product developer to realise how the product can be better designed for manufacturing, without compromising the customer related features.

Safe and available factories could also enable more visits for the general population, customers or even school children, bringing much value to the brand reputation, sales but also contribute with knowledge and insight to the societal educational system. Instead of having the doors locked, students could enter the buildings that from the outside look grey and quiet, and realise that these are full of people, technology and excitement. An example of this is the new Sandvik Coromant facility in Sandviken, where large glass walls make it possible for bypassers to see into the workshop. Certain technology can also attract younger engineers, for example additive manufacturing (3D-printing), human robot collaboration and other state of the art areas. So, even if for example additive
manufacturing today struggles a bit to find financially feasible applications, it could improve recruitment base and also be a platform to develop invaluable knowledge to obtain a competitive edge for the future.

Decisions on buying a “turn-key-solution”, ready to start producing straight from the supplier, or build the complete system up from scratch within the company, also have a huge impact on the company competence development over a long period of time. Even though it looks expensive and requires a lot of effort to develop a system in-house, the competence and improved ability to continuously develop and improve the system in the future might be detrimental to stay competitive. These aspects are very difficult to include in both the technical evaluation and financial models of the investment, but should nevertheless not be disregarded.

5.5 General discussion

To get a grip of the manufacturing system and investment complexity, it is easier to start simple on a high level. The investment process is the same as any other process, and can be represented as a black box with input, output and some control parameters. So to be able to improve the process output, for example the manufacturing system and financial results, the controlling variables needs to be understood rather than keep measuring the output. The manufacturing engineer spends time trying to understand what part of the manufacturing process is related to the good and bad quality of the products made. In the operational system, the process control variables are things like the machine, tools, speeds and feeds, the people, as well as the raw material going into the process. The economist seems to see this slightly differently, where the output is a financial result, either profit or loss. The variables determining this are cost and tied up capital.

Some high volume manufacturing industries or other industries with low fixed costs might not be so interested in looking at the cost per product in relation to volume. For sure, everyone drives improvements to reduce cost, but where the fixed cost stands for a small part, the volume reduction itself will not be a risk factor to the same degree. However, before making the decision to not focus on the volume sensitivity, it should be first determined through the method presented in this work.

The value consideration during manufacturing system design is in theory a common sense approach. In reality, decision makers tend to ask for more concrete data to base their decisions. There is always a force to evaluate the value in financial terms. With the right competence and investigation, some aspects are possible to translate to money. However, there are many uncertainties and
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different possible outcomes of the future, that in the end of the day, the company management have to make a risk aware decision based on their experience and professional judgment. There are available algorithms designed to manage the complexity of the world. However, even these can give the wrong answers, and when relying on decision support tools giving a weighted answer, there is little possibility to scrutinise the answer. One example of this is during the 2016 presidential election in the U.S., where one of these advanced decision support tools named Ada were used to anticipate where campaigning efforts should be focused [71]. The system is believed to have made some good advice, but due to the unusual circumstances around the elections there were also areas where it could not give adequate decision support. All and all it resulted in a lost election.

Successful investments are being made today with the strong emphasis on economy and short term financial payback, so is there any problems? One big reason for success is due to the skilled people involved in the investment projects. Unofficial and sometimes even unintentional decisions are constantly being made throughout the projects, which ensures a successful investment. This happens for example when experienced people are setting technological directions, specifying requirements and selecting suppliers, based on their gut feeling. Sometimes decision support tools are even intentionally tweaked when these skilled people consider that the “wrong” answer has been given, to ensure that an investment direction that feels right is favoured. This works while there is a critical mass of experience and skill. However, to be less reliant on this and to better understand the process, the investment process must instead include the value focused approach rather than the financial approach. Additionally, the focus should also lie in the system design to ensure that the value is realised. An example on this is Axiomatic design, where complexity is eliminated to ensure that the system becomes robust to fulfil the requirements [72].

As described in this thesis, a company holistic value approach can make a company more competitive. However, there is also a wider perspective that should be considered and taken advantage of. There is a close interlinkage between the factory and the location of that factory. The supply of energy, knowledge and workforce are important external value chains to be considered when making decisions on the industrial structure design. For example, Facebook decided to locate one of their large data centres in the city of Luleå, north of Sweden. Here there is a surplus of clean renewable energy from the hydroelectric dams, cold winter air to cool down the servers and a technical university supplying skilled people [73]. Similarly, the location of new factories and development of manufacturing systems require a wider perspective to ensure the solutions become truly sustainable.
6 Conclusions

Which financial element has the largest influence on the Operational Manufacturing profit?

When analysing the financial elements’ influence on the manufacturing operational profit, volume has a significant impact on the profitability. However, volume is a process variable that is difficult to influence from a manufacturing functions perspective, therefore the effect of it must instead be controlled. The reason it has such a great impact on the financial result is because of the proportion of fixed cost.

Financial decisions and financial results are important. However, as realised during the deep dive into the world of economy, during an investment situation most (if not all) data is predicted or estimated. What really makes an investment successful or not does not coincide with how well these predictions are made. It rather lies in the details, the system design and the fulfilment of other non-financial objectives with the investment. This can be compared to the common manufacturing process, where there is an input, output and variables controlling the process. The financial result is the output of the process, like a dimension on a machined part. Therefore, it does not matter how many times it is calculated or measured, it will always stay the same. The only way of making a difference to the output is to take control of the process, and truly understand what has an influence.

How should this financial element be considered during the manufacturing system investment process?

The financial success of a manufacturing system is not only related to the cost of making a product, but the system’s ability to cost efficiently meet changes in market demand. So, by considering the proportion between fixed and variable cost during the investment project, the risk of reduced sales and volume sensitivity can be controlled.

Cost control is important for a business to stay competitive. Strategically it is important to focus on activities that are profitable to ensure that the business is financially sustainable long term. However, if the business already has evaluated the overall feasibility of making a specific core product, it is inevitable that a
significant investment will be required. The individual investments options should then perhaps not be financially evaluated using traditional models. Some say that as much as 70-90 percent of the product cost is already determined during the design of the product [74], [75]. Therefore, other key aspects are more relevant and should be the focus for the investment project organisation. If there still should be a financial evaluation, instead of looking at investment cost or operational cost even, the manufacturing system’s resilience to meet changing circumstances is a better financial oriented objective to achieve. For example, proposed in this thesis is that cost sensitivity to volume changes could be a more relevant factor to evaluate due to the uncertainty of the future. A cost-predictable manufacturing system can be more beneficial than producing at the lowest possible cost during high market demand. Depending on the cost structure, the manufacturing system can be more or less resilient to changes in sales volumes, effecting the overall company cash flow and profitability far more significantly than the proportion of attention these aspects get during the development phase. In the capital intense industries where there are large parts of fixed costs, the decisions to always invest and buy machines instead of leasing, will affect the company’s ability to meet future downturn in sales volumes. The proportion of fixed cost over variable cost should be considered in relation to how sensitive the company wants to be to sales volume reduction. This can easily be done by using the proposed graphical support tool, including visual graphs and the sensitivity index (I_s) to inform the decision makers on what the current status is and which areas to address.

**What other non-physical objectives, apart from profit, are important in a manufacturing system investment?**

As with a dimensional feature on a part, the manufacturing process cannot be looked at in isolation. The whole value chain that would potentially influence the financial output needs to be considered to avoid sub-optimisation. Even though the financial result is improved on a single manufacturing system through a specific investment, where the control is tangible and easier to manage, the company’s ability to be competitive might be significantly influenced in other areas. Apart from cost control through consideration of fixed and variable cost, the manufacturing system can contribute with more value to the company than what it is today designed for. There are several aspects that can be looked at to better support the business value chains, for example support the company’s ability to develop future innovative products. This can be supported through having the capacity and flexibility in the manufacturing system to produce prototypes for the product development process. It would give quicker feedback on the producability of the product, as well as increased awareness in
manufacturing for the product designers, to better see the manufacturing opportunities in the design. In similar ways, other company core processes like purchasing, sales, marketing, service and product recycling can be supported through the manufacturing system to gain better synergies between the traditional functions. Another example where manufacturing brings value is through visits and demonstrations of the manufacturing systems. The manufacturing company could then also contribute with value externally, which long term will also be beneficial for the company by an increased recruitment base. However, apart from gangways to walk in, there is a lack of design requirements to bring as much value as possible to these visits. Moreover, younger children are often completely prohibited in a manufacturing environment as most of the existing safety features are not specified for this age group. If these future generations could have a safe and easy access to the technological filled environment that the industry is, perhaps the interest in engineering programmes at universities would increase. If the factory were more accessible to teachers, students and other in the general population, the industrial awareness and understanding could also be increased. Availability will also make it easier to bring customer to the impressive factories, where advanced technology and enthusiastic employees every day produce customer value, which hopefully would strengthen the argument for the customer to choose these products. Most large manufacturers do offer the possibility to visit some factories, but no example have yet been seen where this is considered in a systematic way within the manufacturing system investment process. It instead seems to have been a project at a later stage where this has been recognised as a beneficial improvement to the existing factory.

6.1 Further research

The manufacturing system value to the company is often recognised, but not clearly defined. Large companies have some sort of a make vs. buy process of deciding which products to make and which to buy. Customers are brought to the factories and other types of visit centres are established for the general population. The decisions of these processes are not only based on financial results, far from it. It is for example already recognised that making products in-house gives synergy effect on things like product development and competence management. Bringing customers to the factories increases sales and improves relationships. Bringing general population to visit centres improves brand value and reputation, already recognised by Kellogg in early 20th century [76]. These aspects can be rather difficult to evaluate in financial terms as they sometimes even are crucial for the company survival. Therefore, these decisions are made on a strategic level through reasoning and management consideration. So, as this is recognised on a strategic level, these intangible aspects should then also be
systematically considered during the detailed manufacturing system design to ensure a successful fulfilment of intent.

The next step and future work is proposed to be an investigation of what type of values manufacturing brings to a company. The focus point will be the already identified key and core processes at industrial companies in Sweden, and how these can be supported by targeted design features in the manufacturing system. The first study will be to identify key value chains, to thereafter investigate how the manufacturing system can be designed to amplify the value delivery.

As already recognised in this work, the market demand and volume volatility has a large influence on the manufacturing and company profitability. To address this further, it would be interesting to start the manufacturing value investigation with the core process sales. There is already some involvement as there are volume predictions fed into the investment project, but not as much on how these will change over time. It would also be interesting to investigate more in detail on how the manufacturing system can help boosting sales.
7 References


REFERENCES


REFERENCES


Money talks while volume and value should run the show

An evaluation of financial parameters for decision making during manufacturing system acquisition

Market economic values have for the last decades been given an increasing role with a capitalistic focus as a consequence. As a counter reaction, the concept of sustainable development has emerged, complementing the economic focus with environmental and social aspects. However, there are still challenges on how to make balanced investment decisions based on all three viewpoints, which consequently makes the decision makers still primarily reside to the established tangible financial data.

The purpose of this research is to in-depth investigate the manufacturing world of economy, but from a technical engineers’ point of view. A financial analysis is done to understand the investment economical components and how these are related to the profitability of manufacturing systems. Furthermore, to connect cost with contributed value of the manufacturing system, a holistic business value chain analysis is done to ensure that less tangible aspects can be understood and utilised.

The result of this research highlights that sales volume is overlooked during the investment evaluation. Even though it’s difficult to influence, the effect of changes in sales volume should be looked at. This makes it possible to design a manufacturing system that is better at meeting the volatility in the market demand. A portfolio of new graphical representation is presented that can be used as a decisions support tool. Furthermore, to be able to invest in manufacturing systems that contribute to a more competitive company, the wider business value with manufacturing is discussed.