UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master Degree Project in Innovation and Industrial Management

Cost Management in the New Product Introduction Process of *TruPrint 1000*

A case-study of TRUMPF Maskin AB and its costs of Introducing New Additive Manufacturing Systems to the Swedish Market

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Abstract

The current trend within the manufacturing industry is increased digitalization, automation, and customization, known as *Industry 4.0 or the Fourth Industrial Revolution*. *Additive Manufacturing (AM),* also known as *3D printing (3DP)* can be considered as one spark of Industry 4.0. AM technologies can be applied to a wide range of industries, from manufacturing of steel and metal products to paper and plastic products (Gao et.al, 2015, Thompson et.al, 2016). Their flexibility and speed enables mass customization of products that can have virtually any geometric shape. Products with new complex shapes can be manufacture in one machine and in one-step process which enables fast processing. Furthermore, AM technologies surpass conventional techniques both in terms of low costs and high functionality when used to produce customized and complex products (Theisse et.al, 2015). For example, AM have realized significant cost savings in the aerospace industry by enabling new lightweight components and enhanced features. Thus, 3DPs are highly accommodated for a pull-based, mass customized, decentralized and interactive manufacturing which Industry 4.0. partly aims for (Lasi et.al., 2014). However, demands on these new technologies impose new costs to AM providers, especially in the New Product Development (NPD) process and New Product Introduction (NPI) process. To improve the planning of the NPI process, and as a consequence, help the decision-making process of resource allocation and investments, costs need to be estimated and allocated. Hence, metrics needs to be developed that can support the strategic management and process improvement in the NPI process.

TRUMPF Group is one of the leading developers and suppliers of advanced technologies for industrial application and manufacturing. It offers a wide range of technologies and services to manufacturers, allowing them to take advantage of current trends in the manufacturing industry. Among its latest innovations are the 3D printers: *TruPrint Series* used for industrial application. This product group was announced in 2015 as part of TRUMPF product portfolio and among the products was *TruPrint 1000* which can realize many benefits for the metal industry (TRUMPF.com, 2015). However, the development and introduction of new technologies and products affect a company's cost structure spanning from R&D facilities to Strategic Business Units (SBUs). TRUMPF Maskin AB is one of its SBUs responsible for the NPI process to the Scandinavian market. Examples of activities included in this process are marketing, machine-sales, technical support, logistics and after sales services. New products require both internal and external customer training. Internal customers demand product information and resources to enable and optimize the NPI process. The external customer needs education of how to exploit the opportunities of the new products. Thus, new metrics and cost models are necessary that measure the cost of activities in the NPI process, supports strategic planning and enables improvement of these activities.

"If you don't measure it, you can't manage it"

This thesis examines the cost of activities in the introduction of the metal 3D-printer *TruPrint 1000* from TRUMPF Group to the Scandinavian market and analyzes:

- The activities in the new product introduction process in TRUMPF Maskin AB, with emphasis on the metal 3D printer *TruPrint 1000*. The activities are identified and included in a process map.
- NPI metrics *and time-driven activity based costing (TDABC)* are used for developing a novel cost model for the NPI process. This cost model aims to be used as framework in which all costs can be recorded and allocated or apportioned to the activities involved in the NPI process of *TruPrint 1000* and similar technologies, supporting strategic management and process improvement.
- How the costs affect the business performance of TRUMPF Maskin AB.
- Contribution margin for *TruPrint 1000*.

The new product introduction process is used as a synonym to the New product introduction process. These processes look different depending on firm characteristics and context. The new product introduction process is for this study categorized into four activity centers in which related activities in the NPI process takes place:

1. The laser-machine sales department (new product documentation, NPI process development, new product training, new product project management, negotiations, contracting and sales),
2. The marketing department (new product promotion, advertisement, new product event planning and coordination, customer contact, customer relationship management etc.),
3. The after sales services department (new product service and material preparation, technical support training, maintenance training, installation training, customer education services, spare-parts administration, product enhancements, service level management etc.),

4. And the Tech-Days/new product show event.

Preface

This paper presents the final thesis of a master degree research project from the MSc in Innovation and Industrial Management programme at the School of Business, Economics and Law: Gothenburg University. It is collaboration between the Institute of Innovation and Entrepreneurship at Gothenburg University and TRUMPF Maskin AB in Alingsås.

I especially want to give thanks to my supervisor at TRUMPF Maskin AB, Mr Hubert Wilbs, for his tireless support, vast knowledge and insightful ideas. In addition, many thanks to Ms Karin Gustafsson, Mr Mikael Olsson, Ms Benitha Benjaminsson, Ms Anna-Karin Baldreus, Mr Henning Kristensen and many more at TRUMPF Maskin AB for sharing their knowledge and enabling this project.

Furthermore, many thanks my supervisor Dr. Daniel Ljungberg at Gothenburg University for his support and expertise knowledge in innovation management and innovation performance.

It has been a very insightful journey, getting to know all the perks and pitfalls in new product introduction and cost management. Though the more information I obtained on the subject, the more I knew I did not know.

Gothenburg, June 2017

Odia Okhiria

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1. Introduction

This chapter is an introduction to the TRUMPF Group Industry and the challenges TRUMPF Maskin AB are facing regarding the costs of introducing new products and innovations from TRUMPF Group to the Scandinavian market. This chapter also introduces the purpose, objectives and delimitations of the project. Lastly, an overview of the research area is presented.

1.1. Background

Schilling (2013) defines technological innovations as the act of introducing a new device, method, or material for commercial or practical objectives. New technologies have since the first industrial revolution raised the competitive bar for organizations and enabled possibilities that have had a clear positive net effect on the society. *Additive Manufacturing (AM)* (also known as 3D-printing (3DP*),* free form fabrication, direct digital manufacturing etc.) is an emerging technology with a potential to revolutionize the metal manufacturing field, the global parts manufacturing and logistics landscape. It has the capability of flexible, fast and mass customized production of complex geometric shapes. This enables local manufacturing and the production of parts-on-demand which reduces the need for assembly and transportation. At the same time AM offers the potential to reduce cost, especially for customized production where parts previously had to be processed in different machines (Frazier, 2014). Furthermore, AM technologies will reduce the energy and material consumption compared to conventional subtractive manufacturing techniques and thus reduces the carbon footprints of supply chains (Gao et.al, 2015). TRUMPF Group is a family owned company that has taken advantage of these opportunities to produce their own series of 3D-printers: *TruPrint Series (TRUMPF-lasers.com, 2017).*

The development of 3DPs has been rapid during the past decades. Lately, AM technologies have experienced a two-digit annual growth rate (Thompson et.al, 2016). The development and upgrading of products and services are necessary to compete in a science-driven industry. Thus, R&D and manufacturing are key resources and core competence for maintaining a high rate of development of new AM technologies and likewise, Strategic Business Units (SBUs) are keys to make them commercially available. The increased market introduction of new AM technologies increases the costs for SBUs serving the different markets of Multinational Corporations (MNCs). Introducing AM technologies require investments and activities in services, staff training, customer education, marketing, administration, sales, logistics, after-sales services etc. These processes are known as New Product Introduction (NPI) or New product launch (NPL). They are together with the post-introduction activities apart of the last phases in the new product development (NPD) process. The cost imposed on companies during and after the NPI process is considered to be one of the most significant cost aspects of a firm’s NPD process (Liao et.al, 2016). The SBUs of TRUMPF Group are responsible for the NPI to domestic foreign markets. These markets need to absorb the MNC’s high NPD rate to enable its new technologies for foreign markets. Keeping up with this high NPD rate requires a high frequency of NPIs, demanding a lot of resources. If the demand is relatively low then the marginal costs per unit increases and the marginal revenue decreases. These costs derive from the investment in the NPI activities and post-introduction activities; investments such as new product knowledge, components, and technical skills. In addition, each SBU needs to estimate the cost and benefit from updating these capabilities. It is therefore necessary to measure the cost of the NPI activities so that they can be compared with the sales price per unit of product and sales volume. As a consequence, the company’s Swedish SBU, TRUMPF Maskin AB, has identified a need to develop metrics that support the decision-making process and estimation of resources consumed by different activities in the NPI process. These cost metrics should provide information that guides actions towards the desired direction of the firm without necessary knowing the exact details of the activities being measured (Melnyk et.al 2004).

The 3D printer *TruPrint 1000* is among TRUMPF Group’s latest products which demand that TRUMPF Maskin AB adapt their capabilities and resources for the introduction and sale of the technology. Thus, cost models are needed that map the activities in the NPI and supports planning and cost management in the introduction of the new technologies. The cost model can be described as a framework or a set of cost metrics which aims to include all costs that can be recorded and allocated or apportioned to specific activities of new product introductions. Given that sales revenue, profit and service level (outputs) are estimated over time, cost models enable firms to measure and plan inputs (cost of capital) to business processes (Cooper and Edgett, 2008). Thus, cost models enable firms to estimate their productivity more accurate, support decision making and improve NPI process performance. The cost model should ideally provide useful information to all organizational levels- from strategic-to operative decision-making (Rummler and Brache (2013, p. 297-306).

According to the Chartered Institute of Management Accountants (CIMA) (2017), Activity-Based Costing (ABC) and Activity Based Management (ABM) can be used for this purpose. Many researchers and companies claim that the ABC method have helped to produce significant business benefits in firms who have implemented these practices, (Cagwin and Bouwman, 2002; Kaplan and Anderson, 2004; Kaplan and Cooper, 1998; Jänkälä and Silvola, 2012). The model is used to identify the activities of an organization and the cost of each activity link to the resource consumption by each product and service. The ABC model is claimed to have improved the profitability for several firms who have adopted it. CIMA (2017) argues that ABC and ABM have allowed for much greater transparency and understandings of an organization's operations, allowing management to take smarter decisions and drive real change and business benefits through the bottom line. Furthermore, Kaplan and Cooper (1998) argues that it can be applied both manufacturing and service firms.

Despite the benefits of ABC, there are several problems regarding the cost and complexity of using the model. In large scale implementation and use, firms with relative dynamic processes and resources spending have experienced that ABC is too complex and resource demanding. Kaplan and Anderson (2004) suggest the Time-driven Activity Based Costing (TDABC) system to deal with this problem. TDABC is claimed to have improved business performance for many companies that previously used a more traditional costing system or the ABC system. Thus, in an attempt to enable these benefits, a TDABC model has been developed for the NPI process in TRUMPF Maskin AB. The aim of the model is to support both operative and strategic decision making in the NPI process.

1.2. Problem discussion

One problem with measurement systems, e.g. cost models, are their cost of development and usage. As the number of details and metrics involved increases, their complexity increases, which increases the cost for development and usage (Kaplan and Cooper, 1998), (Drury, 2012, p.48). Kaplan and Anderson (2004) argues that this problem can be solved with the TDABC model that enables easy measurement of complex operations. In addition, Cagwin and Bouwman (2002) found that ABC was successfully in complex and diverse firms with a limited number of intra-firm transactions.

Another difficulty with measurement systems is to design them so that they guide and provide clarity of purpose, real-time feedback and predictive data, and insights into opportunities for improvement (Melnyk et.al, 2004, p. 210). To solve this problem people needs to identify metrics that not only effect the current performance of a firm but also its long-term goals. Additional difficulties involve the implementation of measurement systems and ensuring their continuity (Franceschini et.al, 2007, p. 7). Ensuring continuity can be especially difficult when demands on operating systems are highly dynamic, due to product mix, varied customer demands etc. (Melnyk et.al, 2004). However, the successful TDABC model would solve this problem by allowing effective and cost-efficient usage to ensure continuity (Kaplan and Anderson 2004; Turney, 2005). Furthermore, Rummler and Brache (2013, p.268) acknowledge the risk of measurement systems not being accepted or resisted by performers within the NPI process. However, this risk can be minimized by engaging and motivating managers and employees in the development of the measurement system (Hauser and Katz, 1998). In addition, findings from Tung et.al (2010) suggest that the perspectives of Balanced Scorecard (BSC) when developing measurement systems can enhance their effectiveness.

Talke et.al (2010) argues that there exists little research related to the conceptualization and measurement of introduction activities. Bstieler (2012) argues that the high risks and costs entailing the new product introduction process are considered the least well managed phase of the NPD process. Thus, in order to improve the cost management associated with the introduction of new products, cost metrics and cost models needs to be developed for the NPI-phase (and post-NPI phase). Still we see a continuous growth of AM technologies applied for industrial manufacturing and a trend of more and more manufacturing equipment suppliers innovating new products/services and adding more value in their value propositions. The increased development of new AM technologies, combined with the increased services that Industry 4.0 generates, makes it necessary for SBUs to continue to develop their capabilities. Thus, one may ask if it would not be to the benefit of the SBU to use cost models, such as TDABC, to measure costs of activities in the NPI processes and allow for process improvement and cost-efficiency. Furthermore, would it not be to the benefit of the MNC that uses innovation as a key competitive strategy like TRUMPF Group, to include this cost models in the assessment of its NPI activities to allow for improved strategic effectiveness (e.g. product mix decisions)? In addition, can an incumbent supplier of manufacturing equipment and technologies afford not to develop cost metrics and models for product introductions if it is to improve its innovation performance in a highly dynamic, science-driven, competitive and technology-oriented market?

1.3. Case description – TRUMPF Maskin AB

In 2000, TRUMPF Group made its first entrance with its 3D printer *TrumaForm* which was one of the first AM-technology used for industrial production of metal objects. In 2003, TRUMPF Group presented its *TrumaForm LF* and *TrumaForm DMD 505* machines at EuroMold. The LF machine uses the same technique that is built on today's upgraded 3D printer *TruPrint 1000*, known as Laser Metal Fusion (LMF). TRUMPF Group stopped to produce TrumaForm 3D printers due to an immature market. However, they continued to develop the DMD (Direct Metal Deposition) technique and apply it to other technologies in their product portfolio.

In 2016 TRUMPF reentered the market with *TruPrint 1000* and *TruPrint 3000* both using LMF for industrial application and TruLaser Cell 3000 using Laser Metal Deposition (LMD). The former LMF machine (*TruPrint 1000)* can be used to produce complex metal components of virtually any geometric shape. The latter (*TruPrint 3000)* can produce the same quality products but in larger complex metal parts (optics.org, 2014, TRUMPF-Laser.com, 2017, wholersassociates.com, 2008). Furthermore, TRUMPF Group announced their newest 3D-printer *TruPrint 5000* in November 15, 2016, with expected introduction in 2017. *TruPrint 5000* is also based on laser metal fusion (LMF). It offers high part quality and meets the stringent manufacturing requirements for large-scale industrial production (TRUMPF.com 2017).

TRUMPF Maskin AB has requested a cost model of the activities of introducing new technological innovations to the Swedish market with special emphasis on its new 3D-printer, *TruPrint 1000*. This machine significantly cuts costs in manufacturing of complex products and adds substantial value to manufacturers. Among the customers are for example aerospace, automobile, jewelry and dental companies (TRUMPF.com, 2016; Gao et.al, 2015,). Furthermore, in November 15, 2016, TRUMPF Group announced their new 3D Printers *TruPrint 3000* and *TruPrint 5000*, both which still are to be introduced to the Swedish market. However, the innovation promises of TRUMPF Group need to match the resources and capabilities invested in respective NPI process. This must be addressed to follow the strategy of the organization, improve NPI processes and effectively utilize the potential of new products/services. Fundamental is then, to develop a good cost model that illustrates costs of activities in the introduction of new technologies.

1.4. Purpose and research question

The focused objective of the study is to explore, describe and analyze the cost of introducing innovations from TRUMPF Maskin AB to the Scandinavian market with focus on evaluating the cost of introducing its new 3D-printer *TruPrint 1000* in Scandinavia. The results generated are not aimed to be generalized to all subsidiaries of TRUMPF Group due to the uniqueness of each subsidiary and region. However, they aim to act as support and guideline for future studies and evaluation of innovations in similar cases. A novel cost model has been developed based on the TDABC system. This system has improved the business performance for many firms (Kaplan and Anderson, 2004; Jänkälä and Silvola, 2012), especially when combined and integrated with a company's ERP system (Stout et.al, 2011). The cost model aims to provide a framework in which all costs can be recorded and allocated or apportioned to the introduction of *TruPrint 1000* and the most similar technologies. This cost model can later be extended to other NPI processes and business processes within TRUMPF Maskin AB and TRUMPF Group if it is argued to provide desired benefits. Finally, the cost model aims to contribute with and understanding of how the cost of introducing new technologies at TRUMPF Maskin AB can be traced and measured to support management and decision making.

1.4.1. Selected Research questions

1. *How can a cost model for TRUMPF Maskin AB be developed to trace costs in their new product introduction process?*
2. *How can the cost model be used to improve business performance?*

1.5. Objectives

A. What costs should be measured in the New Product Introduction (NPI) process of *TruPrint 1000 to the* Scandinavian market?
B. What activities are consuming the resources during the NPI process?
C. How should activity costs and tasks be measured?
D. To develop a cost model for the NPI process in TRUMPF Maskin AB.
E. Conduct contribution margin analysis.
F. How can the cost model be used to improve business performance?

1.6. Delimitations, Abbreviations & Research Overview

This thesis includes limitations in order to allow for more depth in the study. This research study is limited to evaluate the impact of the new AM technologies: *TruPrint Series* impact on the cost structure of TRUMPF Maskin AB with focus on costs derived from introducing new technologies from TRUMPF Group. A detailed empirical study regarding the cost of introducing the 3D printer *TruPrint Series 1000* by TRUMPF Maskin AB has been conducted, including a description of cost metrics and models. Figure 1 illustrates the research overview and the process of developing the cost model for TRUMPF Maskin AB.

This thesis includes several abbreviations. The list below includes explanations of the most frequently used abbreviations.

Word/Name	**Abbreviations**	**Definition**
New Product Introduction/New product launch	*NPI/NPL*	Communication commercialization and distribution of a new product (Andrew et.al, 2008; Liao et.al, 2015; Tang and Collar, 1992).
New Product Development	*NPD*	Invention and commercialization of a new product (Andrew et.al, 2008).
Activity Based Costing	*ABC*	Allocating costs to activities linked to cost objects (products, customers or services) (Drury, 2012).
Time Driven Activity Based Costing	*TDABC*	Allocating costs to activities based on time estimates linked to cost objects (a product, customer or service) (Kaplan and Anderson, 2004).
Contribution Margin/Cost Volume Profit	*CM/CVP*	The profit/loss generated from sales incomes minus variable costs (Drury, 2012).
Variable costs	No abbreviation is used	Includes incremental costs/direct costs and some indirect costs. Variable costs only include indirect costs linked to the cost object (a product, customer or service) (Drury, 2012).
Additive Manufacturing/3D printing	*AM/3DP*	A manufacturing method in which objects are built by adding a certain material layer by layer in contrast to subtractive methods like laser cutting (TRUMPF, 2017).
Laser Metal Fusion	*LMF*	An additive manufacturing method used by for example *TruPrint 1000* (TRUMPF, 2017).
Laser Metal Deposition	*LMD*	An additive manufacturing method used by for example *TruLaser Cell 3000* (TRUMPF, 2017).

List 1. Abbreviations and their meaning. Own developed model.

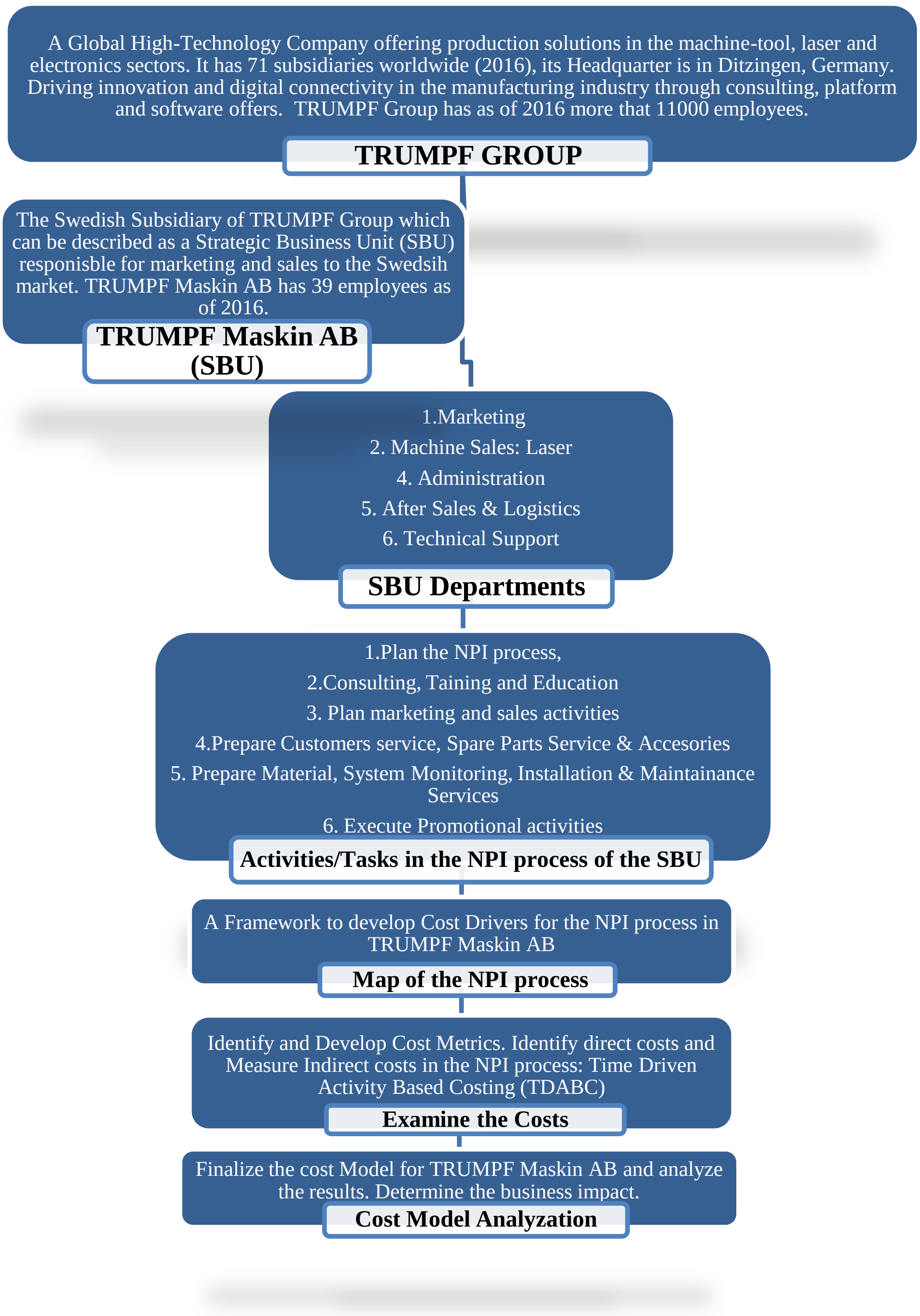


Figure 1. The Research Overview. Own developed model.

2. Literature review

This chapter aim to provide a more detailed understanding of the research project and case study based on literature. The literature review describes the context of the industry (high-tech manufacturing industry), and cost object (the additive manufacturing technology TruPrint 1000). Then the role of strategy (vision/purpose) and people (stakeholders in the NPI process) is described when developing measures, metrics, and cost model. The NPI process and the process approach/process models is then described. The role of measurement systems and metrics/indicators to manage the NPI process are described to understand their importance to management and their pitfalls. Then the development process of cost models/systems and cost level measurements are described through the activity based costing system. In addition, information for decision-making and profit statement, i.e. income effects of the cost system and cost-volume-profit analysis (contribution margin) are described. Finally, the chapter is summarized in a cost-model development framework.

2.1. Context: The cost object's/product characteristics - The AM Process and its Application

One of the forces that are responsible for the industrial transformation, i.e. the fourth industrial revolution is additive manufacturing (AM), also known as direct (digital) manufacturing, free form fabrication, or 3D-printing etc. (Frazier, 2014). It is currently the fastest emerging technology in the manufacturing industry (Frazier, 2014).

AM can be defined as the process of joining materials to create objects from 3D model data of a CAD file (illustrated in Figure 2.). The 3D printer applies a material e.g. metal powder. In the case of metal 3D printing, metal powder is applied through a feeder, then melted and/or fused by laser or electronic beams to form the desired 3D shape in the CAD file. The AM technology fused deposition modeling (FDM) has been used since the 1980s and was initially used for production of prototypes. Different AM technologies are now replacing some conventional production technologies for series manufacturing, i.e. rapid manufacturing. Rapid manufacturing includes the manufacturing of parts, components and end-products (Rayna and Striukova, 2016; Baldinger et.al, 2016). Today, two of the most promising metal 3D-printing processes are Laser Metal Fusion (LMF) and Laser Metal Deposition (LMD) also known as Laser Cladding and direct energy deposition (DED) (Gibson et.al, 2015).

Picture 1 and 2. Pictures of the 3D metal printers TruPrint 3000 (on top) and TruPrint 1000 (below). Source: TRUMPF.com (2017-04-06).

The AM process is usually done with materials being built layer by layer as opposed to subtractive manufacturing methods. Subtractive methods are the process of subtracting raw materials to form a desired shape as opposite to additive methods that add raw materials to form a desired shape. Both the subtractive processes (e.g. laser cutting) and additive processes (e.g. LMF and LMD) can be done with laser which are controlled by a computer program. The AM process are designed and executed through Computer Aided Designing (CAD-file). Sensors are built into the process to measure and determine heat, material properties and path planning as illustrated in figure 2. The materials used in AM include metals, ceramics, polymers, composites, and biological systems (Frazier, 2014). Baumer et.al (2016) argues that metallic powder bed fusion systems are generally viewed as one of the two most widely applied AM techniques by manufacturers of highly engineered end-use products. Metallic processes such as LMF and LMD are capable of generating material properties that match or even exceed their conventional counterparts. For example, both methods can be used to produce complex shapes that enhances product features and reduces the weight in the aerospace industry.

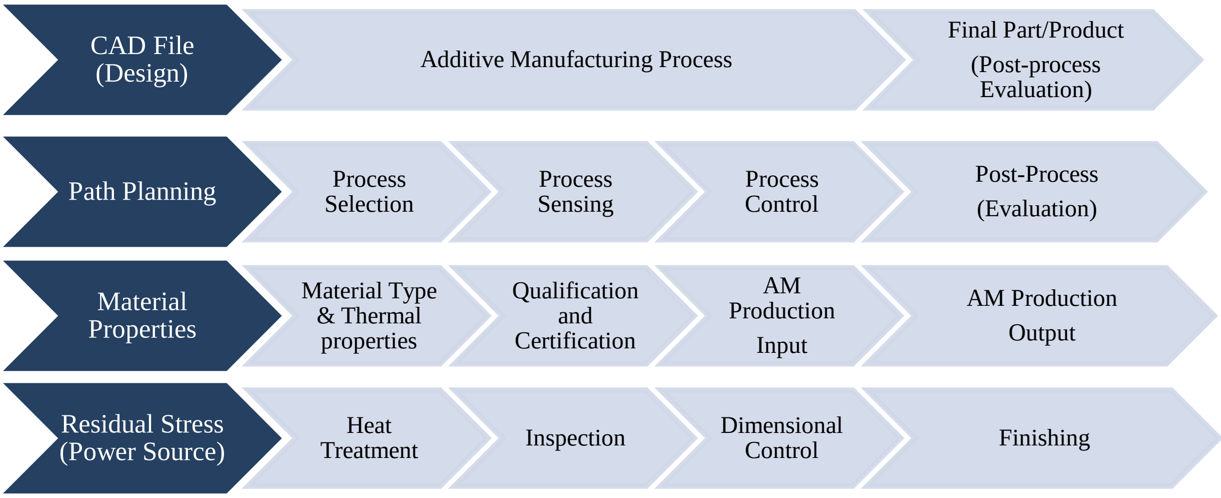


Figure 2. An overview of the AM process. Source: Simpson et.al (2017). Own developed model.

3D printers are used for the construction of many metal products such as cars, electronics and airplane components. It is applied in many industries ranging from the construction industry, the spare-part industry, electronics industry, and the bio-printing industry, as illustrated in figure 3. As illustrated, AM can be applied in many fields but most benefits are derived from using AM to fabricate functional parts, i.e. fully functional production components. The second most popular application is rapid prototyping for fit and assembly. Thus, the main application of AM is used to foster new product development (NPD). This is possible because of the various benefits that AM provides, such as improved product quality, reduced costs (less assembly and tooling etc.), shorter delivery cycles (reducing time to market) etc. (Kianian et.al., 2016).

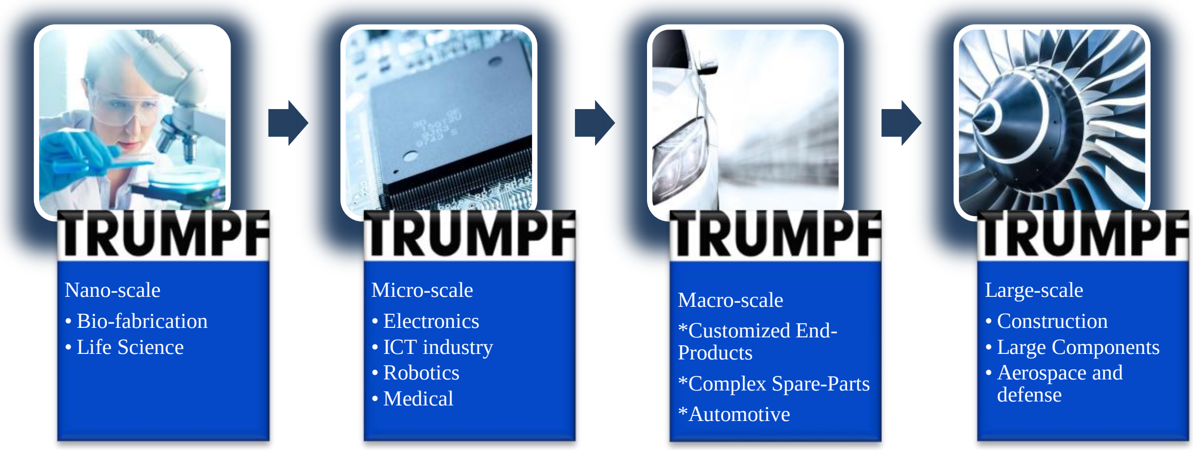


Figure 3. Industrial application of AM. Source: TRUMPF.com (2017-04-06); Murphy et.al (2015); Gao et.al (2015;) and Wohlers et.al (2014). Own developed model.

2.1.1. Context: The Market (opportunities) of AM - Past, Present & Future

The AM industry had an impressive growth rate over the past decades. In 2013, it was recorded to have the highest growth rate of all manufacturing technologies (Schröder et.al, 2015). Most researchers agree that we will see a continuous growth of AM technologies in future (Schröder et.al, 2015; Thiesse et.al, 2015). AM had a double-digit growth in 18 of 27 years (Thompson et.al, 2016). The market for AM, including all products and services worldwide, grew to $ 3.07 billion in 2013 and had a compound annual growth rate (CAGR) of 34,9%. In 2014, the estimated volume of AM end use parts was valued to $1,748 billion in 2014 with a 66% increase from 2013 (Thompson et.al, 2016) and fabricated AM parts have increased with approximately 39 % between the years of 2003 and 2014 (Kianian et.al., 2016). The market value is estimated to reach above $10 billion in 2020 (Thiesse et.al, 2015, Schröder et.al, 2015). Thompson et.al, (2016) speculate that the AM market will grow to more than $21 billion by 2020 and Thomas (2015) argues that the AM market will be worth $196,8 billion in 2035. The milestones, events and developments for the adoption of AM technologies are illustrated in Figure 4.

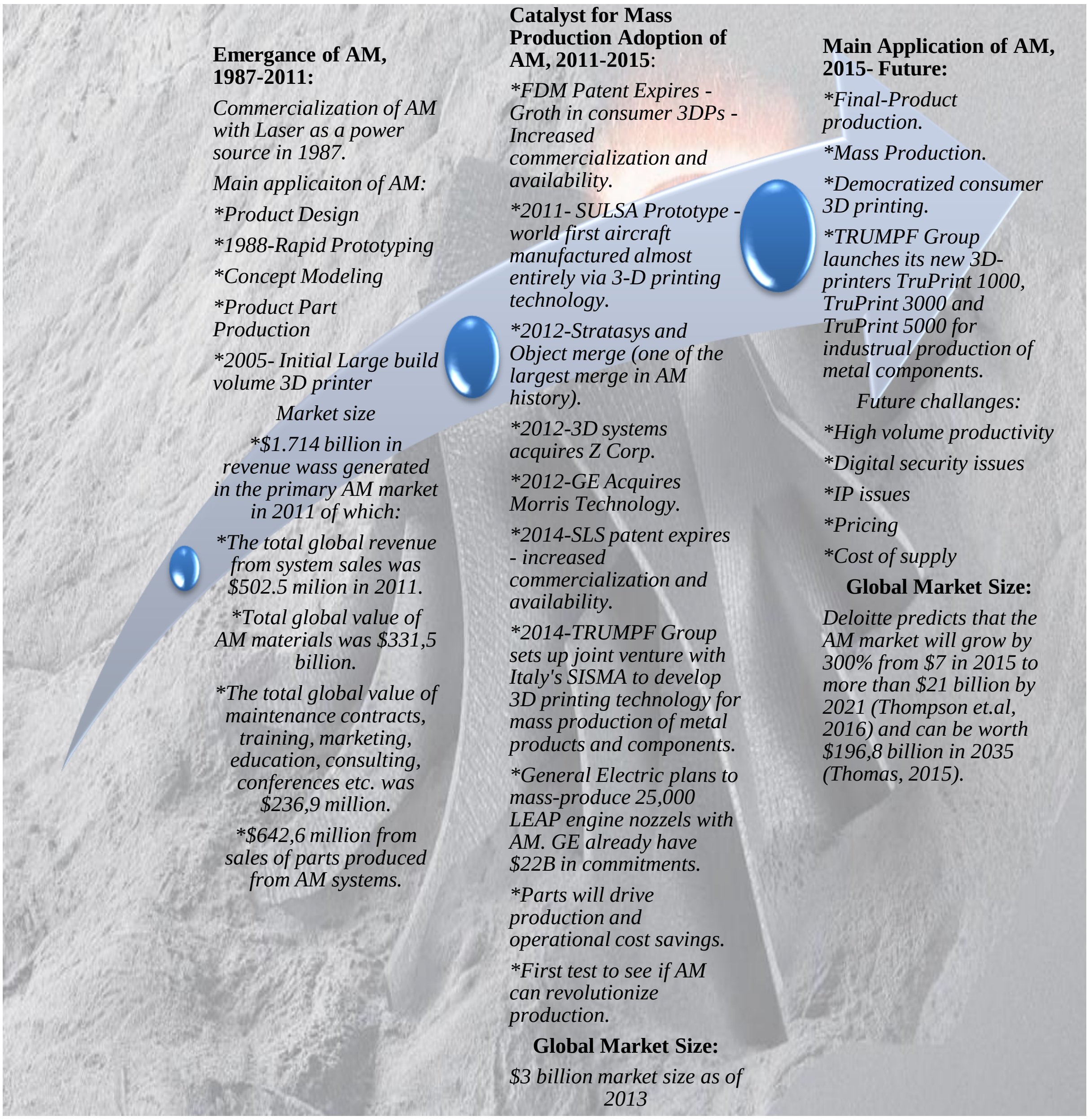


Figure 4. An overall adoption of additive manufacturing technologies. Sources: TRUMPF.com (2017-04-06); Forbes.com (2015); Optics.org (2014); and Wohlers & Gornet (2014); Thomas (2013). Own developed model.

Metal AM is usually addressed as an important and rapidly emerging manufacturing technology that has the potential to revolutionize the global parts manufacturing and logistics landscape (Frazier, 2014; Herzog et.al, 2016). According to Additively.com (2017). the number of patented publications around 3D printing increased by approximately 60 % during the period of 2012-2013 (see Figure 5). Processes like selective laser melting (SLM), selective laser sintering (SLS), and fused deposition modelling (FDM) are capable of producing direct parts in end-user quality out of metal or thermoplastics (Klahn et.al, 2015).

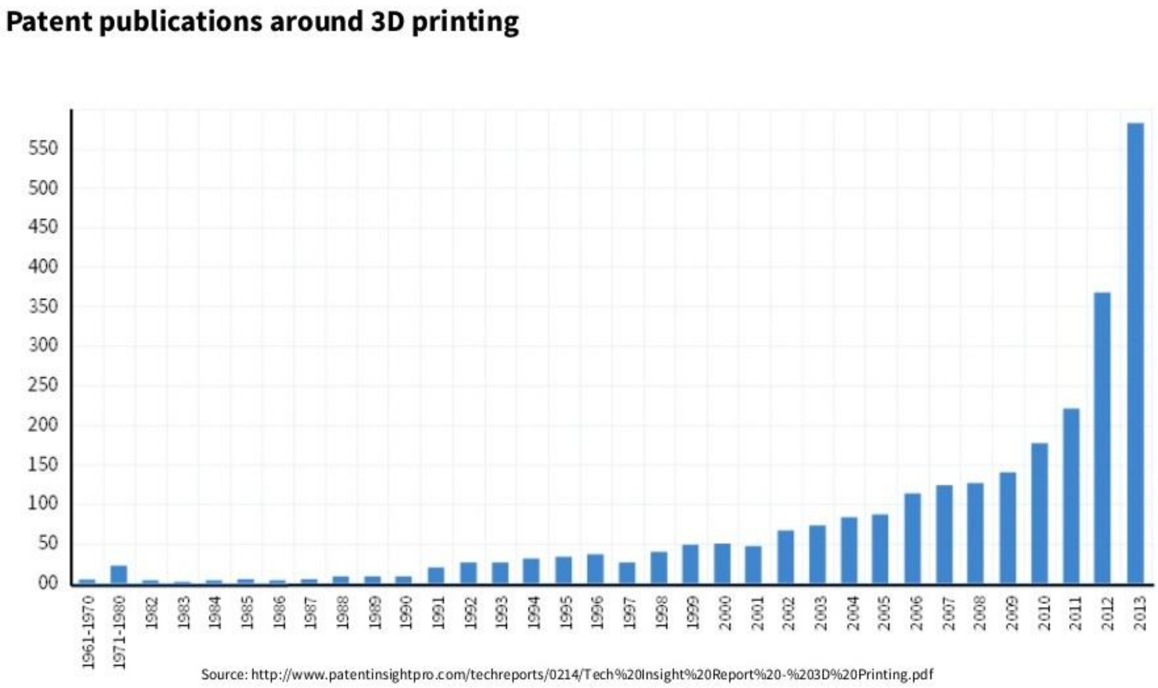


Figure 5. The development in patent publications around 3D printing in the period of 1961-2013. Source: Additively.com (2017-04-06) Patent iNSIGHT Pro (2014).

2.1.2. Context: The Benefits of Additive Manufacturing – New Machines Building the Future

There are many opportunities with AM. Baldinger et.al (2016), argues that the great potential of AM derives from two areas of applicability. First, AM can be applied for on-demand and on-location production of customized parts in the supply chain and enable it to be profitable. Second, it enables the production of new geometric shapes previously not possible, allowing complex lightweight structures or performance-optimized shapes to be produced. Similarly, Weller et.al (2015) argues that the advantageous of AM derive from its applicability to market environments characterized by demand for customization, flexibility, high design complexity, and high transportation costs for the delivery of end products. Furthermore, AM technology allows manufacturers to produce customized products without incurring any cost penalties in manufacturing as neither tools nor molds are required. In addition, it enables production of complex and integrated functional designs in one-step process and parallel processes, such as geometric metallic shapes that previously was not possible. Amongst the techniques available today, LMF, LMD, laser sintering and laser melting seem to be the most promising technologies for rapid manufacturing. The benefits of additive manufacturing have been summarized in figure 6.

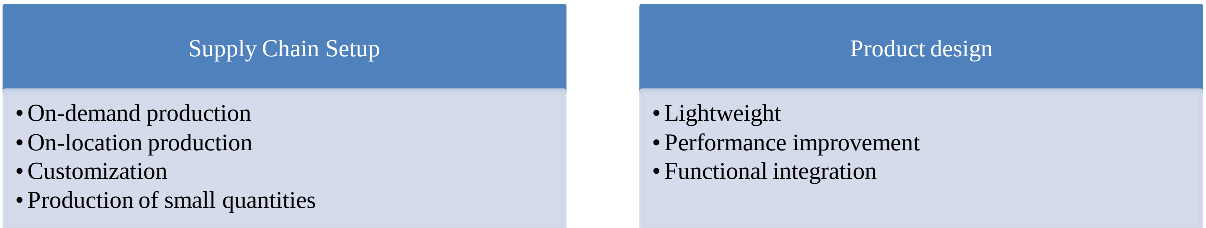


Figure 6. Production/logistics (right and product (left) benefits of Additive manufacturing. Source: Baldinger et.al (2016); Weller et.al (2015).

Examples of 3D-printed parts that have potential to realize substantial profit improvements per unit consumed in the aviation industry are General Electric’s Leap Engine and fuel nozzle. According to Kellner (2014) the new leap engine can save airlines up to $1.6 million per airplane per year in fuel costs through optimized design, counting to 66% of previous weights. In addition, TRUMPF Group's *TruPrint 1000* have 3D printed energy turbines and mounting brackets for airline construction. These products are capable to save weight. The energy turbine is capable of saving 30-50% in product weight and to improve mechanical qualities (TCTmagazine.com, 2016-06-28, 14:50). Other applications for *TruPrint 1000* are the dentistry industry and automotive which is estimated to both enhance the production time and quality of the product, illustrated in figure 7.

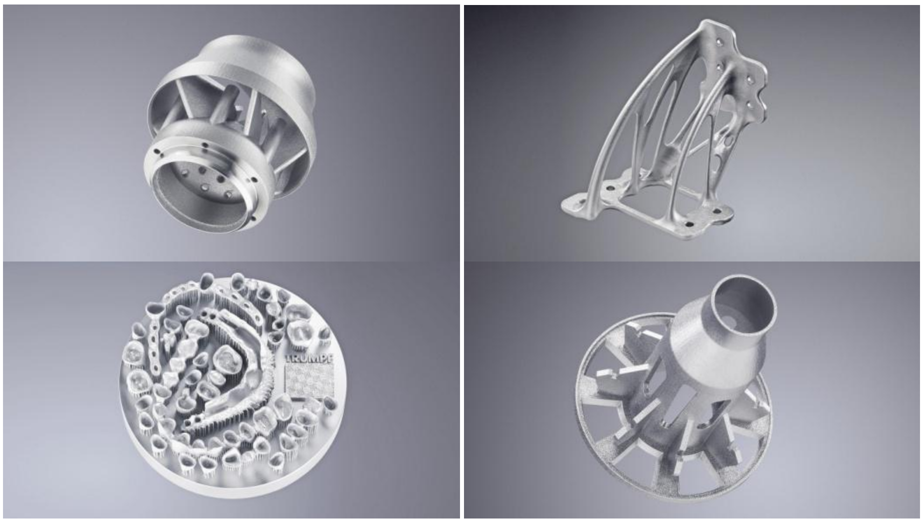


Figure 7. A glance at the 3D printed products by TruPrint 1000 including the Energy Turbine (upper left), Mounting Brackets (upper right), Dental Crowns and implants (lower left), and automotive impeller (lower right). Source: TRUMPF.com (2017).

Thompson et.al (2016) argues that the roles and relationship between the engineer designer and the manufacturer will continue to be redefined by AM. Their roles will be merged into one individual and one location and allow for new businesses to emerge such as home fabrication and small businesses (Rayna and Striukova, 2016). In addition, AM reduces the need for post-processing which makes manufacturing systems simpler. Furthermore, the automation of AM processes, especially post-processing and part transfers between machines, will also increase. This allows for the integration of sensors and information processing capabilities in AM production systems. According to Frazier (2014), the developments of closed-loop systems, also known as feedback control system, real-time, sensing, and control systems are essential to the qualification and advancement of AM. This is to ensure quality, consistency and reproducibility across AM machines. Furthermore, sensors are needed to measure the melt pool size, shape and build temperatures in the process of AM with metals. In addition, Frazier (2014) argues that AM enables distributed manufacturing and productions of parts-on-demand while offering the potential to reduce cost, energy consumption, and carbon footprint. Thompson et.al (2016) argues that cyber-physical manufacturing systems will eventually be used for most production scale in AM which allow for cloud-based AM. The researchers argue that the benefits of cloud-based approaches are process optimization, adaptive process planning, and shop floor planning, scheduling, and (real-time) maintenance improvement.

Rayna and Striukova (2016) argues that particularly one variant of AM has great adoption potential and the potential to profoundly disrupt business models. The AM method called *direct digital manufacturing*, or simply *direct manufacturing* has this potential. This means that 3D printers are used to manufacture fully customized end products for final use. This emerged during the late 2000s, when the quality of the product became good enough and when the cost of 3D-printing low enough. This made it more affordable for companies to produce customized and/or personal products (service offering). Direct manufacturing technologies affected the value delivery by being significantly cheaper and simpler to use for the production and modification of personalized products. This made lower volume of production economical and enabled more targeted market segments to be served by fully customized products which enabled new pricing models to appear. However, besides of having the impact on the product and service offerings such as lower cost of producing final parts and a greater variety of products offered, direct manufacturing enabled large-scale mass customization where customers are participating in a co-creation process in the firm's value network. This is likely to result in higher value of the resulting product than for mass-produced items which impact the value creation of business models. Direct manufacturing enables crowd-sourcing to take one step further by extending it to the manufacturing stage of production process. Further, using 3D printers to manufacture removes volume requirements related to production. The set-up costs for 3D printing manufacturing are very low which enables firms to serve any niche regardless of how small it is. It is only when a significantly high number of units needed to be produced that mass production becomes more economical than 3D printing. Thus, direct manufacturing also significantly changes value delivery. The shortened production time, the reduction of manufacturing costs and the possibility to customize products at the design stage enables companies to use online 3D printing services to sell their products directly to consumers. In this case, no transportation or physical storage is involved until the consumer purchase the product (Rayna and Striukova, 2016).

These benefits and many more provides a growing market for AM technologies. However, most researchers and experts agree that AM technologies currently are most likely to complement conventional manufacturing processes by their flexibility and applicability to mass customization (Gao et.al, 2015).

2.1.3. Context: Identify the AM Challenges and Manage the New Product Costs

There are many challenges associated with AM. Firstly, the international competition is growing. Wholers Associate says that the US leads with the largest installed base of additive manufacturers (Industrial-lasers.com, 2016-12-07). Furthermore, in order for AM to be successful, it is crucial to design parts specifically for AM (Baldinger et.al, 2016). Hence, the problem is to identify what value AM can generate both in terms of production/logistics and product benefits. Other major challenges with AM are the development of IPR strategies, the legal nature of CAD files and licensing schemes for CADs (Ballardini et.al. 2016). Thompson et.al (2016) argues that the engineering designers of AM products need to think differently in order to create robust industrial solutions and take advantages of its emergent benefits. Thus, new classes of design tools, rules, strategies, and production planning techniques will be needed beyond what is required today. Furthermore, design activities, design as a field of study and practice, and training need to integrate all the developments in tools, rules, theories, methods, processes, and planning adapted to AM processes. Thus, academia and research needs to transfer their analysis, design representations and optimization tools to industrial practice while updating their staffs' skills and knowledge through training to keep up with the pace in research and development.

Currently, AM is mainly suitable for low volume series and where value-added per unit is high (Hällgren et.al, 2016, Rayna and Striukova, 2016). Baumers et.al (2016) argues that AM has potential to become applicable to mass production as the technology continually is being developed to increase its manufacturing productivity, i.e. to lower the cost per unit for manufacturers and to enabling economies of scale. Hence, AM is today not capable to compete with conventional manufacturing methods in terms of economies of scale. But due to their increased phase of adoption and technological development, AM technologies might impose a threat to conventional mass production process in the future.

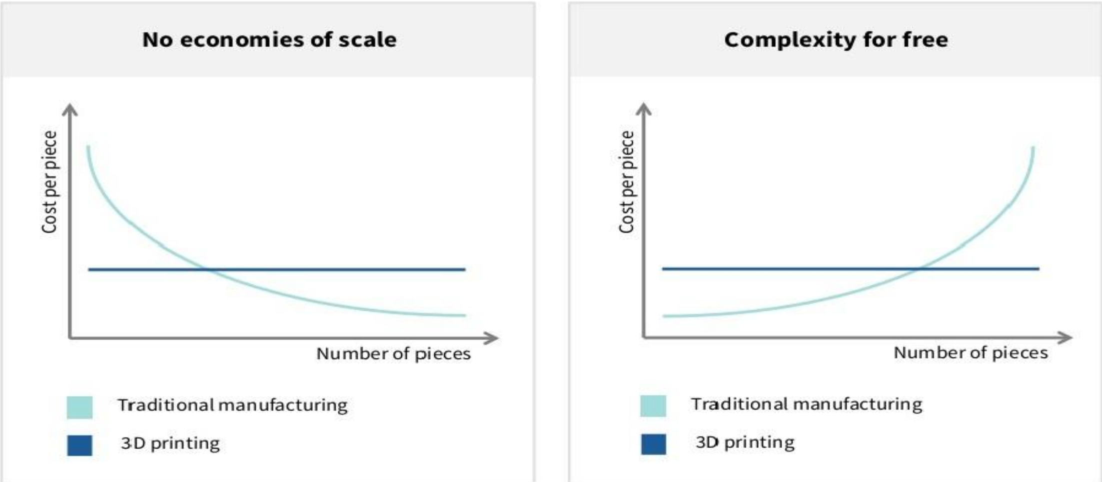


Figure 8. The two fundamental differences between traditional manufacturing and 3D printing/ Additive Manufacturing. Source: Additively.com (2017-04-06).

Regarding technical challenges, Frazier (2014) argues that high priority should be in the development of integrated in-process sensing, monitoring, and controls in the AM processes which demands the integration of ICT. Additionally, machine-to-machine variability, such as process capability and production resources, need to be understood and controlled.

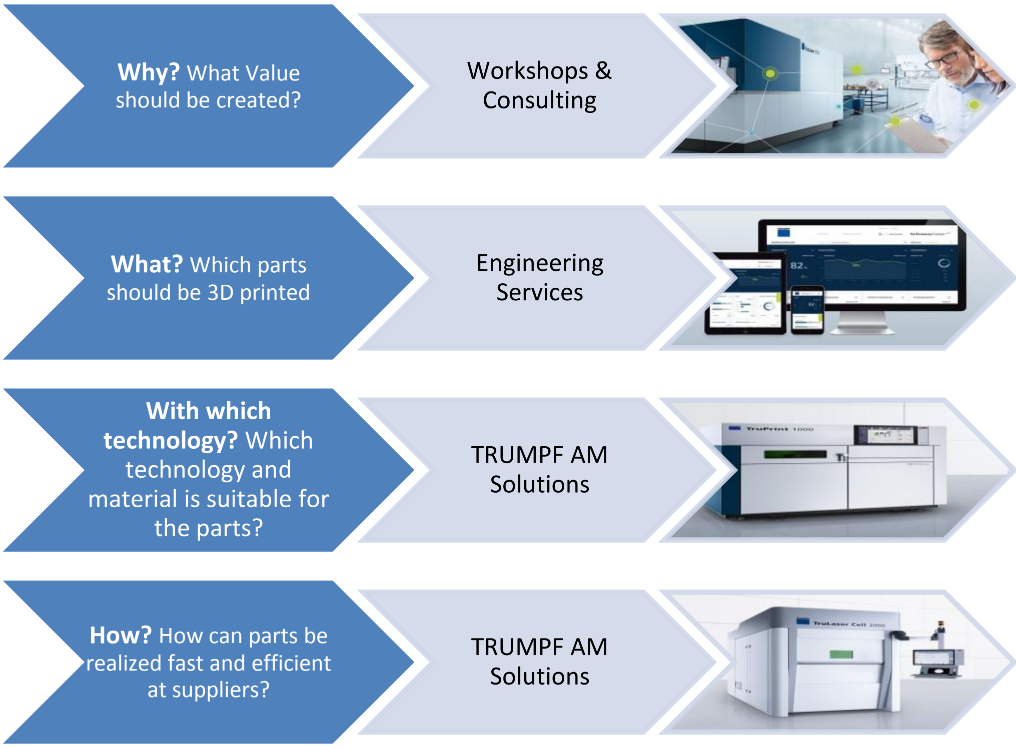


Figure 9. Four Challenges/questions regarding 3D printing. Inspired by: Additively.com (2017-04-06); TRUMPF.com (2017).

Simpson et.al (2017) highlights the importance of research for development, training for provision and education for usage regarding AM technologies. In addition, the researcher argues for the importance of building teams with different backgrounds in order to nurture creativity and provide for industrial AM solutions and development (Simpson et.al, 2017). Gao et.al (2015) argues that education and training in 3D printing will be crucial for the future customer to adapt and innovate in AM. Thus, there is a need for an industrial workforce that is knowledgeable about the technologies and how to apply them to solve real-world problems. This workforce is a part of the NPD and NPI processes (idea generation, R&D, business model generation, manufacturing, commercialization and product introduction/realization) which together makes AM more and more mature for industrial applications. Therefore, it is necessary to have companies like TRUMPF Group that develops technologies, services, and invest in the NPI process to realize and enhance the capabilities of AM technologies. However, this also implies that the technology needs to be investigated and evaluated in terms of cost, cost of introduction, training and education in order to prioritize- and allocate resources effectively and perform NPI activities efficiently. Furthermore, measurement allows for improvement. Thus, generating effective cost metrics for relevant processes is necessary in order to support the development, NPI, implementation and use of AM technologies. The National Science foundation (NSF) had identified several key educational themes for the maturing of AM technologies. Theses regarded: (1) AM processes and process/material relationships, (2) engineering with emphasis on materials science and manufacturing, (3) professional skills for problem solving and critical thinking, (4) design practices and tools that leverage the design freedom enabled by AM, and (5) cross-functional teaming and ideation techniques to nurture creativity (Simpson et.al, 2017).

Rayna and Striukova (2016) points out that fierce competition is most likely to be triggered in the direct manufacturing industry, just like any previous digitization episode. The research of Christensen and Bower (1996) showed that new and emerging firms are more likely to develop disruptive innovation due to established firms focus on mainstream markets. The AM equipment supply industry already show great potential of developing disruptive technologies of the industry, with new entrants such as Desktop Metal (desktopmetal.com, 2017) and Markforged (markforged.com, 2017) founded in 2015 and 2013 respectively. Desktop Metal recently received a $ 45 million funding round including investors such as GV (formerly Google Ventures), BMW I Ventures, and Lowe's Ventures. Some of its earlier investors include Stratasys and General Electric (GE) Ventures (3dprintingindustry.com, 2017-02). According to desktopmetal.com (2017-02-07), Desktop Metal have developed a complete end-to-end printing system that could enable mass production of parts. This 3D printer is yet to become announced. Furthermore, Markforged have already announced their new 3D-printer called Metal X which according to 3dprintingindustry.com (2017-01-06) might be a revolution in 3D printing. However, TRUMPF Group's new 3D printers TruPrint 3000 and TruPrint 5000 announced in November 15, 2016 offer many opportunities. Both can be combined in connected manufacturing systems. They offer many different solutions for more productive and cost-efficient production in the context of industry 4.0. Both can be used to manufacture complex metal parts through Laser Metal Fusion. TruPrint 5000 is also capable to meet the stringiest requirement for large-scale industrial production of complex metal parts (TRUMPF.com, 2017). The programming system used for TRUMPF's 3D-printers are Siemens NX software which is intended to streamline the process of 3D printing metal (3dprintingindustry.com, 2017-01-17).

Regarding AM, there are also issues related to profit allocation when intermediaries are involved e.g. intermediaries that provide online 3D platforms may come with significant costs. They may in some cases take as much as 30-50 % of the revenues. For SMEs, it might be hard to cope with the costs of creating and monitoring their online 3D-platform in which customers customize their product in the design-process of production. Furthermore, it might initially be hard to reach out to a larger mass of people with the online 3D-platform to balance the sales with the costs if the company is new and emerging (Rayna and Striukova, 2016). TRUMPF Group has developed their own business platform AXOOM.com which provides smart solutions for AM, logistics and businesses (TRUMPF.com, 2017).

2.2. Strategy: Translate the vision & Align Metrics with Strategy to Achieve Corporate-wide Goals

A strategy is according to Kahn et.al (2006), the defined plan and focus for the NPD/NPI efforts of a business unit, division, product line or individual project. The strategies of firms should determine what metrics to develop (Emerald Insight, 2009). This is to ensure that the metrics align with the firms' goals and can be used to pursue and achieve these goals (Kahn et.al, 2005). The notion that measures are essential for the realization of business objectives is nothing new. Doran (1981) highlighted the importance of making both long-term and short-term goals quantifiable and suggests that companies should have metrics that identify process progress in his development of the SMART criteria:

- **S**pecific: goals should target as specific area for improvement.
- **M**easurable: goals should be quantifiable and thus, metrics needs to be developed to enable progress evaluation.
- **A**ssignable: a description of the goals should specify who will carry them out.
- **R**ealistic: goals should represent the results that realistically can be achieved, given available resources.
- **T**ime-bound: a description of when the goals should be achieved.

These criteria can be considered as a general framework for setting meaningful goals in order to make them useful. Furthermore, Doran (1981) underlines the importance of goals to enable organizations to focus on problems, to give the company a sense of direction and to provide quantitative support and expression of managers' beliefs. "*The establishment of objectives and the development of their respective action plans are the most critical steps in a company's management process"* (Doran, 1981, p.35).

Melnyk et.al (2004) argues that the metrics and performance measurement are critical elements in translating an organization's mission, or strategy into reality. Strategies and metrics are inevitably linked to each other and is only useful to businesses when combined: "*Strategy without metrics is useless; metrics without a strategy are meaningless"* (Melnyk et.al, 2004, p. 209). Since the strategy can be described as a method or plan designed to bring about a desired future and to achieve a goal or solution to a problem (Businessdicitonary.com, 2017), it is important that the metrics accurately reflect the strategic objectives to enable firms to evaluate and reach the goals of the firm (Malnyk, et.al, 2004). Furthermore, if the strategy changes, the metrics should be changed to reflect the new strategy accordingly, if not, they will become useless. Thus, not all metrics are useful and the metrics consistency with the strategy should be assessed over time (Malnyk et.al, 2004, p. 215). As Albert Einstein explicitly stated:

"Not everything that can be counted counts and not everything that counts can be counted."
– Albert Einstein, Source: Hillman (2014)

2.2.1. Strategy: How to Align Metrics with Strategy

Kaplan and Norton (1996) have developed a framework that allows managers to align both financial and non-financial measures to their strategy. They call it *Balanced Scorecard (BSC)* which is based on two models: "*Managing strategy: Four processes*" and "*Translating vision and strategy: four perspectives*".

Translating vision and strategy consist of four perspectives that support managers in the implementation of the vision and strategy. All four perspectives include objectives, measures and initiatives that communicate different information appropriate for different purposes and different actors: (1) the financial perspective includes financial performance information to shareholders, (2) the customer/stakeholder perspective includes information to both external and internal customers (3) the learning and growth perspective is the information to key-stakeholders that enables the achievement of the company's vision, and (4) the internal business process perspective includes information on the type of business process that the firm must excel at in order to satisfy shareholders, as well as internal- and external customers (Kaplan and Norton, 1996).

Managing strategy includes four processes, namely: (1) *translating the vision, (2) communicating and linking, (3) business planning, (4) feedback and learning* (Kaplan and Norton, 1996).

1. *Translating the vision* is the articulation of the shared company vision, supplying strategic feedback, facilitating review of strategies and promotes learning. This process helps key-stakeholders to build a consensus around the organization's vision and strategy. The vision and strategy should be translated into a set of related objectives and measures, agreed upon by all executives, to provide useful guides for operational action. These objectives and measures should be integrated with each other and drive long- and short term success by directing peoples' actions according to the organizations commitment.
2. *Communicating and linking* is the vertical communication of the company's strategy which begins with educating those who will execute it. Similar as before, each corporate goal (i.e. strategy and vision) should be translated into objectives and measures that is adopted to each operating unit and individual of the company. This is to ensure that all levels of the organization understand the long-term strategy and that both departmental and individual objectives are aligned with it. Through this communication, each department and individual should understand their responsibilities and accountabilities in order to promote commitment towards the long-term strategy. Furthermore, the specific measures for each department and /or individual should be valid and reliable in order to reflect their performance accurately over time. In addition, the reward systems should be thought-through to balance the reward with the outcome; this can include financial and/or non-financial rewards. However, accurate feedback regarding work efforts and results is essential to the learning process, acknowledgement and motivation of individuals and business processes.
3. *Business planning* is the integration of vision and strategy into business processes and financial plans to ensure accurate allocation of resources, correct prioritization of activities, and aligned coordination of initiatives and actions toward long-term strategic objectives. This process involves the selection of measures of progress from all four score card perspectives (Figure 7) and setting targets to them. Based in this, the scorecard users should:
   a. determine the activities and actions that will drive them toward their targets (i.e. select the activities that generate business value such as activities in NPI processes),
   b. identify the measures that will apply to those activities from the four perspectives,
   c. and establish the short-term milestones (main processes and activities performed by a specific entity in specified time-periods within a target's timeframe) that will mark their progress along the strategic paths they have selected.
4. *Feedback and learning* is the process of managing the results generated by the developed metrics that is used to reflect the performance and results of business activities. Thus, this is the phase were focus is on whether the company, its departments or its individual employees have met their short-term targets from all four perspectives (financial targets, customer targets, internal business process targets, and learning and growth targets). This feedback system should be able to test, validate, and modify the cause and effect relationship between business activities and outcomes in order to steer them towards the business strategy and vision. Thus, the scorecard facilitates strategic learning since it establishes a strategic review, the causal relationship between performance drivers (activities, products and services) and objectives, and periodic review sessions to evaluate the validity a unit's strategy and the quality of its execution.

2.3. People: The Enablers of Strategy, Process & Measurement

The internal customers/stakeholders (e.g. owners, managers & employees) are the enablers of the activities of organizations on all levels, form vision and strategy to operational activities. Chuang et.al (20014), have concluded from their study that internal customer satisfaction and team orientation are key factors influencing service quality, employees' productivity and thus, the sustainable competitiveness of a company. They recommend companies to deploy extensive training to improve employees' skills, promote cross-functional teamwork activities to infuse flexibility to employees' jobs. This can greatly improve employee's engagement and commitment towards the company and thus enhance its ability to reach its goals and missions.

Furthermore, the internal customers are the ones that create, execute and monitor visions, strategies, tactics, performance measurement systems, as well as informational and physical flows of organizations. In addition, internal customers determine the rate of organizational learning, the service quality (Chuang et.al, 2014) and are the essence of innovative capabilities (Saunila, 2017). According to Saunila (2017), innovative capabilities can be viewed as being based upon multiple and simultaneous influences of individual and collective aspects, including:

- Leadership practices,
- Employees' skills and innovation,
- Processes and tools for managing ideas (generated and managed by the HR),
- Supportive culture,
- External sources for information,
- Development of individual knowledge,
- Employees' welfare,
- And links to strategic goals.

The effectiveness of performance measurement systems (PMS) is highly influenced by internal customers. Tung et.al (2010), argue that managers and their support towards measurement systems are highly influential in the effectiveness of the PMS in respect to the performance related outcomes. Furthermore, greater commitment towards staff training enables superior achievement of staff-related outcomes. In addition, they suggest that managers should put great emphasis on staff-related outcomes by designing the PMS so that employee contributions and employee needs are incorporated into it. Their findings also suggest that the perspectives of Balanced Scorecard (BSC) when developing measurement systems can enhance their effectiveness. Incorporating learning and growth perspectives into the performance measures for internal business processes had a positive causal relationship with the effectiveness of PMSs performance-related outcomes. In addition, incorporating both "learning and growth" and "customer/stakeholder" (sustainability perspective) had a positive causal relationship with effectiveness of the PMSs and staff-related outcomes.

2.4. The Process Approach: What to Measure, Manage and Improve

A process can be defined as "*an integrated system of activities that uses resources to transform inputs into outputs"* (Franceschini et.al, 2007, p. 4). Similarly, Rummler and Brache (2013, p. 54) define processes as the vehicle through which work gets produced. Franceschini et.al. (2007) argues that the process approach is a strong tool to manage activities and related resources which enables organizations to be more efficient. The International Organization for Standardization (ISO 9001:2015), argue that the process approach includes:

*Management systems that integrates processes and measures to meet targets.

*Defining interrelated activities and checks of processes that delivers intended outputs.

*Detailed planning and defined controls that are documented as needed, depending on the context of the organization.

Process management requires identifying specific activities, responsibilities, and metrics for testing effectiveness and efficiency (Franceschini et.al, 2007). Franceschini et.al (2007, pp. 4-5) defines effectiveness and efficiency as follows: *"Effectiveness means setting the right goals and objectives, making sure they are properly accomplished (doing the right things). Effectiveness is measured comparing the achieved results with target objectives. On the other hand, efficiency means getting the most (output) from your resources (input), whether they are people or products (doing things right). Efficiency defines a link between process performances and the resources employed."*

Rummler and Brache (2013, p. 54) argue that process goals need to be set so that both external and internal customer requirements are achieved. Goals for processes should be linked with external customer requirements and must be derived from the organization goals, e.g. sales, service and billing. While goals for the processes of internal customers, e.g. planning, budgeting and recruiting, should be driven by the requirements of internal customers.

Franceschini et.al (2007) argues that process models are essential to process management because they describe and illustrate the major activities, decision-making practices, interactions, constraints, and resources of organizations while its targets are included. Models, techniques/methodologies should be able to highlight process characteristics and peculiarities (organizational, technological, relational aspects etc.). This involves the use of different information sources and information systems that enables the mapping and display of activities/actors involved in the process. Thus, a process is made of several activities, and generally several processes interconnected: the output from one process becomes the input in another. A detailed level of analysis means that each process is broken down into sub-processes until the intended level of organizational components, relevant for the analysis, have been identified. The components are then mapped to improve the analysis and to increase the understanding of the process. In addition, process mapping enables analysts to conduct process performance simulations to identify "optimal" solutions to operational conditions in terms of costs, time and quality. Thus, process modeling enables functions, activities, resources, and physical/information flows to be identified and viewed together (Franceschini et.al, 2007, pp.4-5).

2.4.1. Process: The NPD structure

According to Andrew et.al (2008), New Product Development NPD processes can be described as all the activities encompassing the generation, commercialization and realization of new ideas. They assort these "innovation-to-cash" activities into 4 categories to enable measurement of the NPD process: (1) Start-up costs, (2) Speed, (3) Scale and (4) Support costs (including post-introduction investments). These categories can be used to represent a "cash curve" of innovation. This cash curve is a depiction of the cumulative cash investments and returns (can be depict in both expected and actual return) of an investment over time, from the beginning of the development to the point where the product or service is removed from the market. The metrics used for each category should be dictated by the company's particular strategy and operational agenda. The following set includes some examples of metrics that can be used for each category (Andrew et.al, 2008).

1. Start-up costs: the number of full-time staff involved (by key function), operating expenses (cash and allocated costs) and capital expenditures.
2. Speed: the actual time to market, decision-making time, time to key checkpoints and actual versus planned full-time-employee hours.
3. Scale: actual versus planned volume produced, actual versus planned product availability, actual versus planed first-year sales (by channel, segment and region) and actual versus planned distribution.
4. Support costs: cannibalization of existing products in the portfolio, marketing and promotional activities, pricing actions, and key staff devoted to the project, product maintenance and service costs.

The activities of a NPD process include ideation (idea generation), R&D, business model generation, manufacturing and post-introduction as illustrated in figure 10. The new product introduction is a hectic time for companies, involving costs for marketing and sales, after sales services (spare part service, customer service, and accessories service), technical services, customer/user adoption and post-introduction improvement. All expenses and revenues derived from the NPD process should be measured. To succeed, companies need to install a broad suit of measures and hold people accountable to the measured input and outputs of the NPD process (Andrew et.al, 2008). Figure 10 illustrated the interlinked chain of major activities (on top) in the NPD process in which the outputs from preceding activities becomes the inputs in the following activities. It also shows the three major steps in the NPD process: (1) Idea generation/testing & prototyping, (2) Commercialization/final product, (3) Realization/New product introduction/launch (Andrew et.al, 2008).

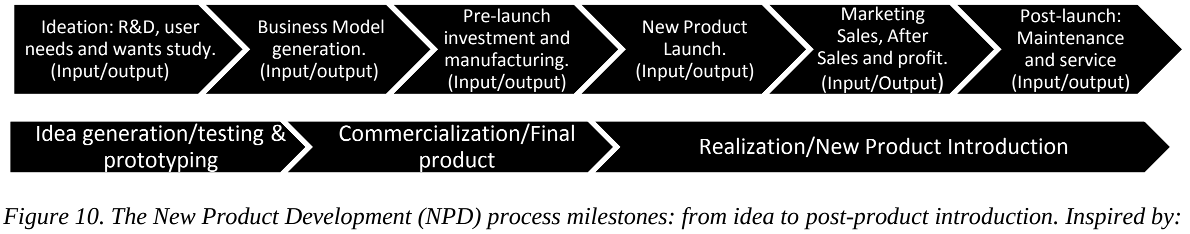


Figure 10. The New Product Development (NPD) process milestones: from idea to post-product introduction. Inspired by: Andrew et.al (2008, Exhibit 11, p. 14); Cooper and Kleinschmidt (1986, p74, Exhibit 1). Own developed model.

2.4.2. Process: The New Product Introduction Process

A New Product Introduction (NPI), also defined as a New product launch (NPL), have several similar and general definitions that are relatively simple to depict in theory. While the process in reality often has unique and more detailed characteristic, depending on the business organization and context it is developed and implemented in. Tennant and Roberts (2003) argues that the NPI process often are defined and implemented along common generic themes, whilst the detailed process description and practices vary across organizations. As a consequence, this often causes inconsistent application and process conformance. However, it exists several similar and general description of the NPI/NPI process. According to dictionary.cambridge.org (2017), NPI is the introduction of a new product for sale for the first time and the attraction of people's attention to it. Similarly, NPI can be defined as the activities that brings a new product to its target market (Doyle, 2011), and the debut of a product into the market (Businessdicitonary.com, 2017).

The process includes marketing, sales and distribution activities. Thus, the NPI process can be defined as the process of making a new product commercially available. The NPI process (illustrated in figure 8) is arguably the most important milestone of the NPD process and one of the most demanding in terms of resources and capital investments (Liao et.al, 2016). Cooper (1999) underlines that a strong market introduction is essential for successful projects and that high-quality introductions are well planned, properly resourced, and well executed. Firms with successful product introductions have invested twice as much time and resources to the introduction as unsuccessful ones. Despite its importance, it is often considered as a conventional audit mode, which does not tend to facilitate senior management and supplier involvement, or drive organizational learning to improve the process (Tennant and Roberts, 2003). Furthermore, most of the NPI's fail and there is a need to shed light on the process and address it with performance measures and metrics (Cooper, 1999).

The NPI process is in most literature associated with the marketing and sales activities of a firm (Cooper, 1999, Talke et.al 2010). However, marketing and sales are also associated with pre-introduction activities that enable a customer-centric view in the planning of sales and marketing activities. Tang and Collar (1992) divides the NPI process into three main phases: (1) *pre-introduction programs*, (2) *introduction programs* and (3) *post-introduction programs*.

1. The pre-introduction programs objective is to create the most favorable market and competitive conditions that accelerate product diffusion. The activities of this phase must be rooted in the strategic goals of the new product. Thus, the pre-introduction phase encompasses:

> *Verification of the strategic assumption of the new product, including product-positioning, i.e. articulation of what place the product should occupy in the market, and on what basis it should compete (its relative benefits and differential advantage).
> *Defining competitive actions, such as to identify the shortcomings of the product, anticipate the behavior of competitors, trade press and consultants, and develop proactive actions. Thus, this is when methods to communicate and demonstrate the product benefits and advantages are developed.

2. The introduction programs are the more convincing and comprehensive communication and demonstration of the functions and benefits of the new product. This usually includes execution of marketing activities such as advertisements, new product show events etc. It also involves sales and customer negotiations. Similar as in the pre-introduction stage, it is important to collaborate with all major external stakeholders and act upon the developed plan in the pre-introduction phase.

3. Finally, the post-introduction programs key objective is to sustain and improve the market and competitive conditions for the new product. This stage involves the development of metrics that can identify the factors influencing the performance in the value chain, support management and investment decisions.

All key-participants along the value-chain are included in the pre-introduction, introduction and post-introduction processes to address all the critical factors that affect the rate of new-product diffusion in the market. Thus, teamwork between the key internal stakeholders (managers and project staff) and external stakeholders (customers & suppliers) underlines the success of the NPI.

Talke et.al (2010) argues that new and complex products' competitive advantages, such as new 3D-printers' cost-value ratio or technical specifics, are difficult to observe and understand by customers. Hence, customer adoption barriers will be higher, and thus more explanation, demonstration and persuasion are needed compared with more simple products.

In addition, similar as a strategy, Rummler and Brache (2013, p.287) argues that in order to enable process management and continuous process improvement, it need to have measures. Measures are the foundation of process management and continuous improvement, which ensures that departmental goals align with the firm's strategy and promotes cross-functional process effectiveness. Thus, measures should reflect both the customer, stakeholders and financial needs; in the end of the value chain and upstream. In addition, they should represent the condition of processes and be used as management instruments. Hence, when creating new processes, such as a NPI, process measures should be implemented with it as they provide the link between the overall organizational measures (such as return on earnings and market share) and the measures of operational activities, individuals and teams. Furthermore, the process measures that have been identified need to be implemented, traced and linked to the individual performer metrics *(*Rummler and Brache, 2013, p. 267). This allow determination of whether the process is achieving its goals for effectiveness and efficiency, and identification of areas for further improvement.

Fu and Jones (2015) have used measures to identify and assess training effectiveness during the NPI and compare it to other managerial intervention. They underline the importance of sales training for New product introductions. Business-to-business salespeople serve as important intermediaries between the selling firms offering and the customers' perception of the new products. Thus, salespeople have a pivotal role in the customer adoption of new products. However, the researchers argue the is the best interests of both managers and their organizations to ask whether expenses in sales training are justified by the benefits it produces. Hence, measures for the evaluation of effectiveness in the sales training process and the results it produces are desirable to support resource utilization improvement. The results from their case-study showed that the value of sales training to a NPI, called "the innovation commercialization process", is both effective in enhancing overall sales performance, and in enabling salespeople to succeed early and improve their overall productivity.

2.4.3. Process: The Post-Introduction Process - After Sales Services

Dombrowski and Malorny (2016) argues that after sales enables manufacturers to increase added value provided to customers after an initial sale and thus improve their relationship with customers. They divide after sales services into three organizational segments: (1) spare parts service, (2) customer service, and (3) accessories business. Spare parts service includes disposition/arrangement, pricing, spare parts sales, spare parts logistics, demand forecast etc. Customer service involve maintenance, repair, overhaul, training and qualification, installation and operation, product observation etc. Accessories can include license products, product enhancement and technical equipment.

Furthermore, Dombrowski and Malorny (2016) divide the objectives of customer services into internal and external objectives. This can be compared with the separation of internal customers (employees, managers, stakeholders, partners etc.) and external customers (the users of the company's products and services). The internal objectives of the customer service derive from the management of the manufacturer. Possible internal objectives in after sales service are the enlargement of service portfolio (trainings, innovative upgrades, full-service agreements etc.), increase of employee loyalty, long-term relationship with employees and partners, differentiation from competitors, reduction of reaction time, reduction of process time, effective service network, reduction of failure costs and profit increase. The internal objectives have to be chosen and adjusted to the specific offered customer service and cannot be generalized for the field of customer service. External objectives are demanded of the external customer who expects that its production is in top condition at all times so that there are almost no downtimes that incur high costs. Further they demand fast 24/7-services and contact persons, fast replacement and supply of defect parts, flexibility, high service quality, defect liability, fast reaction times and predictable costs, i.e. fast problem solutions. The external objectives can be identified by executing customer demand analysis. There are possible conflicts between internal and external objectives (e.g. high profit in customer service vs. favorable prices) that must be identified and a solution must be found for the internal and external objectives as well as the conflict of objectives. Hence, the appropriate internal and external objectives have to be identified and evaluated against each-other (Dombrowski and Malorny 2016).

2.4.4. Process: Value-Added Services and Education

Stump et.al (2002) describes the role of education in the activity dimensions of seller-buyer relationships during the NPD process: Education involves the education of customers regarding the offerings provided by the seller.

The educational activities often revolve around explaining underlying technology and innovation; its relative advantages; delineating appropriate product installation and usage; suggesting product enhancements and services; as well as specifying performance criteria to be used in evaluating the innovation. Technology-oriented industries with a rapid pace of technological change usually demand extensive educational efforts of buyers' as their knowledge structures become obsolete. Thus, education and openness becomes competitive advantages for the providers as the necessity to educate their customer's increases. The focus of the customer education should be on the innovations impact on costs and benefits/profits, rather than overemphasizing the complex technical attributes of the product. Furthermore, the technology providers/sellers should actively attempt to manage buyers' expectations regarding what the product can do for them. This often means that the provider needs to lower the buyers' unrealistic expectations.

Brettel et.al (2014), argues that value added services provided from manufacturing companies allows them to differentiate themselves in addition to high product quality in order to ensure a strong competitive position. Industry 4.0 can be viewed as a metaphor for a lot of value added services and product enhancements (accessories etc.) that are applied in the manufacturing industry to increase profitability. For example, Internet of Things (IoT) and Cyber-Physical-Systems (CPS) takes the Just-In-Time (JIT) concept to another level as it allows processes to start instantly through customer orders, instead of going via a "middle man". These services need to be integrated with the manufacturing machines provided by the supplier which means that it is essential to have collaborative networks to enable Industry 4.0. Furthermore, he has developed a model which illustrates the connection between three main research fields for Industry 4.0: *Individualized Production, Production Networks, and End-to-end Engineering* in a virtual process chain. Each research field has been assigned with relevant sub-topics that enable the research field as shown in figure 11.

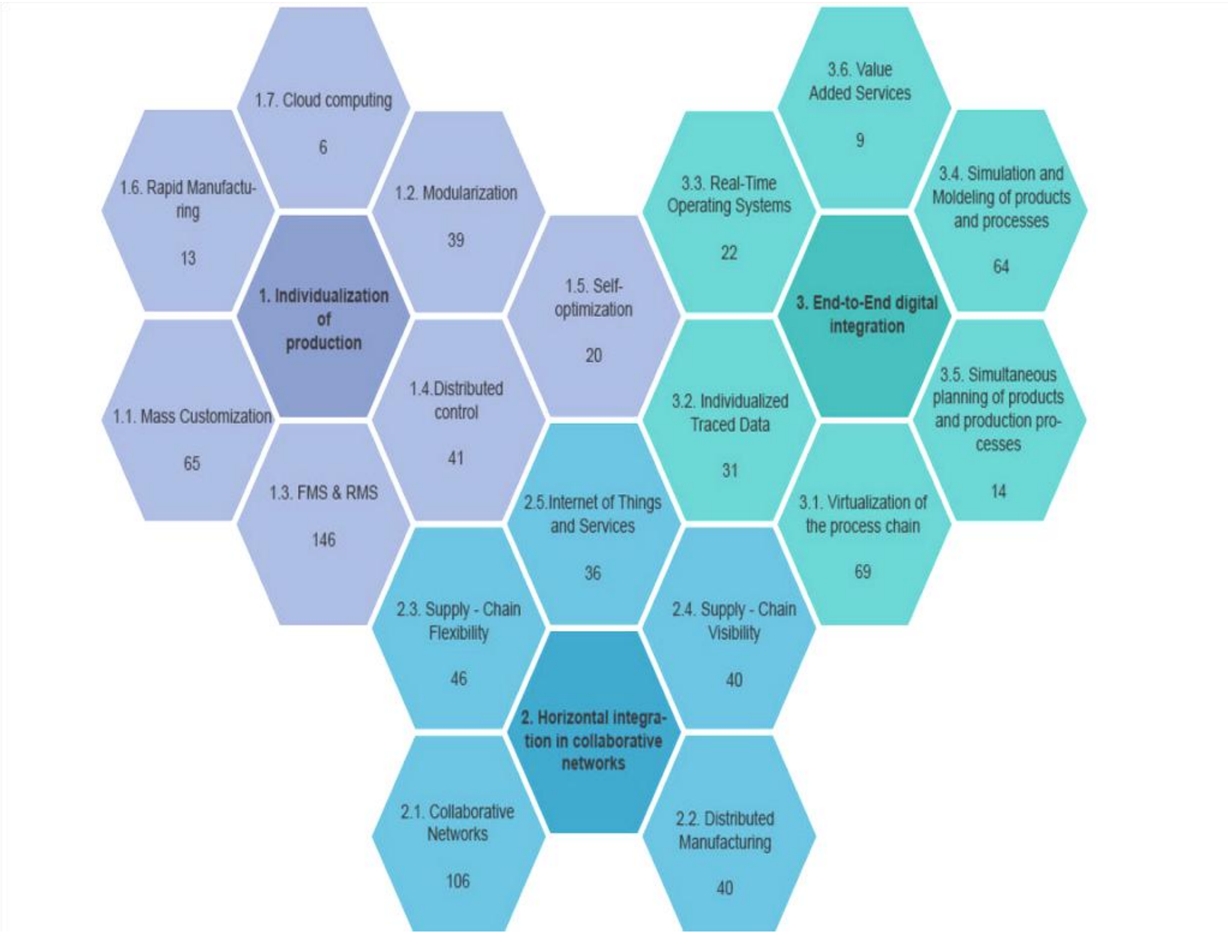


Figure 11. Industry 4.0 related research streams; the numbers underneath the topics illustrate the assigned articles from their research. Source; Brettel et.al (2014, p.41).

2.4.5. Process: Summary of the New Product Introduction Process

According to the literature review (Tang and Collar, 1992; Andrew et.al, 2008, Stump et.al, 2002; Dombrowski and Malorny, 2016; Rummler and Brache, 2013), the NPI process can be divided into three stages: pre-introduction, introduction and post-introduction as illustrated in Figure 12.

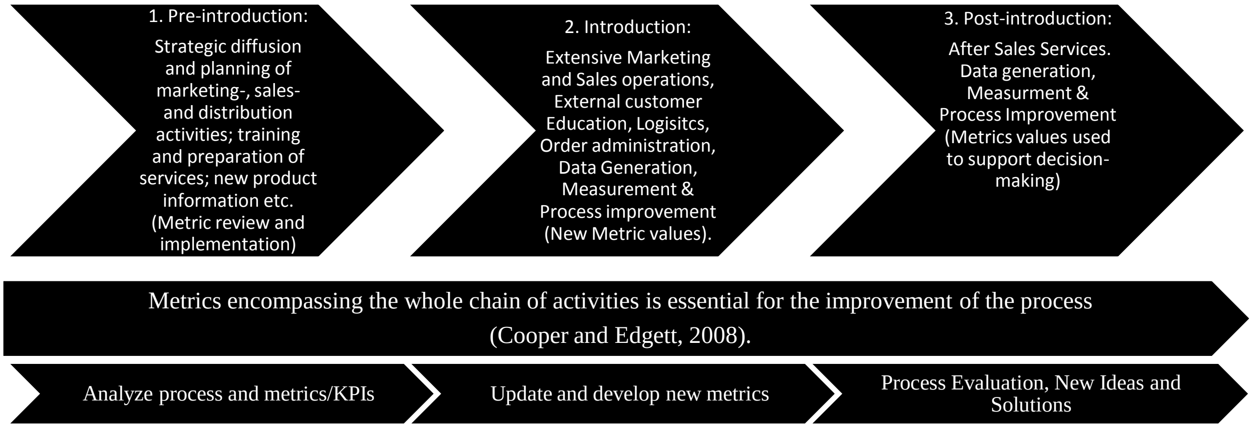


Figure 12. The three steps in the New Product Introduction (NPI) Process. Inspired by: Tang and Collar (1992, pp. 23-26); Andrew et.al (2008); Rummler and Brache (2013, p. 267, p. 287); Dombrowski and Malorny (2016). Own developed model.

Step 1. "Pre-introduction" includes the planning of marketing and sales activities according to the product characteristic and strategic intent, and additional preparation to enable product diffusion, such as training of staff, logistic and service etc. Thus, a product positioning plan, distribution plan, and initiatives for process management and process improvement are developed (Andrew et.al, 2008). In addition, Cooper and Edgett (2008) suggest that this stage should include the use of metrics to measure process performance. This will allow identification of variances, problem solving sessions, and correction of actions that prevent future reoccurrence of undesirable results.

Step 2. "Introduction"- this step is the execution of the strategic planning processes and operational preparations done in step 1. Liao et.al (2015) argues that this is the most investment-intensive for the execution of marketing, sales and distribution activities of the new product, which should align with the strategic and tactical plans developed in step 1 (Tang and Collar, 1992). Oxforddictionaries.com (2017) defines marketing as the action of business of promoting and selling products or services, including market research and advertising. Thus, step 2 encompasses extensive communication, demonstration and eventually the sales of the new product attributes and benefits to targeted markets, segments and customers. Important activities include, advertisement, product illustrations, negotiation, contracting, logistics, order administration, and distribution to customer/user. In addition, this step should include useful performance measurement of processes in order to enable efficient and effective management, and process improvement (Franceschini et.al, 2007).

Step 3. "Post-introduction" is the After-Sales Services regarding spare parts, customer service and accessories that make sure customers are satisfied with the products and services of the organization. Hence, the needs and the demands of the customers must be fulfilled for them to spread a positive word of mouth (Dombrowski and Malorny, 2016). This step should also include measurement and continuous improvement of the NPI process by the use of metrics that explains what factors (sources of cost and revenue) that influence the value delivered to customers and the business performance (Andrew et.al, 2008, Tang and Collar, 1992). Data from accounting and financial activities can be used for quantitative metrics, e.g. NPV (Kaplan and Norton, 1996).

To accommodate process analysis and management, it is suggested that metrics should be developed and used for all three steps of the NPI model and allow for continuous process improvement (Cooper and Edgett, 2008). In fact, Cooper and Edgett (2008) argue that metrics should be developed for the whole NPD process since teams cannot be held accountable for results, while learning and improvement is next to impossible without metrics in place.

2.5. The Nature of Measures and Metrics - Why measure?

Measurement and *Metrics* are not the same. Businessdictionary.com (2017) defines measurement or measuring as the process of quantifying values into specific units. The result of measurement is called *measures* which are the number or quantity that records a direct observable value or performance (Businessdictionary.com, 2017). While metrics are defined as a set of standard measurements (merriam-webster.com, 2017) by which efficiency, performance, progress or quality of a plan, process, or product can be assessed (Businessdictionary.com, 2017). Similarly, and indicator is a measurable variable used as a representation of an associated (but non-measured or non-measurable) factor or quantity (Businessdictionary.com, 2017). Francschini et.al (2007, p.8 and p.12) argue that the terms "metric" and "indicators" has been, and can be used interchangeably. According to Melnyk et.al (2004, p. 211) *"a metric is a verifiable measure, stated in either quantitative or qualitative terms and defined with respect to a reference point".* A verifiable metric (indicator) is based on and agreed upon a set of data and a well-understood and well-documented process for converting this data into measures. Thus, given the same data and process, independent sources should be able to arrive at the same metric value from their measures. Hence, metrics are measures that capture characteristics or outcomes in a numerical or nominal form (Malny et.al, 2004, p. 211). Further, Franceschini et.al (2007, pp.7-8) argue that an indicator is "*the qualitative and/or quantitative information on an examined phenomenon (or a process, or a result), which makes it possible to analyze its evolution and to check whether quality targets are met, driving action and decisions".* Quality can be recognized as the ability to fulfil different types of requirements (productive, economic, social, etc.) that is specified and agreed-upon by different people, with concrete and measurable actions. For example, a quality target could be to produce a product, with zero defects, or deliver a service within a specific time-frame and budget (Francschini et.al, 2007). Thus, given these similarities, metrics and indicators will be used as synonyms and interchangeably in this thesis hence forth.

Cooper and Edgett (2008) argues that metrics is fundamental for enabling management. Melnyk et.al (2004) acknowledge that metrics fulfills the fundamental activities of measuring (evaluating how things are doing), educating (teaching us the value of things), and directing (potential problems can be identified and managed by the metrics). Several researchers: Cooper and Edgett (2008), Franceschini et.al (2007, pp. 10-11), and Melnyk et.al (2004, p.211) propose three basic functions of metrics (indicators):

- *Control:* Metrics enable people to evaluate and control the performance of the resources of which they are responsible.
- *Communication:* Metrics communicate performance to internal- and external stakeholders for several purposes. However, poorly developed metrics can lead to users feeling frustrated and confused. In contrast, *"well-designed and communicated metrics provide the user a sense of knowing what needs to be done without necessarily requiring him/her to understand the details of related processes"* (Melnyk et.al, 2004, p. 211).
- *Improvement:* Metrics identify gaps between performance and expectations that ideally point the way for intervention and improvement. The feedback provided by the process can be used to identify productive process adjustments or other actions.

"A useful metric is both accurate (in that it measures what it says it measures) and aligned with your goals. Don't measure anything unless the data helps you make a better decision or change your actions." – Seth Godin

Kahn et.al (2005) argues that metrics enables fact-based analysis of resources and capabilities by establishing a set of measures and indicators for relevant NPD activities to identify gaps in value-generation, -waste/costs and drive improvement. In order to know the productivity and performance of processes, they need to be measured and metrics needs to be developed for each activity. As Cooper and Edgett (2004, pp.82) puts it: *"you can't manage what you don't measure"*. Andrew et.al (2008) argues that measurements gives more, better and more up-to date information of a company's practices which over time can translate into a significantly higher return on innovation spending. However, it is important to identify and measure the parts of the NPD process that is most relevant to the company's objective and strategy and pick the metrics accordingly. The productivity of NPD processes can according to Cooper and Edgett (2004) be defined as the profit or sales (output) achieved divided by the costs and time (input) of all the activities that enables the commercialization of ideas. Furthermore, principles and lessons of Lean Manufacturing provide some guidance to NPD metrics, such as removing waste (efficiency) and reducing time-to-market (speed).

Cooper and Edgett (2008) argue that only 30 % of corporations measure the performance or outcomes of new product project once the product has been introduced. As a result, it is not clear whether a NPI was successful, if it met its performance targets, what to learn from the process and how to improve it. However, high-performing businesses have both qualitative metrics (employee motivation, customer satisfaction etc.) and quantitative metrics (financial; costs, revenues, profit, time; time to market or on-time performance, etc.) in place, that provides useful information for learning and continuous process improvement.

Melnyk et.al (2004, p.210) argues that there is a need for measurement and metrics that go beyond simple reporting to create means for identifying improvement opportunities and anticipating potential problems adopted to dynamic environments. Thus, new metrics systems need to be flexible in recognizing and responding to changing demands placed on firms and operating systems. This is due to product mix, heterogeneous customer requirements, as well as changes in operating inputs, resources and performance over time. Furthermore, metrics are commonly viewed as important means to communicate priorities within firms and across supply chains and should provide: clarity of purpose, real-time feedback, predictive data and insights into opportunities for improvement.

2.5.1. The pitfalls of Metrics

There are several challenges in choosing and implement successful metrics program. Kahn et.al (2005) argues that many companies are not using metrics to their full advantage and presents four primary reasons for this:

1. Metrics used are not the right ones.
2. Tracking mechanism are inadequate.
3. Bottom-line implications of performance are not considered.
4. Management process is missing.

Furthermore, too many metrics will be misleading as they tend to become contradictive, and too much focus on metrics will make them overvalued, rather than the real goal of delivering value to the marketplace (Kahn et.al, 2005).

Hauser and Katz (1998) identified seven pitfalls that lead to counterproductive metrics. These are: (1) delaying rewards, (2) using risky rewards, (3) making metrics hard to control, (4) losing sight of the goal, (5) choosing metrics that are precisely wrong, (6) assuming your managers and employees have no options, and (7) thinking narrowly.

1. *Delaying rewards* consider the risk that long-term metrics such as long-term cost reductions, reduced lifetime product development costs, or defects discovered over the life of the products, will be undervalued. This is because they delay rewards towards future outcomes that may be hard to tie back to the employees or managers that have enabled them. Thus, present actions and decisions tend to bias toward short-term payoffs. Therefore, metrics should be able to measure daily activities that impact future outcomes by enabling employees to make tradeoffs that maximize long-term profit to the firm.
2. *Using risky rewards* consider the fact that any metric that depends on an uncertain outcome from influences that are beyond the control of managers and employees imposes risks or 'risk costs' in the performance assessment. For example, suppose that a firm uses a metric that measure R&D effectiveness by measuring the profit obtained from new products over a time-period, divided by the percent of revenue spent on R&D investments in a specific point in time/time period and/or for a product(s). Thus, this metric attempt to reflect the R&D effectiveness based on the net revenue that R&D contributes to the firm. However, R&D is one of the most risky and long-term investment that a firm can make. Hence, managers and employees that uses these metrics will prefer projects that are less risky (and more short-term oriented). Consequently, a significant portion of R&D projects can be falsely rejected or selected by solely relying on this metric.
3. *Making metrics hard to control* is the pitfall of using metrics that reflect the outcomes, e.g. revenues and cost metrics, but do not consider the whole impact that each unit, department or individual have contributed with for the company's long-and and short-term goals. For example, engineers may have influenced a significant proportion of a product's costs derived from conducting a service that is necessary to satisfy customer needs. Thus, given that the cost metric is equally valued by managers and employees, it may result in decisions to avoid that service since it effects the short-term interest of the firm, although that it might be in the firm's best long-term interest to satisfy the customer needs.
4. *Losing sight of the goal* is the mistake of using metrics that are misaligned with the firm's goal to provide value to customer and generate profit. In some cases, some aspects of the value-added services may be too overvalued by metrics, meaning that the costs that they require are greater than the actual value delivered to the customer. For example, metrics for comprehensive design and quality testing may

be used to improve some aspects/components of a product's quality. However, the outcome of these procedures may be that the improved quality of the components may be far beyond customer demands. This results in increased costs relative to the value-added which consumes resources that could have been invested in activities that generates more costumer value relative to costs. Hence, this leads to a more imbalanced relationship between customer satisfaction and long-term profit. In other cases, metrics may be misaligned with goals by measuring the aspects that do not capture the profitability and competitiveness towards the intended direction of the firm.

5. *Choosing metrics that are precisely wrong* is concerned with the relevance of metrics, i.e. the risk of choosing metrics that can easily be measured with great accuracy but do not measure what is relevant to the real goals of the firm. Thus, firms should "*measure what is truly important, not just what is easy to measure. Vaguely right is better than precisely wrong"* (Hauser and Katz, 1998, p. 521).
6. *Assuming your managers and employees have no options* is considered with how metrics systems promotes productivity. The risk of designing a metrics system is that it only provides metric values that indicates the option for managers and employees to work harder, but not *smarter.* Since most managers and employees work hard, the goal of a metric system should be to provide alternative actions, that enables them to work smarter. This means that metrics systems should guide decisions and actions to produce same/improved results (output), given that the actions consume less/the same amount of resources (input). Thus, when designing a metrics system, it is important to consider the alternative metrics available to managers and employees that promotes productivity. This also involve the metrics systems resource consumption, i.e. the additional cost or effort required to use and maintain it. For example, if measurement system requires 10 per cent of the productive time available of internal customers, then it should raise productivity by more than 11 percent.
7. *Thinking narrowly* this pitfall considers how metrics systems are narrowly designed so that they do not capture the actual *source* to the cost-and-benefit values that are measured. For example, a company could use metrics that measure the cost and speed to conduct customer service activities to solve specific customer problems, while none of them measure the actual source to these problems. In the case of new product development, it could be that a specific component intended to be integrated into the new product, an older software, already is causing problems customers. However, this can't be recorded and communicated because it is not measured. Thus, the firm's service unit would not see that the time and cost spend on customer service is caused by the software. Hence, these metrics do not communicate the issues to the software developers so that they can anticipate and solve the problem before it occurs for the new product.

2.5.2. Avoiding the pitfalls of Metrics

Hauser and Katz (1998) argues that choosing the right metrics is critical to business success as they guide the behavior of a firm. Firms need to identify metrics that not only effect the current performance of a firm but also its long-term goals. The key concept is not that the metrics must have a *direct* causal effect on eventual outcomes. For example, in a SBU, the number of sales times margin (revenue) might be a good metric for the sales force, but less directly and less immediate for the technical support team. Instead, customer satisfaction might be a more appropriate metric to improve the value-added activities performed by the technical support- and after sales service teams. This would in turn lead to increased sales in the long-term as customer satisfaction increases. Furthermore, additional complementary metrics may be necessary to develop for the evaluation of long-term revenue. This could for example be cost metrics of installation and service support, marketing expenses and investments in internal/external customer education or training. These expenses can be considered to be complementary outcome metrics to customer needs, revenue and market share. This is because the cost metrics would allow for efficient resource management and resource allocation to different activities such as marketing, sales and after sales services. Consequently, this would improve the firm's overall profitability and perhaps improve the customer satisfaction and the revenue in long-term. Thus, it is crucial to develop different metrics for different business activities that accurately reflects their respective performance so well that it guides the improvement processes of the firm, as Hauser and Katz (1998, p. 520) explicitly states:

"The key concept is that the metrics are chosen so that actions and decisions which move the metrics in the desired direction also move the firm's desired outcomes in the same direction."

2.5.3 Building a framework for metrics

Kahn et.al (2005) argues that effective metrics are easily understood, communicable, quantifiable, and recordable, and allow for automated data collection when possible. Schilling (2013) argues that multiple measures should be used to give a fair representation of the effectiveness of the firm's development strategy, industry, and overall innovation performance. Emerald Insight (2009) suggest metrics should be introduced to identify the parts of the innovation process that are most relevant to measure according to the business's objectives and strategies. Dombrowski et.al (2013) have developed seven criteria that could be used when choosing the right metrics which are: (1) *Relevance for the Enterprise Targets, (2) Quality of Data, (3) Compatibility of the Hierarchy, (4) Variability, (5) Periodicity, (6) Visualization, (7) Effort.*

1. Relevance for the enterprise means that metrics should be suitable to support the strategy and targets of the enterprise to help the employees work in that direction.
2. Quality of Data includes two important criteria for metrics: validity and timeliness. Validity means that metrics should be able to be influenced by the users of the metrics. For example, the cost metrics of marketing and education processes should enable the costs to be manipulated to improve the corporate resource allocation and increased efficiency in the marketing tasks based on the data generated from these cost metrics. Furthermore, the metrics users must be able to recognize the cause and effect relationship between the activities that are measured and to be able to influence them directly in desired direction. Thus, it is necessary to develop metrics that actually measure what they are supposed to measure to provide an accurate understanding of what is going on, and to enable processes to be influenced thereafter. For example, the enterprise-wide cost of marketing or education cannot be traced back to a specific activity, but the costs of the specific marketing and education process provides information that allows the management to influence them comprehensibly. The timeliness concerns the time it takes to deliver the feedback of processes which depends on the circumstances. However, fast feedback gives managers a detailed profile of the performance and documentation of the changes over time.
3. Compatibility of the hierarchy is the notion that metrics should provide information that is relevant for the person that monitors the processes being measured so that the metrics helps the users to adjust their work. The metrics can be different in detail and occur on different hierarchal levels of the enterprise. Some metrics need to be modified to show relevant information while others can be used at all levels.
4. Variability means that it is possible to change the weight of metrics importance when the goals are changing due to changes in the corporate environment. Thus, the metrics should be able to reflect the new values that occur due to changes, or the metric user should be able to modify or prioritize their values according to the new goals.
5. The Periodicity of metrics concerns the time it takes to measure processes or collect data which generate metrics with enough information to provide support to decision making. The periodicity of metrics depends what they are intended to be used for and who is going to use it. For example, the performance metrics used for the prediction of the future stat of the corporation are measured in longer cycles, and are often used at corporate level in summarized amount of information. In contrast, at the operational level, current state can be measured in shorter cycles to provide information of whether targets have been achieved and allow for faster response to changes. The periodicity or measures for the current state and short-term goals, needs to be less than a month. Thus, the closer the recordings are to the value creation process, the more often feedback should be given through the metrics.
6. Visualization concern how metrics are illustrated, i.e. how the collected data is communicated, so that as much of its data can be understood as fast as possible and as accurate as possible. Thus, the metrics should be as close as possible to the workplace and language of the employees so that they can understand their importance.
7. The Effort of metrics concerns the tasks necessary for the usage of measures which includes: the generation of data, collection/measurement of data, processing of measures, and generation of valid feedback and representations of processes' value. The effort of metrics can be used to evaluate how much they generate in value compared to the cost of usage, i.e. the productivity of metrics.

Similarly, Hauser and Katz (1998, pp. 522-527) propose seven steps toward good metrics, namely: (1) Start by listening to the customer, (2) Understand the job, (3) Understand interrelationships, (4) Understand the linkages, (5) Test the correlations and test manager and employee reaction, (6) Involve managers and employees, (7) Seek new paradigms.

1. *Start by listening to the customer* means that firms should develop metrics that is based on the voice of the customer. *"The voice of the customer consists of a set of words and phrases that describe, in the customers' vocabulary, what he customer wants or desires in a product or service"* (Hauser and Katz, 1998). These needs and desires are best determined by direct interviews with customer, in which they are identified and prioritized. However, these needs are not yet metrics until they are tied to the decisions and actions of firms which align with the long-term profitability of the firm.
2. *Understand the job* emphasis the importance of understanding internal customer values, tasks and responsibilities and how their decisions and actions affect the metrics and the desired outcomes. Internal customer values are associated with rewards to promote motivation, engagement and satisfaction. To understand how internal customer decisions and actions relates to outcomes, firms need to identify and classify their daily activities and trace their relationship to outputs. This includes creating a detailed map of work processes that enables the user to track and diagnose changes in, for example, time and effort allocation. Effective metrics systems should provide information about these changes that allow employees to change their efforts in response to the metrics system and improve outcomes. For instance, if the metrics system measure changes in time and cost (effort) allocation, then the detailed map of work processes allows the user to track and diagnose these changes which can provide simple solutions to critical bottlenecks.
3. *Understanding the interrelationships* is concerned with the importance of creating metrics based on the understanding of interrelationships between both internal and external customers. This is so that the metrics guide decisions and actions to generate desired and balanced inputs and outputs within the interlinked and interdependent value chain. For instance, the design of a metric system in a manufacturing company should align with supplier, manufacturing, marketing and sales, and eventually the external customers' needs. In this case, the metrics for the supplier should guide its decision and actions in generating inputs that encourage the manufacturer set higher targets or lower cost targets. The manufacturers output should in-turn encourage marketing and sales to set higher targets or lower cost targets. These targets should be considered in order to develop metrics that do not conflict with each other, and they should align with the long-term goals of generating customer value and profit.
4. *Understand the linkages* is the processes of linking efforts both to metrics and outcomes based on the combined understanding of previous steps: the external customers' needs and internal customer objectives (step 1), the efforts and work processes of internal customers (step 2), the interlinkages and interdependency of the value chain, i.e. interrelationship (3). While keeping the seven pitfalls in mind, this should provide enough information to propose metrics that have a good change of aligning employee actions and decisions with the long-term needs of the firm.
5. *Test the correlations and test manager and employee reaction* means that the metrics system should be tested before implementation or full-scale implementation. This can be done in a pilot test for which a certain set of metrics are selected that are assumed to have positive correlation with desired outcomes when used. This will create and index for each metric that allows the metrics developer to select the metrics that have the greatest positive correlation with the outcomes, as well as being the easiest to use and simplest to implement, called 'lean metrics'. Furthermore, the pilot test would allow the metrics users to share information on which metrics that yields valuable insight, provides guidance of actions and how the metrics consumes resources and time.
6. *Involve managers and employees* this is the principle that those who are subject to/using the metrics systems should be part of the team that is responsible for developing them. Hence, the metric users are the ones that are knowledgeable about the processes, phenomena etc. that needs to be measured in order to provide helpful feedback and guidance for their daily activities.
7. *Seek new paradigms* the final step encourages the metric developers to use the information in step 1-6 creatively to develop metrics that enables managers and employees to discover new, more efficient ways of accomplishing goals. Thus, creating a better solution (a new paradigm).

Muller et.al (2005) provides a framework to support the development of customized innovation metrics. This framework includes the resource view which addresses the importance of allocating resource to alter the balance between optimization (tactical investment in the existing business) and innovation (strategic investment in new businesses). The resource input measure the resources allocated to the company's innovation which are capital, labor and time. The resource output is the return on investments in strategic innovation. Examples of input metrics are the percentage of capital invested in innovation activities such as marketing and sales, and the percentage of workforce time that is committed to innovation projects, e.g. internal and external customer education of new products. Output metrics could for example be the number of sales per unit.

2.6. The Nature of Measurement Systems: A system of Metrics

When the process map has been designed, it needs to be combined with a systematic monitoring plan, and periodic performance recording to evaluate process performance and enable process improvements. This creates the process measurement system. A business measurement system provides the data that will be collected, analyzed, and reported to make sound business decisions, given that it is strategically planned and align with the company's mission. Thus, measurement systems are essential for testing whether the objects of processes are meeting stakeholder needs (Franceschini et.al, 2007). Melnyk et.al (2004) argue that the (performance) measurement system is responsible for coordinating metrics across the various functions and for aligning the metrics from the strategic (top management) to the operational (shop floor/purchasing/execution) levels.

Franceschini et.al (2007, p. 6) argue that a measurement system can be defined as *"A system of indicators should become an information system for estimating the level* of achievement of quality targets". They have categorized process measurement systems into two main activities: *(1) Definition of indicators and (2) Decision.* Definition of indicators (metrics) consist of defining and selecting the performance measurements that should be used and which data that should be collected. Each metric should be selected depending on the process critical aspects and growth potential. Decision means that the courses of action are decided upon based on the information generated from the metric. The choice of course of action depends on the gap between targets and the values generated by the measurement, i.e. the values of the metrics. For example, if the measured values are far below targets, then more radical improvements of respective business process are needed, e.g. reengineering. If targets are met, but could get better, then maybe individual problem solving or incremental improvements (step by step) are appropriate. Figure 13 shows the functions of the process measurement system in which process outputs (from the "Implementation" stage) are turned into inputs for the measurement system. The analysis of results means that evaluations are performed based on the metrics values generated from the measurement phase. This information is then used to take decisions concerning the attribution of responsibility, or the assigning of resources, giving guidelines and directives, which aim to influence the firm's future behavior. Furthermore, the measurement process should be technically and economically efficient. This means that most variables will provide quantitative data because they are easier to measure than qualitative data. Quantitative businesses data is usually referred to monetary values and is most practical to measure. However, qualitative data can usually detect consequences of actions and/or firms' behaviors more efficiently – but is more difficult to be assessed in terms of money (Franceschini et.al, 2007).

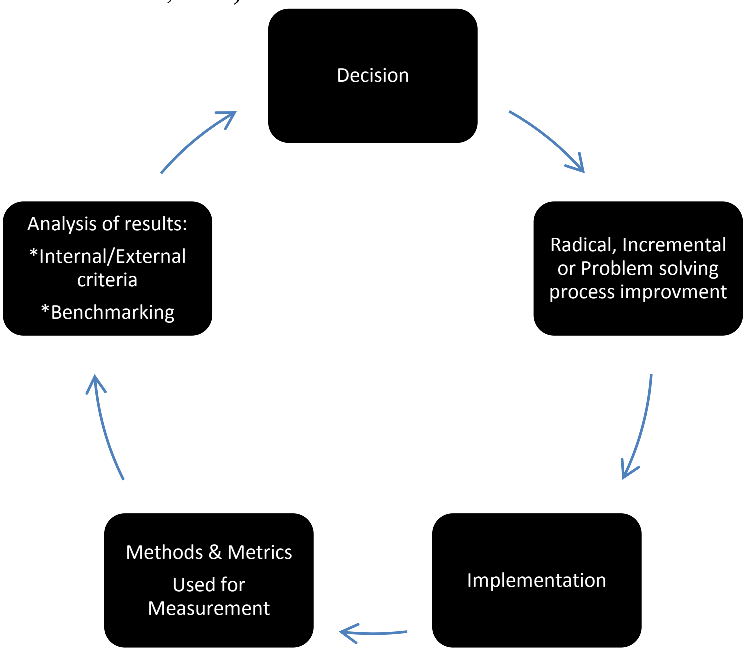


Figure 13. The process measurement systems' function. Source: Franceschini et.al (2007, p. 6).

2.6.1. Building a Measurement system

When building a measurement system, it is important to consider the different levels of an organization that needs to work together in order to enhance organizational effectiveness and efficiency. Taking this into consideration, Rummler and Brache (2013, p. 297) have divided organizations into three steps: (1) *Organization level, (2) Process level,* and (3) *Job/Performer level.*

1. The organization level is the macro view of the organization which emphasize on the organizations relationship with its market. The variables included in this level that affect the performance are strategies, organization wide goals and measures, organization structure, and deployment of resources. The development of measurement systems starts at this level, determining the critical outputs and goals. Since, the goals of an organization should drive all other measurement, it is particularly critical that they (Rummler and Brache, 2013, pp. 297-298):
    - *Are based on the documented requirements of external customers and the strategic business requirements of the organization.*
    - *Are universally understood within the organization.*
    - *Reflect the organization wide performance to which all subsystems (processes, departments, and jobs) should contribute.*
2. The process level is the cross-functional work processes, such as a marketing and sales processes. These performance variables must be aligned with customer needs, and work effectively and efficiently, so that the process goals and measures are driven by the customers and the organization's requirements. At this level, the process measures are linked to organizational measures by linking their outputs. In a high-tech company, the critical process for achieving organizational goals can be the NPD process.
3. The job/performer level concern the actual activities conducted by the people or members of an organization doing various jobs, such as hiring and promotion, job responsibilities and standards, feedback, rewards and training. At this level, firms need to ensure that each function's measures reflect (Rummler and Brache, 2013, p. 306):
    - *Its contribution to overall process (and, in turn, organization) goals*
    - *The contribution it needs to make to other functions so that they can make their contributions to process and organization performance.*

The process map should make it easier to see the contribution each function is expected to make to the process and can be extended to reflect the goals of each function that contributes to the NPD/NPI process.

2.6.2. Challenges with Measurement Systems

One of the main difficulties of measurement systems are to design them so that they guide and provide clarity of purpose, real-time feedback and predictive data, and insights into opportunities for improvement (Melnyk et.al, 2004, p. 210). Furthermore, it is argued that additional difficulties involve the implementation of measurement systems and the ensuring their continuity (Franceschini et.al, 2007, p. 7). Ensuring continuity can be especially difficult when demands on operating systems are highly dynamic, due to product mix, varied customer demands etc. (Melnyk et.al, 2004). Furthermore, Rummler and Brache (2013, p.268) acknowledge the risk of measurement systems not being accepted or resisted by performers within the process.

2.7. Costs, Time and Quality: The Key Success Factors of the NPI process

Companies need to be cost efficient and have good cost information to improve their decision-making, business processes and business performance. An accurate and effective cost system is essential for the success of companies. An effective cost system should be able to pinpoint the cause and effect relationship between activities and the resources they consume (Drury, 2012).

"Managing with information from financial accounting systems impedes business performance today because traditional cost accounting data do not track sources of competitiveness and profitability in the global economy. Cost information, per se, does not track sources of competitive advantage such as quality, flexibility and dependability. […] Business needs information about activities, not accounting costs, to manage competitive operations and to identify profitable products" (Johnson, 1980, 44-5).

In accounting management, costs are separated into direct and indirect costs. Drury (2012) defines direct costs as costs that specifically and exclusively can be traced to a cost object, e.g. raw material, spare part or finished product. Indirect cost, i.e. overhead costs, cannot be identified specifically and exclusively to a cost object. This could be wages of all employees in a manufacturing department whose time cannot exclusively be identified with a specific product. The gross profit margin is the sales revenues minus the direct costs attributed to a product, usually the manufacturing costs including cost of material, machine and labor inputs. These direct costs that vary per production or sales volume are usually called incremental or marginal costs (Investopedia, 2017). The contribution margin is the sales revenues minus the direct costs and indirect costs. The total indirect costs and direct variable costs linked/allocated to a specific cost object are defined as total costs (TC) (Drury, 2012). Similarly, Investopedia (2017), defines total costs (TC) as the sum of fixed costs and variable costs. Variable costs are defined as costs that varies with process output. Fixed costs, such as rent, advertising, insurance, office supplies tend to remain the same regardless of process output. Fixed costs are usually regarded as overhead or indirect costs. The contribution margin (CM) can be calculated as follows: sales price minus the total variable cost regardless if the cost is incremental, labor or indirect/overhead. The CM can be used to support management to make more precise decision, more accurate budgeting, identify bottlenecks in terms of profitability etc. (Investopedia, 2017).

However, as Johnson (1980) argue, costs are not the only elements necessary for measuring the success of business processes. Cycle times, quality and the rate of responsiveness to customer demands are other elements that needs to be measured in order to enable business performances improvement. Atkinson (1999) argues that the essential aspects for measuring success of a project of business process can be summarized in the so called "Iron Triangle". These are costs, time and quality, i.e. the key success factors of business processes, illustrated in figure 14.

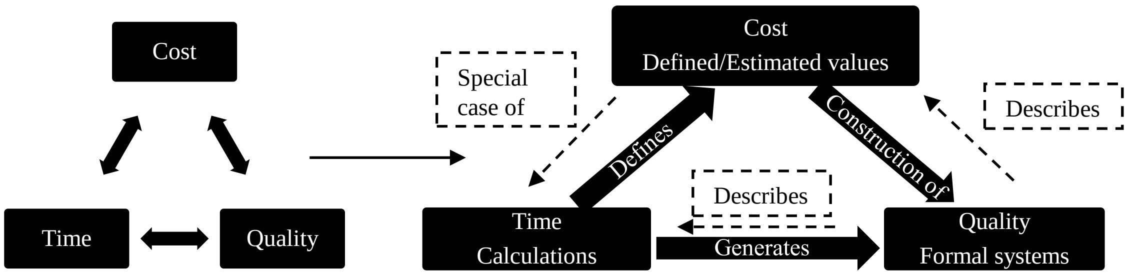


Figure 14. "The Iron Triangle" (left) consisting of three essential performance parameters: Cost, Time and Quality. The modified iron triangle (right) explaining relationships. Inspired by: Atkinson (1999, p.338) and Tagemark (2014).

The cost, time and quality aspects should be used together as a change in one of the variables are likely to cause a change in another variable. However, the prioritization amongst the variable depends on the situation. For example, if the company's key competitive advantage is to deliver the products with the highest quality to the market then quality would likely be of high prioritization within the company. Thus, costs would naturally increase if more resources are invested into quality control check-points. In contrast, if the key competitive advantage is to develop and introduce new products as fast as possible to as low cost as possible then time and cost would naturally be prioritized. Consequently, the company might need to lower quality targets (Atkinson, 1990). On the other hand, too low quality targets will result in more product returns and repairs which would push costs downstream the supply chain; delay and even increase cost and time investments.

This problem is associated with what Cooper (1999) calls "the seven blockers": *ignorance (1); lack of skills (2); faulty or misapplied new product process (3); Too confident (4); lack of discipline (5); In just too big hurry (6);* and *Too many projects and not enough resources (7).*

The first blocker (ignorance (1)). meaning that the managers or teams lack experience or understanding of what is required to make new product successful. As a consequence, they rely on wrong metrics and criteria. This can partly be solved by designing a detailed step-wise process map that connect the interrelated and dependent process activities.

The second blocker (lack of skills (2)). This means that skills and knowledge are missing for which mainly can be solve through team training; cross functional teaming; competent project leaders; and clear definitions of standard and performance expectations/criteria.

The third blocker (misapplied new product process (3)) happens when the new product roadmap is missing the key elements and/or are poorly applied. This may be caused by having too many gates/checkpoints. Although checkpoints are needed to ensure that the outputs from each step fulfill certain criteria, too many of them will create much more bureaucracy than necessary. Other causes are inflexibility in adopting the process to the estimated risk with the product. Hence, low risk should allow for detours to be designed in the process so that it speeds up. This can be solved by measuring the key successful factors in the process, i.e. cost, time and quality, to understand what made previous processes successful or not and then adjust activities in the process accordingly. For example, cycle times can be shortened by outsourcing.

The next blocker (being too confident (4)) is associated with being too confident that the process outcomes will meet expectations. The cost of the process might exceed expectations which would result in lower marginal income per unit if the price and number of sales remain constant. The solution is again to measure the key success factors in the process since accurate and effective metrics provides evidence of process performance.

The fifth blocker (lack of discipline (5)) is the occurrence of allowing key success activities to be optional, lacking clearly defined criteria and too frequent changes of priorities. This is a top-down problem in which responsible senior leaders must understand the vital role of new products in their business, the function of activities and how to prioritize among them. In addition, a process managers needs to be installed to manage the implementation process so that it works efficiently and effectively.

The sixth blocker (In just too big hurry (6)) is the problem of speeding up the process at the cost of the other two key success factors: cost and quality. Prioritizing cycle time reduction are necessary since studies have revealed a strong positive correlation between time efficiency and profitability in new product project (Cooper, 1999). However, limiting the key success activities such as marketing and quality of execution will have the opposite results if they decision of shortening them or removing them are well motivated. One solution is to develop a roadmap that outlines when it is acceptable to cut down on activities. For example, say that the following conditions exist:

- the concept is strong;
- the product category is well known and have been successful in the past;
- the marketing plan is simple and incorporates only well-known elements;
- the sales and advertising are ready;
- the technology is known and in use within the company;
- the product tests are strong and;
- the process capacity is reliable.

If these are the conditions, then it may be appropriate to cut down on activities (Cooper, 1999).

The seventh and final blocker (too many projects and not enough resources (7)) occurs when there is an imbalance between the number of active projects and the amount of resources (money and people) conducted. A solution to the problem is to develop a funnel process in which the project is cut down as it progresses while considering strategic and operative objectives. Another solution is to conduct a capacity-versus-demand analysis done in two steps: (a) Determine the demand created by your active projects, and (b) determine demand generated by your business's new product goals (Cooper, 1999).

Furthermore, Atkinson (1999) argues that criteria for successful process management can be divided into two main stages: *the delivery stage* and the *post-delivery stage*. The delivery stage includes the measurement of the process efficiency, i.e. doing things right. This means that activities are being measured based on how well they have been performed in terms of time and cost during the process. The post-delivery stage measures process effectiveness, i.e. getting things right. This means that the outcomes are being measured based on how well they are achieving their quality targets. Common quality targets are the impact received by the customer (customer benefits and satisfaction), business success (e.g. profit per unit sold and market share), and future preparation (long-term outcomes such as increased capabilities to realize next strategic goals). In addition, different criteria demand different amount of time to be measured. For example, the impact received by the customers is quality criteria which can be measured within a couple of weeks after implementation. Business success can be measured after one or two years, and preparations for future (long-term strategic success) are measurable after about four to five years.

The summary of the dimensions, aspects and metrics used to estimate the cost and performance regarding the NPD processes, with special emphasis on the new product introduction of finished goods phase, is summarized in figure 15.

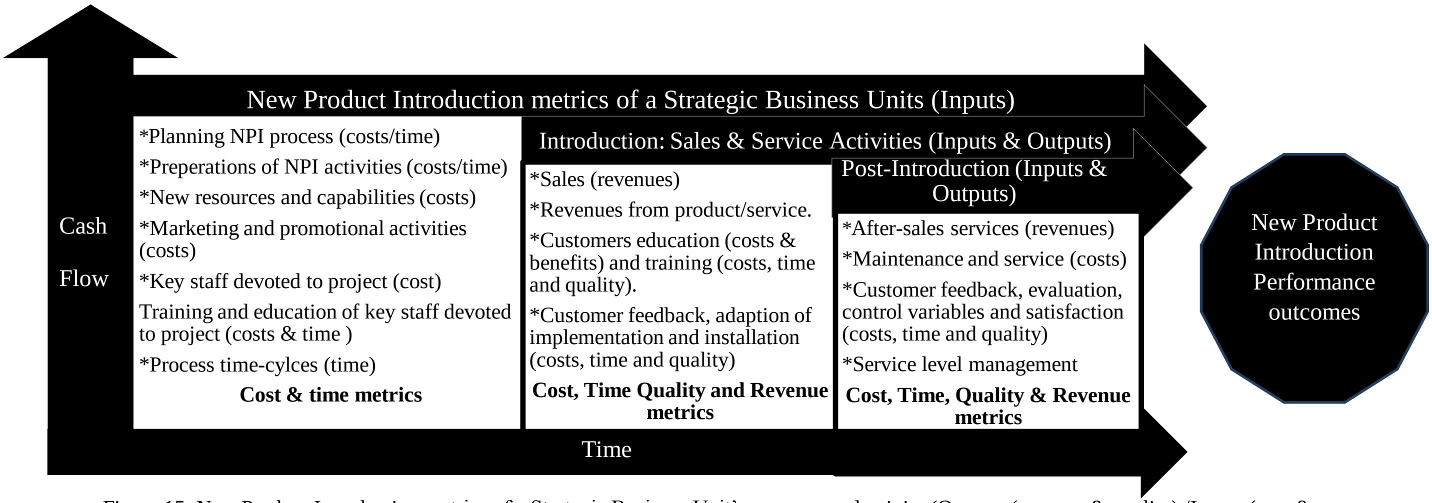


Figure 15. New Product Introduction metrics of a Strategic Business Unit's process productivity (Outputs (revenue & quality) /Inputs (cost & time). Inspired by: Andrew et.al (2008, pp.13-14), Stump et.al (2002, pp. 443-444), Muller et.al (2005, pp. 39-40) and Atkinson (1999). Own developed model.

2.7.1. Costs - Assigning costs & Cost systems

According to Kaplan and Cooper (1998, p. 2), cost systems are needed for three primary reasons:

1. *Valuation of inventory and measurement of the cost of goods sold for financial reporting.*
2. *Estimation of cost of activities, products, services, and customers; and*
3. *Providing economic feedback to managers and operators about process efficiency.*

Cost accumulation systems are used to assign direct or indirect costs to cost objects. Direct costs can accurately be traced to cost objects called direct cost tracing. This is because they can specifically and exclusively be traced to cost objects while indirect costs usually are common to several cost objects. Assigning indirect costs to cost objects is called cost allocation and is used when the quantity of resources consumed by a particular object cannot directly be measured. The basis used to allocate cost to cost objects (activities, products, material etc.), is called *allocation base* or *cost driver*. If cost drivers are significant determinants of cost objects, the terms *cause-and-effect allocations*, or *driver tracing* is used. If cost drivers are not significant determinants of cost objects, the term *arbitrary allocation* is used. The latter type of cost drivers is more likely to result in inaccurate allocation of indirect cost to cost objects. For example, if a large portion (e.g. 30%) of direct labor hours where used as cost of material receiving for a required product, but few materials where necessary for the product, it would allocate a large portion of the cost of material receiving. This would result in an inaccurate assignment of resources consumed by the product because the direct labor hours do not reflect the actual cost of material being consumed. Thus, for an accurate assignment of indirect costs to cost objects (e.g. products and services) cause-and-effect allocations/driver tracing should be used (Drury, 2012).

However, there are cost-benefit issues related to cost systems varying levels of sophisticating for cost assignment summarized in Figure 16. Drury (2012) underlines that the most accurate cost system should not be the aim. The goal should instead be to have a costing system that is improved up to the point where the marginal cost of improvement equals the marginal benefit from the improvement. This means that one unit of detail/measure should be added to the cost model as long as it contributes with more benefits than costs. Furthermore, the optimal costing system varies by several factors and the portion of indirect cost represented in a company. For example, the optimal cost system would be located towards the extreme left for an organization whose indirect cost has low percentage of total variable costs; a standardized product range; and whose resources are consumed in similar portions. In contrast, for a company with a high portion of indirect cost and whose products consume different proportions of organizational resources, will be located towards the extreme right. As Drury (2012, p.48) puts it *"more sophisticated costing systems are required to capture the diversity of consumption of organizational resources and accurately assign the high level of indirect costs to different cost objects".*

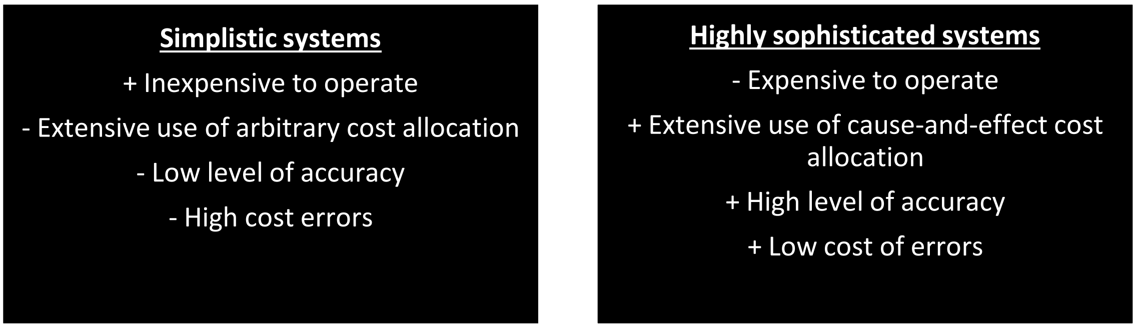


Figure 16. Cost systems varying levels of sophistication for cost assignment. Source: Drury (2012), Figure 3.2, p.48. Own developed model.

2.8. Costing model – The Activity Based Costing System

One accounting method that has proven to be useful in guiding management action that can translate directly into higher profits is the Activity Based Costing (ABC) system. This method was developed in the late 1980s aimed to be mainly used for cause-and-effect indirect cost allocation (Drury, 2012). According to Kaplan and Copper (1998), the cost drivers in ABC are the aspects of activities that determines its resource and/or time consumption which accurately relates to the output of an activity, e.g. a document, product or service. Hence a cost driver of setting-up/installing a manufacturing machine could for example be the *set-up hours* for machine installation. Similarly, for the activities of maintaining the machine, the *maintenance hours* could be used as the cost driver etc. Cooper and Kaplan (1991) argues that ABC is a powerful tool in calculating costs and provide useful information to management that can translate directly into higher profits. ABC reveals the links between performed activities and their demands in terms of resource consumption. In other words, ABC helps managers identify cost-drivers of processes. This is because the cost drivers provide information of what different sources (activities) of the process that causes cost to occur, i.e. how the activities consume resources and at what rate.

According to Kaplan and Cooper (1998, p. 79) ABC systems address the following set of questions:

- *What activities are being performed by the organizational resources?*
- *How much does it cost to perform organizational activities and business processes?*
- *Why does the organization need to perform activities and business processes?*
- *How much of each activity is required for the organization's products, services, and customers?*

Thus, the ABC system encourage managers to drive expenses, first to activities and processes, and then to products, services and customers with the aim to provide an economic map of operations (Kaplan and Cooper, 1998, p. 3). Similarly, Stout et.al (2011) concluded that the overall goal of the ABC model is to allocate indirect (support) costs so that the resource demands/consumption of an organization's cost objects (products, services, and customers) becomes more accurately reflected in the cost information.

2.8.1. Costing Model - The Elements of the ABC Model

Turney (2005) argue that the key elements of an ABC model can be summarized in two different views: the *cost assignment view* (vertical view) *and* the *process view* (horizontal view). The cost assignment view (illustrated in figure 17) is the vertical dimension of the ABC model. From top down, it explains that resources (1) are consumed by the activities (3) of an organization. The resource consumption causes costs to occur for a company. These costs need to be measured and linked to the approximate resource consumption rate by the identified activities. This approximation is called resource cost assignment and the links they create is called resource drivers (2). The activities (3) are then linked with cost objects (5), called activity cost assignment and the links that are generated from this step is called activity drivers (4). The cost objects, i.e. products, services and customers (5) are the final outcomes of the activities in the organization.

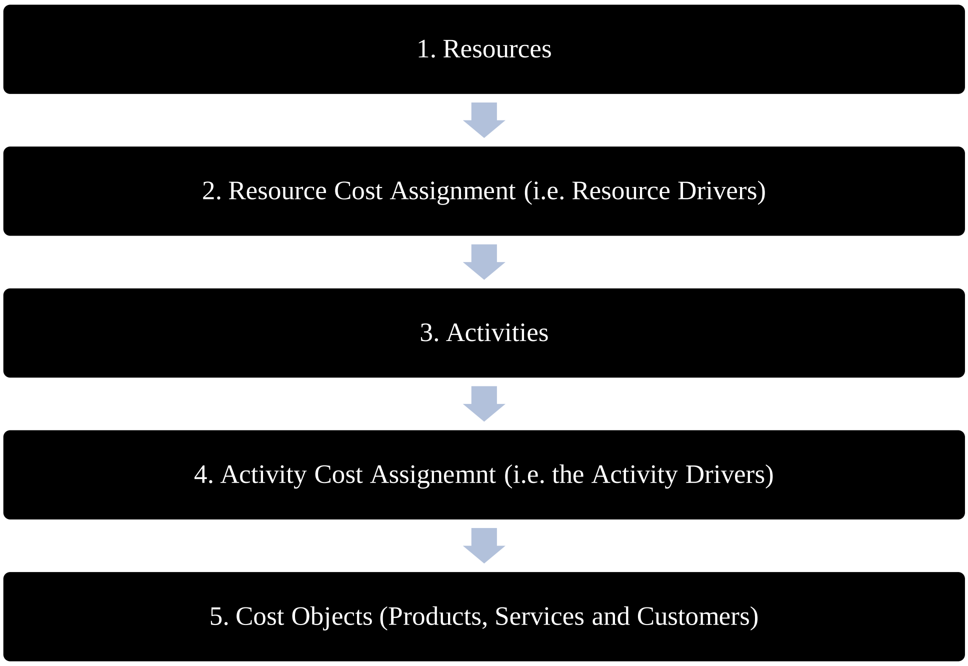


Figure 17. The *Cost Assignment View (Vertical View) of the traditional ABC model*. Source: *Turney (2005, p. 94, figure 5-1).*

Turney (2005, p. 95, figure 5-2) defines eight key elements in the ABC system: (1) resources; (2) activities; (3) activity centers; (4) resource drivers; (5) activity cost pools; (6) cost elements; (7) activity drivers; and (8) cost objects: *Resources* are economical elements, such as human- and/or financial capital and assets, that enables a firm to conduct activities. Resources should be managed with caution, with a good tactical and strategic understanding of values, behaviors and organizational procedures while taking the context/surrounding into account. The resources become costs when they are consumed, or when the proportion “a” (0<a<100%) of the resource is used up. Thus, they are the sources of costs such as the salaries of professionals, staff, cost of processing sales, returns, marketing, office space, cost of information systems etc. *Activities* are the processes or procedures that cause work, usually for achieving a pre-established goal. The goal and contextual factors influence their characteristics. For example, the activities of customer service may be to process an order, to solve product-related problems or processing of new sales orders. These activities are then identified and collected to form activity centers, which are clusters of activities (usually clustered by their relatedness of function or process). For example, the activities of a NPI may be collected by their function, such as marketing functions, sales functions, technical functions etc. Similarly, Drury (2012) argue that activities consist of the aggregation of many different tasks (marketing task, sales tasks, customer service tasks etc.), events or units of work that cause the consumption of resources. *Resource drivers* are the factors chosen to approximate the use of resource to activities. Thus, when used, the resource drivers represent the actual measurements or estimates of effort demanded, or resources spent per activity (Turney, 2005). For example, the activities of the customer service procedure may be categorized into: (1) solving customer problems, (2) process returns, and (3) testing returns. The resource drivers will then represent the percentage of customer service resources spent on respective category. For example, solving customer problems (activity 1) make up 60% of customer service resources/costs, while activity 2 & 3 makes up 20% respectively (illustrated in figure 18).

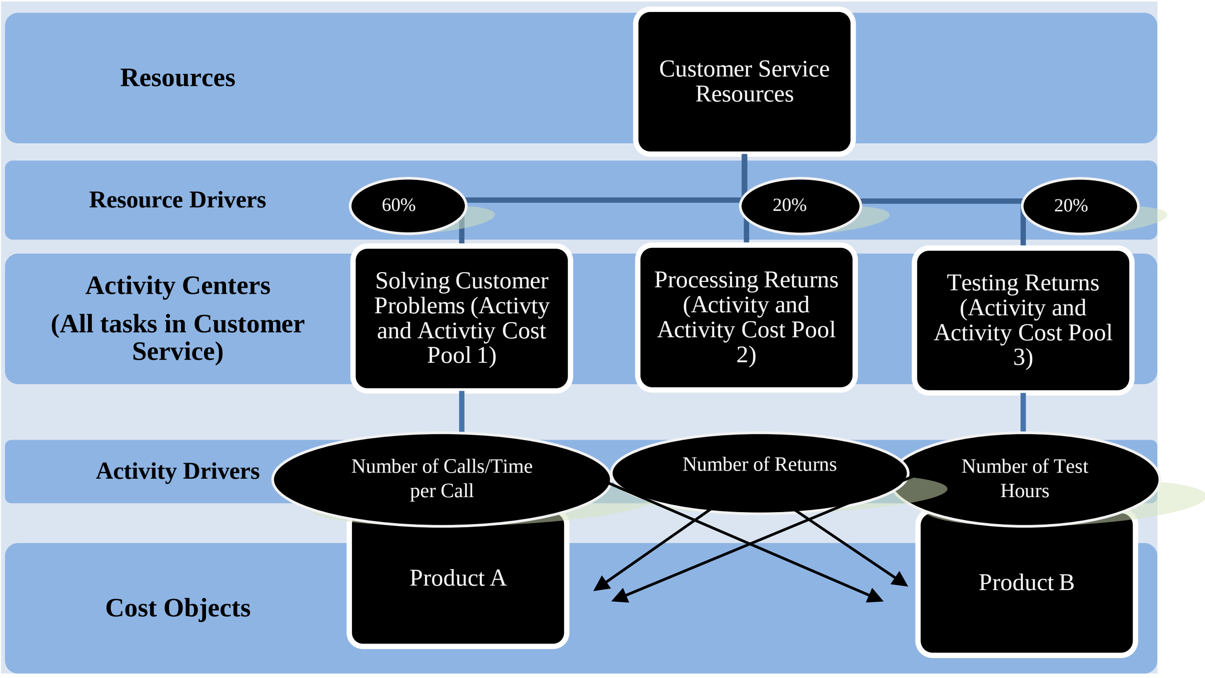


Figure 18. The Building Blocks for the Cost of a Customer Service Department. Source: Turney (2005, p. 96, figure 5-3).

When each resource driver has been identified, and approximated for each activity (e.g. the salary of employees in processing returns and the cost of preparing documents) they become *cost elements* in an *activity cost pool*. The cost elements represent a proportion of each resource, e.g. salary, which is assigned to an activity (for example, converting customer requirements into precise service specifications). Thus, cost elements are the result of resource drivers, i.e. the cost of the activity. Cost pools are the total of all cost elements of an activity (Turney, 2005). *Activity drivers* are the measures of cost objects' (products', services' or customers') consumption/use of the resources that has been assigned to the activities. They represent the link between cost pools and cost objects. For example, the processing of returns can be linked to a specific product or/and customer. The *cost objects* are the products, services or customers which are the final link to which cost is traced in the ABC model. Cost objects represents the reason why cost elements occur, why activities are performed, and why resources are needed/consumed. They are also being used as the purpose to motivate and support decisions in what and how much resources per activity that should be invested in.

Turney (2005) argue that the basic elements provided from the assignment view and process view (figure 19) provide the building blocks for creating accurate and useful cost information about the strategy and operations of a firm.

Figure 19. The Process View of the traditional ABC model. Source: Turney (2005, p.94, Figure 5-1)

The process view is the horizontal dimension of the ABC model which supply information about the performance of activities based on two key aspects: *cost drivers* and *performance measures* (Turney, 2005). The cost drivers are casual variables that determine the workload of an activity generated from different sub-activities/tasks or moments of processes. For example, the number of sales per customers determines the number of order processes that needs to be administrated. Thus, order processing can be considered as sub-activities of sales activities or individual tasks of after-sales staff. Other examples of cost drivers are that the number of defects or product enhancements ordered by a customer or/and for a product. The number of defects determines the time and resource consumption for activities such as maintenance. The number of product enhancements ordered determines the time and resources consumption for related activities such as installation and customer education services. Furthermore, the time and resources spent on training of staff and customer educational services for a new product are cost drivers for educational activities. Turney (2005) argue that the identification of cost drivers allows organizations to prioritize among activities and cost objects based on efficiency gains. For example, a reduced number of different products reduce the need to invest in education and product-related knowledge. However, it is important to take strategies, goals and long-term perspectives into consideration when making such decisions, e.g. a reduced number of products may be contradicting to a firms' strategy or detrimental to customer satisfaction. This is where performance measures come into the picture, the second aspect of the process view. The performance measures of an ABC model should define how well an activity meets the needs of its internal customers (stakeholders: owners, managers, employees, suppliers etc.) and/or external customers (buyers or/and users of a firm's services/products). The measures and metrics should reflect the differences in customers' needs and organizational requirements. For example, the number of customer complaints is an appropriate performance measure for customer service activities, while the number of defects can be associated with the quality engineering (getting things right from the start). The performance measures can be compared with performance goals (performance evaluation) or compared with the performance of comparable activities inside or outside the company (benchmarking).

Drury (2012) suggest that a two-stage allocation process should be used when establishing indirect cost rates too specific cost objects of an organization. Similar as the assignment view, the first stages incorporate a vertical view, while the second stage includes a process view/horizontal view (figure 13). The two-stage allocation process means that activities and indirect costs first are identified to generate resource drivers, cost centers and cost pools. Then this information is used to select cost drivers and calculate/measure the cost rate per task, i.e. to measure the value/rate of each cost driver, and finally assign these cost rates per activity to specific products, services or customers. This is to provide a better understanding of the overhead expenses and to ascertain its cause-and-effect relationship between the cost of activities and specific cost objects (Chouhan et.al, 2016). A theoretical example of the ABC method is illustrated in Table 1.

Activity (1)	Activity cost (2)	Activity cost driver (3)	Quantity of activity cost driver (4)	Activity cost driver rate (5)
Marketing				
Web- advertisement	*$20,000*	*Number of Ads.*	*10*	*$2,000*
Press-releases	*$50,000*	*Number of Pres.*	*2*	*$15,000*
Advertisement Newspaper	*$30,000*	*Number of Ads.*	*4*	*$12,500*
Training				
Sales training	*$70,000*	*Number of hours.*	*100*	*$700*
Service training	*$80,000*	*Number of hours.*	*100*	*$800*
Sales				
Sales calls	*$6,000*	*Number minutes*	*300*	*$20*
Sales meetings	*$90,000*	*Labor hours*	*45*	*$2000*
Assigning cost drivers to cost objects				
Activity (1)	**Activity cost driver rate (2) (derived from col. 5 above)**	**Quantity of activity cost driver used by 100 units of product A (3)**	**Activity cost assigned to product A (Col.2 x Col.3)**	
Marketing				
Web- Advertisement	*$2,000*	*5*	*$20,000*	
Newspaper advertisement	*$12,500*	*2*	*$25,000*	
Press-releases	*$15,000*	*1*	*$15,000*	

Training				
Sales training	*$700*	50	*$35,000*	
Service training	*$800*	50	*$40,000*	
Sales				
Business travels	*$100*	50	*$5,000*	
Sales calls	*$20*	150	*$3,000*	
Sales meetings	*$2000*	22,5	*$50,000*	
Total indirect costs			*$193,000*	
Units of products:			*100*	
Overhead costs per *unit:*			*$193*	
Direct cost per unit:			*$100*	
Total cost per unit of output:			*$293*	

Table 1. An illustration of cost assignment with an ABC system. Source Drury (2012), Exhibit 3.3, p.59.

2.8.2. Costing model - Practical evidence using the ABC model

Bukovinsky et.al (2000) performed a case study of a robotic company in the U.S. in which they applied ABC method for sales and administrative cost in the manufacturing industry. They emphasized on the importance of collecting information for specifying and assigning costs to activities and presented three phases of this process:

- Identify what the company does and its activities.
- Appropriate assignments (resource drivers) to determine the cost of the activities.
- Determine activity drivers to assign the activity costs to cost objects.

Their case study started with questionnaires, asking employees two questions to define activities: *What did they feel was the function of the department? Given the authority, how would they allocate costs?*

The results from their case study resulted in more transparent information regarding the magnitude of expenses in the firm. They concluded that that ABC is as helpful in the administrative and marketing areas as in the manufacturing area (Bukovinsky et.al, 2000).

Chouhan et.al (2016) presents a similar research approach when building the ABC model for a company's manufacturing process, divided into six phases:

1. Analyzing the process and build a schematic view of it.
2. Identify activities through a detailed interview with management.
3. Identify cost elements and define the scope of cost data related with material, objectives of their use, time factor and source of data to provide help for developing the ABC model.
4. Collect the cost on the basis of activities, meaning that the costs association with specific activities are identified. Additionally, cost pools were developed by aggregating the associated costs. This resulted in the identification of 10 cost pools.
5. Classification of cost drivers was done by a cost analysis and the identification of cost drivers for each cost pool through a discussion with management and supervision form employees.
6. Assignment of cost was done by using suitable cost drivers to identify cost objects. This phase also included analysis of the activity model and revelation of process flows.

When the ABC model was build, the next step was to implement and test the system. Chouhan et.al (2016) underline the importance of developing a 'ABC team' which include active participation of top, middle and low Managers. The result form their empirical study and implementation of the ABC model suggest that the ABC logic is a good way to improve management accounting systems to drive strategic decisions not only in the area of overheads but also in the area of other heads of cost accounting. They concluded that ABC can become a technique for the purpose of controlling indirect inventory costs and a medium to improve the operations decision-making. The managers of the company agreed that the model can be proven very helpful and appropriate in valuation and reporting for inventory.

Jänkälä and Silvola (2012) conducted a study regarding how the ABC model influence firms' financial performance based on a survey and archival data. The survey covered information on the use of the ABC and organizational characteristics of small and independent Finnish firms with 10 to 49 employees. The chosen firms that had adapted the ABC model were struggling with a negative growth and a positive profitability prior to their ABC implementation. Their results showed that the firms who conducted large-scale implementation had an improved financial performance within a period of 1 and 2 years. This was relatively better than those who did not implement the ABC system to the same extent whether or not they had better or poor past profitability performance. However, those who had better past profitability performance was not able to improve their subsequent profitability so much as the firms with poorer past profitability after implementing the ABC.

Jänkälä and Silvola (2012) suggest that the ABC model may be a helpful tool for mangers in their operative decision-making and management. This starts in the creation of the ABC model as managers need to think about their business processes carefully and identify all the activities associated with the cost drivers of the process. Therefore, managers will deepen their understanding of both the organizational costs and cost structure on activity level in their firm. Additionally, by using accurate and relevant cost information in decision making, managers can make more profitable product mix decisions. ABC may also assist managers to focus marketing on the most profitable products and customers in generating growth.

Cagwin and Bouwman (2002) study of the use of ABC and its impact on financial performance, return on investment (ROI). Their survey was conducted with questionnaires mailed to employed internal auditor who are members of the Institute of Internal Auditors (IIA). The results from their study showed a positive association between use of ABC and ROI. Firms who simultaneously used of ABC, JIT, TQM, etc. had a net improvement in financial performance greater than that obtained from use the same strategies without ABC. Furthermore, the results from their study indicate a positive synergy between ABC and improvement in ROI when:

- implemented in complex and diverse firms,
- in environments where costs are relatively important and
- where there are limited numbers of intra-company transactions to constrain benefits.

However, there exist no practical evidence from their study that demonstrates that the benefits of ABC are greater than the cost it incurred to adopt and maintain. Although they identified an overall positive synergistic effect from the concurrent use of the strategies, they could not address which specific initiatives provide the effect or whether there may be causal ordering of initiative that is important (Cagwin and Bouwman, 2002).

2.8.3. Costing model - ABC & Business Context

Kaplan and Cooper (1998) suggest that service companies are ideal candidates for the ABC method, because most cost in service firms are indirect, and constitutes a large proportion of the total costs. Drury (2012) suggest that ABC system may be optimal for organizations having an intensive competition and a diverse range of products that consumes organizational resources in significantly different proportions.

Dickinson and Lere (2002) agree on Jänkälä's and Silvola's (2012) perspective that ABC offers a way to improve performance evaluation for the firm wishing to focus on profit growth. However, their recommendation is specifically for firms struggling with increased marketing costs, constant sales, and accounting information that doesn't evaluate sales representative performance in a good way. For example, sales representatives may agree to terms, e.g. numerous hours of customer training, in sales negotiations that increases a company's costs without consequence to his or her own compensation. Similar, in closing a sale, a sales representative may use large quantities of resources. Traditional costing methods do not provide estimates of the increase in firm cost arising from the activities necessary to satisfy these terms. Thus, sales representatives are not discouraged from costly behavior (Dickinson and Lere, 2002). However, ABC recognize the variation in costs as a consequence of changes in other than production volumes such as the amount of time for customer training, referred to as product-level activities. Thus, ABC permits one to estimate the cost of activities associated with marketing and sales resource consumption (sales calls, trade shows, bid preparation etc.). This could increase the sales representatives' understanding of the impact of his or her decision on firm cost and profitability.

2.8.4. Costing model – Developing the ABC

Kaplan and Copper (1998, pp. 79-99) suggest a four steps process for the designing of the ABC model: (1) develop the activity dictionary; (2) determine how much the organization is spending on each of its activities; (3) identify the organization's products, services or customer; (4) select activity cost drivers that link activity costs to the organization's products, services, and customers.

Turney (2005) argues the ABC developers should adhere to "the seven P's": Proper Prior Planning Positively Prevents Poor Performance, and that the following seven questions need to be answered when developing the cost model:

1. Formulate Objectives: What will the ABC model accomplish?
2. Describe Deliverables: Describe the improved information that will satisfy each of the objectives.
3. Set the scope: Determine how extensive a project you will pursue
4. Create the organization structure: Determine how the project will be organized and who will participate.
5. Determine the training requirements: Determine the type and scope of training needed for management, implementers, and users.
6. Complete a project schedule: Determine what tasks need to be accomplished and how long the project will take.
7. Budget the project costs: Estimate the resources required to complete the project.

Turney (2005) argues that there are three primary sources for ABC information:

1. The accounting department has information about the cost of resources, usually obtained from the general ledger.
2. Information about what the activities are, how they consume resources and what cost drivers and performance measure to use comes from the people who do the work or are knowledgeable about the work.
3. Information about cost objects, activity drivers, and some performance measures is found in the company's information systems.

2.8.5. Costing model - Challenges with Activity-Based Costing

Despite the hype around the ABC model, there are several concerns regarding the cost and time consumed for the development and implementation of the accounting system. The results of the study by Jänkälä and Silvola (2012) suggest that small firms that struggle with poor development of sales activate the use of ABC. Furthermore, the results indicate that the chosen firms of the survey that actively used ABC experienced a decreased in growth during the year of the survey. However, this was later turned into a more significant increase in growth after two years compared with the more passive users of ABC. This may suggest that the improved performance was a consequence of improved cost-efficiency and improved competitiveness achieved in the market of small firms using the ABC more extensively. Thus, Jänkälä and Silvola (2012) concluded that their findings suggest that the improvements in growth of small firms using ABC more extensively become visible in two years. This is consistent with the findings from the study of Cagwin and Bouman (2002) that suggest that ABC us unlikely to be associated with significant financial benefits unless it is used extensively. Furthermore, an ABC adoption is a long-term investment that starts to generate financial benefits over time. However, they also acknowledge that performance is a complex and multidimensional construct that can be reflected by many various indicators. Thus, it may be difficult to assess the direct link between financial performance and the ABC model (Jänkälä and Silvola, 2012).

Max (2007) argues that early adapters of the ABC model have struggled with capturing significant ongoing value from their ABC investments. They relied on surveys, estimates, and large staff groups to: maintain the systems, provide reports and interpret the information for the users. Kaplan and Anderson (2004, p. 1) argues that "*many companies abandoned ABC because it did not capture the complexity of their operations, took too long to implement, and was too expensive to build and maintain*". They argue that the traditional ABC model works well in the limited setting in which it is initially applied, typically a single department, plant or location. However, difficulties arise when the model is applied on a large scale for ongoing use.

Max (2007) argues that the allocation of time across employee's pre-defined activities, for example, processing loan applications, is only appropriate in situations where roles remain relatively static over time and where the effort to service customers is relatively homogeneous. Furthermore, they argue that using average costs as the basis for decision-making can hide the wide variations that come from different services levels, unique customer demands, products, service channels etc.

Velmurugan (2010) argues that ABC is feasible for initial pilot studies, but is difficult and costly to scale to company wide application and the main barriers is administrative and technical complexities this barrier. Furthermore, findings from research suggest that behavioral and organization factors play an important role in ABC implementation strategies. Thus, the implementation process of ABC should be tailored to specific cultural context.

2.8.6. Costing model - Time-Driven Activity-Based Costing

Despite the challenges and barriers of implementing the ABC model, Kaplan and Anderson (2004) argues that the solution is not to abandon the concept, but to modify it. They argue that the ABC model have realized several process improvements, cost- and profit-enhancement opportunities. Further, the problem with the ABC model originates from the difficulties of maintaining and updating the model when: (i) process and resource spending change, (ii) new activities are added, and (iii) increases occur in the diversity and complexity of individual orders, channels and customers. However, the model can be adjusted in order to maintain or enhance its benefits while making ABC less complex and less expensive. They propose the *time-driven ABC (TDABC)*, which they have successfully helped 100 client companies implement, such as Kemps LLC (an American dairy company), Klein Steel (a steel service company based in New York) and Banta Foods (a food distributor based in the U.S.). They argue that practical application of the TDABC model has led to substantial improvements in profitability for their clients. The time-driven ABC includes only two parameters that are simpler to update: (1) the unit cost of supplying capacity and (2) the time required to perform a transaction or an activity.

Kaplan and Anderson (2004) suggest five main moments when building the TDABC model: (1) *Estimate the cost per time unit of capacity;* (2) *Estimating the unit times of activities;* (3) *Driving cost-driver rates,* (4) *Analyzing and reporting costs;* and (5) *Updating the model.*

Estimating the cost per time unit of capacity (1) is the direct estimate of the practical capacity of the resources supplied as a percentage of the theoretical capacity. There are various ways to do this. One way is to let managers, as a rule of thumb, assume that practical full capacity is 80% to 85 % of the theoretical full capacity. This means that if an employee work 40 hours per week, its practical full capacity is 32 to 35 hours per week. The time that counts as full capacity may be the actual hours of performing the most common, day-to-day tasks of one's responsibility, or work that is directly related to customer value generation. For example, the expenses for providing education and service for external customers can be regarded full capacity utilization by customer services teams or technicians. But the expense for providing travels and services to internal customers is not included in full capacity utilization. A more systematic approach than the thumb rule would perhaps be to review past activity levels and identify the month with the largest number of orders handled without excessive delays, poor quality, overtime, or stressed employees. For example, suppose the after sales department employs 10 people to do the front-line work and that each put eight hours a day. In theory, therefore, each worker supplies about 40 hours per week. The practical capacity of 80% for each employee is therefore 32 hours per week and 320 hours in total per week, which is 19200 minutes per week. The total practical capacity of 19200 minutes will divide the total salary of the department per week, say $12 000, to get the cost per minute of supplying capacity ($0,625). Time availability is the most common way to measure resource capacity. However, the capacity of resources can be measured in other units in the TDABC system. For example, the space provided in warehouses would be a measure for warehouse capacity, and the megabytes supplied in memory storage would be the capacity for the memory storage. Hence, the first step is to calculate the cost per time unit of supplying resource to different business's activities. Regardless of what approach you prefer for this estimation, it's important not to be overly sensitive to small estimation errors. The objective is to be approximately right, for example, accepting a deviation of 5% to 10 % of the actual number. Major estimation errors will be revealed by the TDABC system over time (Kaplan and Anderson, 2004).

Estimating the unit times of activities (2) includes the estimation of the time it takes to finish one unit of each kind of activity. For example, the time it takes for the after sales department to process customer orders, handle customer inquiries and prepare product maintenance service. This data can be obtained through interviews or direct observation in which respondents estimate the approximate time it takes to conduct each process. The estimation should not be in percentage and the questions should be how long it takes to complete one unit of the activity, e.g. the time required to process one order. It is sufficient for this estimate to be roughly accurate. For example, let's assume that managers determine that it takes 8 minutes to process one order, 44 minutes to handle an inquiry, and 50 minutes to perform a credit check (Kaplan and Anderson, 2004).

Deriving cost-driver rates (3) is the rate of how much cost each unit of an activity takes to perform. This is calculated by multiplying the unit times of activities with the cost per time unit of capacity. Hence, this means that you calculate the given estimations from the previous two steps. From the previous two examples, we have that the cost per minute of supplying capacity is $0,625 and the estimated unit times of order processing (8 min), customer inquiry administration (44min) and to perform a credit check (50 min). Thus, the cost driver rates are $5 per order processing, $27, 5 per customer inquiry administration and $31, 25 to perform one credit check. Once all standard rates have been calculated, you can apply them in real time to assign costs to individual customers and/or products as transactions occur. These rates can also be used in negotiations with customers about the pricing of new business. The advantage compared to the traditional ABC method is that the TDABC allows us to know the actual time consumed by the utilized practical capacity. The traditional ABC method would assume that employees' practical capacity always was fully utilized. This would result in higher cost driver rates and less informative measures to support decision-making. Although the traditional ABC method reflects how workers spend their productive time, Kaplan and Anderson (2004) argues that it would, in this example, ignore the fact that total productive time is 8 hours less than the 40 hours per worker and per week. The calculation of resource costs per time unit (of capacity) solves this problem by incorporating estimates of the practical capacity of resources. This allows ABC cost drivers to more accurately reflect the cost and the underlying efficiency of organizational processes (Kaplan and Anderson, 2004).

Analyzing and reporting costs (4) is the aspect of TDABC that allows managers to report their costs on an ongoing basis in a way that reveals both the costs of a business's activities as well as the time spent on them. These reports will highlight the difference between capacity supplied (both quantity and cost) and the capacity used. This enables managers to analyze the cost of unused capacity and contemplate actions to determine whether and how to reduce the costs of supplying unused resources in subsequent periods. It allows them to monitor these activities over time. In some cases, in times of expansion, this information can save companies from making unnecessary new investments in capacity. Kaplan and Anderson (2004) support this argument by providing a practical example from their study of a hose and belt fabricator based in Pittsburgh, called Lewis-Goetz. The vice president of operation at the company saw from his TDABC model that his plants only operated 27% of capacity. This information allowed him to use the free capacity of 73%, rather than downsize it, for a contract he expected to win later that year, for which he otherwise would have created new capacity.

Updating the model (5) refers to the simplified process of updating ABC model when using the time driven approach. Adding more activities into the TDABC model do not require any new interview of personnel, instead they can simply estimate (approximate) the unit time required for each new activity. This is then included in the calculations. The time driven approach also simplifies the process of updating the cost driver rates. Cost driver rates change because of two factors: changes in prices of resources supplied and shifts in the efficiency of activities. Changes in prices of resources supplied may occur due to an increase in employee compensation or the substitution or adding of new machines. For example, if the salary increase by 8 %, then the cost drivers' rates from previous examples changes to $5,4 per minute for order processing, $29,7 per minute of administration of customer inquiries, and $33,75 per minute to perform one credit check. The second factor that causes change in driver rates change (shift in efficiency of the activity) may be caused by quality programs, continuous improvement efforts, reengineering, or the introduction of new technology. This can enable an activity to be performed in less time or/and with fewer resources. When these changes occur, the ABC analyst recalculates the unit time estimates (and thus the demands on resources) to reflect the process improvements. For example, if the after sales department get a new ERP system that perform a standard credit check in 20 minutes rather than 50 minutes. The change is simply accommodated by changing the unit time estimate to 20 minutes, and the new cost driver rate automatically becomes $12,5 (based on $0,625 cost per unit of supply capacity). In this case, Kaplan and Anderson (2004) underlines the importance of adding the cost impact of purchasing the new ERP system by updating the cost per time unit estimate, so the final figure may be somewhat higher than $12,5. Furthermore, they argue that updates should be done on the basis of events rather than on the calendar (e.g. once a quarter or annually), so that TDABC figures reflect the current conditions more accurate. Hence, anytime the TDABC analysts learn about major shifts in the cost of resources supplied or if the time to perform an activity changes, they update the resource cost per unit or resource cost rate estimates. Similarly, if they learn of major performance shifts in the efficiency with which an activity is performed, they update the unit time estimate (Kaplan and Anderson, 2004).

2.8.7. Costing model – A practical example of TDABC

Stout et al. (2011) conducted a pilot study of implementing TDABC on the existing ABC structure in a domestic consumer-electronics manufacturer. They argue that TDABC require an effective Enterprise Resource Planning (ERP) system to implement and maintain the TDABC system effectively. The ERP system is used in TDABC to eliminate the time for surveys, to develop time equations, and process a multitude of transactions (activities and costs) on a reoccurring basis. Their pilot study illustrates the importance of ERP in relation to TDABC implementation.

Stout et.al (2011) used a two-step process when applying TDABC to cost centers. One of the cost centers was domestic order processing consisting of support costs (salaries, office space, and the like), from two departments: the accounting department and the customer service department. The customer service department included three activities: (1) entering and monitoring orders, (2) create priority list and (3) manage invoices and payment. The accounting department included the same manage invoices and payment activity. Thus, there was in total three activities in the cost center of the traditional ABC structure. These cost centers only used one singe cost driver to assign their costs to cost objects, which was the number of sales orders processed. As argued before, the traditional ABC system do not allow for capturing of potential cost differences that occur from order to order when using a single drive. This is because one singe cost driver assumes that every sales order is the same and an average cost for each activity driver (an average measure of cost linked to the cost object) used to calculate the cost per cost object.

In the first step, Stout et.al (2011) followed Kaplan and Anderson (2004) examples to calculate the cost per time unit of capacity (e.g. the cost per minute of a specific task/moment). This is also known as the capacity cost rate for a cost center and is calculated by dividing the cost of capacity supplied (in this case consisting of employee costs, utilities, machines and the like) with the practical capacity of resources supplied (the time available for employees performing work in the cost center). Hence, the selected cost driver was the time available for the employees performing the order processing work in each of the two departments. The cost of capacity supplied was determined by the managers which estimated that it was $6,624 per quarter. They estimated the approximate time dedicated to domestic order-processing per employee which was 9068 minutes (31 % or full-time9) 878 minutes (3% of full-time) and 1800 minutes (100% of part-time) respectively and 11745 minutes in total per quarter. Thus, the total practical capacity of resources supplied was 11745 minutes per quarter. They divided the cost of capacity supplied ($6625) with practical capacity of resources supplied (11745 minutes) and got a capacity cost rate per minute of $0, 56.

In step two, Stout et.al (2011) continued to follow Kaplan and Anderson (2004) examples and developed time equation which estimated the unit time required to perform each of the three activities in the cost center. This was estimated together with the managers to identify the factors (customer behavior) that cause time for each activity to vary. They concluded that depending on the characteristics of transactions, the time consumption in the cost center range from 5.75 minutes to 12.5 minutes per transaction. The order transaction characteristics selected was whether a customer ordered via the Web (2 min per order), phone (3.5 min per order) or visit (4 min per order). Furthermore, order transaction time consumption was categorized and estimated whether the customer ordered address change (0.5 min per order), warranty (0.5 min per order) and advice (1 min per order) etc. Then, by multiplying the capacity cost rate ($0.56/minute) by these time estimates they showed that the cost assigned to a single transaction ranged from $3.22 to $7. This variation was not able to be detected with the traditional ABC system which only showed an average cost of $7 for each activity since it assumes with one single cost driver that every sales order is the same. This variation allowed management to conduct a more detailed customer- and product-profitability analysis as it became clear which factors of a customer order that costs more or less. For example, a customer order via the Web (PayPal) cost much less than a pay with phone or a check. Furthermore, the approximation of time dedicated for each type of order transaction med in the TDABC model resulted in a lower rate of total assigned cost to domestic order-processing activities ($3872) than the cost of resources ($6624). This provides managers with valuable information since it indicates that the cost center (the aggregated activities), in this case domestic order processing, was most likely working under capacity. Although this disappearance may be captured in the traditional ABC model, TDABC eliminates the subjective process of having employees account for their time as the user of the TDABC system estimates the unit time related to each activity. Hence, Stout et al. (2011) concluded that a TDABC model can provide more accurate costing information than a traditional ABC model.

2.8.8. Designing the TDABC

Turney (2005) argues that designing an ABC model is a critical stage of the implementation process and suggests six steps, each consisting of several rules (see appendix for complete list), when designing an ABC or TDABC model: *(1) Identify activities, (2) reconstruct a general ledger, (3) create activity centers, (4) define resource drivers, (5) determine attributes, (6) select activity drivers.*

1. *Identify activities* is the step of deciding how many details of an activity that should be measured and how to define and describe each activity. When developing the TDABC model, this step also includes the estimation of practical capacity for as many activities as possible.
2. *Reconstruct a general ledger.* This step means that the details of financial data and costs from the general ledger are reduced and adjusted to the needs of the TDABC model.
3. *Create activity centers* means that activities are grouped and reported in a way that is meaningful for the user. Including departmental and cross-functional reports of activities.
4. *Define resource drivers.* This step links the cost to the activities which means that the resource drivers represents the measures used to calculate the cost of activities. The goal is to select resource drivers that

accurately measure the cost of the activities without requiring an excessive amount of time and effort to use in the model.

5. *Determine attributes* means that labels that enhance the meaning of activity-based information are attached to the data system.
6. *Selecting activity drivers* is the step where metrics that represents the cost of activities is assigned to cost objects so that products, customers and other cost objects are costed accurately. In the TDABC model, activity drivers are defined as quantities of outputs, e.g. the number of sessions of staff training per product or customer education per customer/product. It is also defined as the processing time per unit of each cost object, such as the time it takes to finish material preparation, product documentation, NPI process documentation, prepare ads, plan an in-house etc. The assigning of activity costs to cost objects has six rules:

2.9. Information for decision making – Activity Based Management (ABM)

The early adopters of ABC realized that its use could be extended beyond product costing to a range of budgeting and cost management applications, described as *Activity-Based Management (ABM) or Activity-Based Cost Management (ABCM)*. ABM is based on the evidence that activities consume costs and focuses on managing activities that make up organizations to manage costs in the long term. The primarily goal of ABM is to manage the activities that influences customer satisfaction while doing this with fewer demands on resources (i.e. cost reduction). Thus, ABM should provide information on what activities are being performed, the cost of each activity, why the activities are undertaken, and how well they are performed. This requires an understanding of what factors cause activities to be performed and what causes activity costs to change. Budgeting with ABM is based on the cost by activities and provides information on why costs are incurred and the output from the activity (in terms of cost drivers, i.e. factors (e.g. a new product) that causes the change in activity's cost) (Drury, 2012).

ABM can be divided into three hierarchical levels: (1) Activity Analysis (AA), (2) Activity cost Analysis (ACA), and (3) Activity Based Costing (ABC). AA is the identification of activities and procedures carried out to convert resources into outputs. In addition to that, ACA identify the costs and the cost drivers of each activity. Finally, ABC is the highest level which also traces the activity costs to products and services to enable more accurate measurement of product and service costs (Phan et.al, 2014). Thus, Phan et.al (2014) argue that the failure of many prior studies to incorporate the different levels of ABM practices has resulted in an incomplete portrayal of the use and success of ABM practices. AA or ACA can be used for process improvement and cost reduction, but not for making product/service decisions. Many organizations have not implemented ABC as they found most of the benefits in ACA. Furthermore, the Chartered Institute of Management Accountants (CIMA) in UK (2001), argues that ABC become ABM if ABC is used to:

- Design products and services that meet or exceed customers' expectations and can be produced and delivered at a profit;
- Signal where either continuous or discontinuous (re-engineering) improvements in quality, efficiency and speed are needed;
- Guide product mix and investment decisions;
- Choose among alternative suppliers;
- Negotiate about price, product features, quality, delivery and service with customers;
- Employ efficient and effective distribution and service processes to target market and customer segments;
- Improve the value of an organization's products and services.

Turney (2005) argues that ABM aims directly at two goals: (1) to improve the value received by customers, and (2) to improve profits by providing this value. Kaplan and Cooper (1998) argue that ABM accomplishes its objectives through two complementary applications: *operational and strategic* ABM. Operational ABM means *doing things right* which means that organizations should run their processes to accomplish their goals through minimum waste (efficiency), lower cost and high asset utilization. Strategic ABM refers to the effectiveness of organizations, i.e. *doing the right things*, while maintaining a desired level of efficiency. This encompasses shifting the demand of activities from unprofitable services, deals, products or customers towards more profitable uses by the use of the ABC model.

Turney (2005) argues that reducing costs, improving quality, flexibility and service is central to ABM. Cost reduction is done by first changing the way activities are used or performed, and then redeploying the resources freed by the improvement. Turney (2005, p. 146) provides five rules to illustrate how managers can reduce costs permanently with ABM:

Rule 1. Reduce the time and effort required to perform activities.

Rule 2. Eliminate unnecessary activities.

Rule 3. Select low-cost activities.

Rule 4. Share activities wherever possible.

Rule 5. Redeploy unused resources.

Turney (2005) argues that these five rules are as likely to improve quality as they are to reduce cost which makes ABM and quality management go hand in hand. In addition, Turney (2005) argues that the ABC system can be used for Activity Based Budgeting. It means that the more transparent cost information generated from the ABC model allows for more detailed budgeting and the costs linked to the activities can be integrated into business planning processes.

According to the CIMA (2001), ABM support business management by providing information that enables long-term strategic decisions, e.g. product-mix and sourcing decisions. For example, product designers will understand the impact of different designs on cost and flexibility and then modify their designs accordingly. In addition, ABM supports the quest for continuous improvement by allowing managers more insight into sources of cost of activities. This can be combined with other process orientation philosophies such as: Total Quality Management (TQM), just-in-time (JIT), benchmarking and business process reengineering (BPR). Similar as ABM, these are all initiatives designed to improve an organization’s work processes and activities to effectively and efficiently meet or exceed changing customer requirements.

2.9.1. Information for decision making – Income effects of costing system

Variable costing, also known as marginal costing or direct costing, includes both direct- and indirect costs and is used to estimate profit and loss accounts illustrated in figure 20 (Drury, 2012, pp. 146-7).

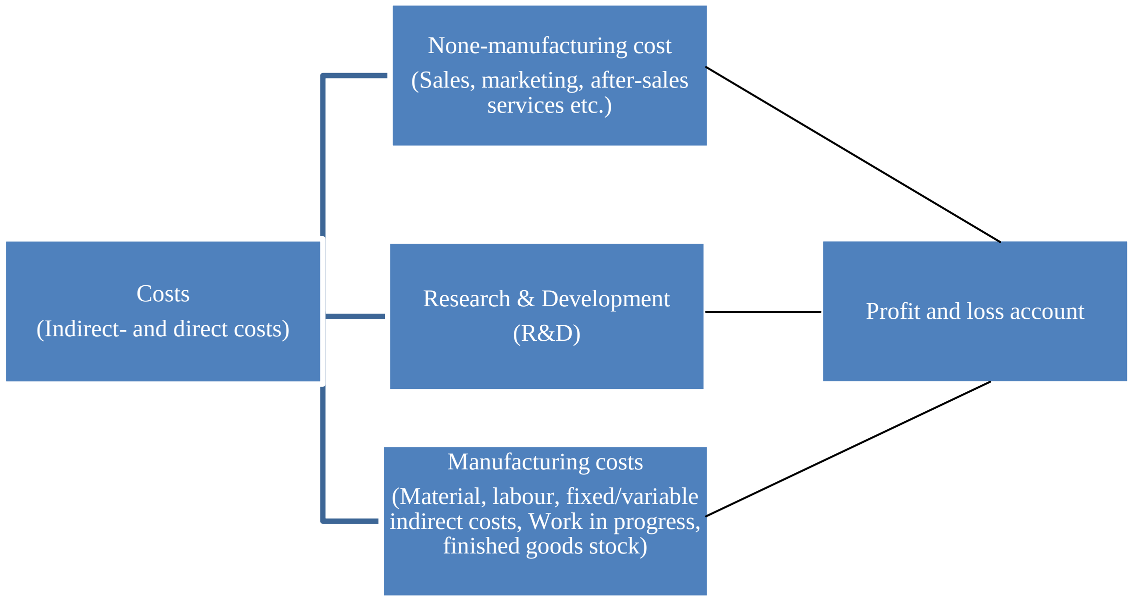


Figure 20. Variable costing system. Inspired by: Drury (2012, p.147). Own developed model.

When the variable costs and sales have been estimated, desirable net profit can be determined through budgeting. Variable costs are relevant for a variety of short term decision-makings such as product-mix and whether to produce an output (product/service) internally or purchase externally (Drury, 2012).

The cost information lays the foundation for the cost-volume-profit (CVP) analysis, also known as contribution margin (CM) analysis. The CM is equal to the sales revenue minus the variable costs. It can be viewed as the fraction of sales that contributes to the offset of fixed costs. The variable cost measurements and estimations allows companies to (Drury, 2012, p. 168):

- Analyze break-even points, i.e. when the total income of sales equals the cost of sales;
- Determine the effects on profit when the selling price or number of units sold varies;
- Estimate what sales volume is required to meet additional costs arising from an increased input of resources and activities, e.g. increased amount of advertising campaigns;
- Allocate resources to increase net profit etc.

These activities are included in the CM analysis which essentially is the analysis between the cost of input, the revenue volume from outputs (products sold and services) and the volume of profit in the short run (Drury, 2012).

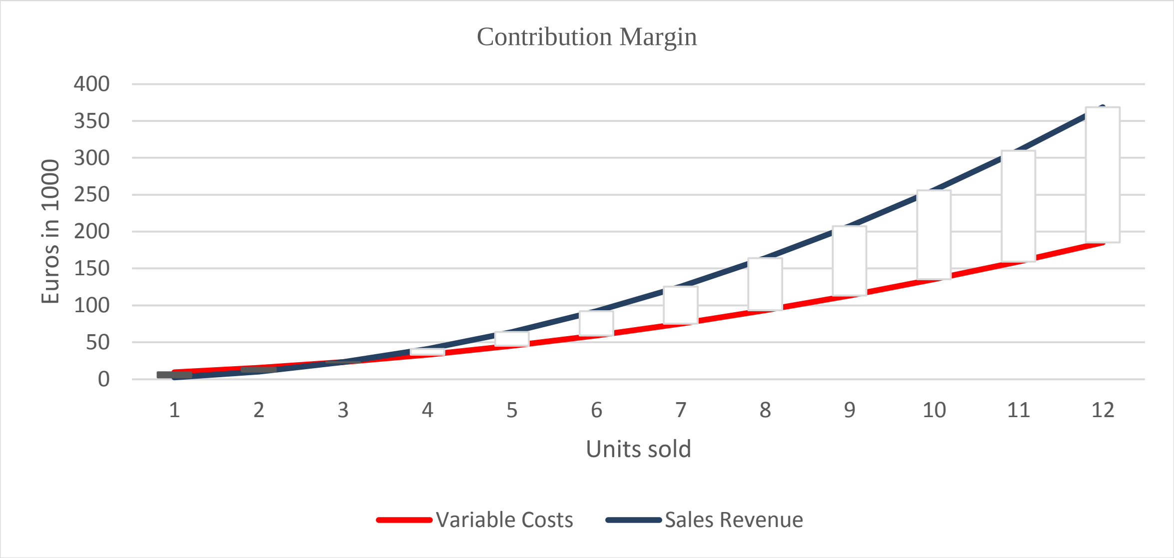


Diagram 1. One example of a Cost-Volume-Profit model. Inspired by: Drury (2012, .169). Own developed model.

Diagram 1 illustrates a break-even point at a total number of 3 units sold where the total revenue (the blue line) equals the variable costs (red line). The fixed costs are independent of variable costs and are approximately 10 000 Euros when there are zero units of outputs produced and sold. Hence, fixed costs are constant and not affected by the variability of activities. Fixed costs may include depreciation of equipment, property taxes, insurance costs, leasing charges etc. The contribution margin is the white markings between the variable costs and sales revenue (Sales revenue – variable costs). When the total number of inputs into the process increases to the point that it causes efficiency and effectiveness of activities to decrease the contribution margin will decrease as well. This is due to the lack of process capacity that causes bottlenecks (Drury, 2012). For example, there may be a lack of capacity to handle an increased number of NPD/NPI projects so that the (variable) costs per activity increases to the point that total cost exceeds the increased number of units sold.

2.10. Cost model communication challenges

There are several risks and challenges associated with the implementation of the cost model. Some of the most challenging concerns the engagement and communication between managers, cost model developers and users as illustrated in figure 21 (next page).

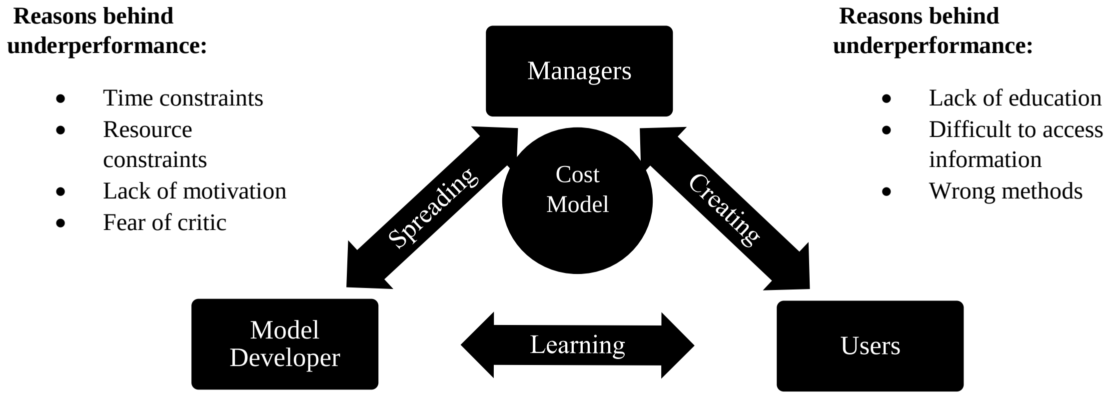


Figure 21. The Challenges with new cost model implementation. Inspired by: Tagemark (2014, p.484). Own developed model.

2.11. Literature summary

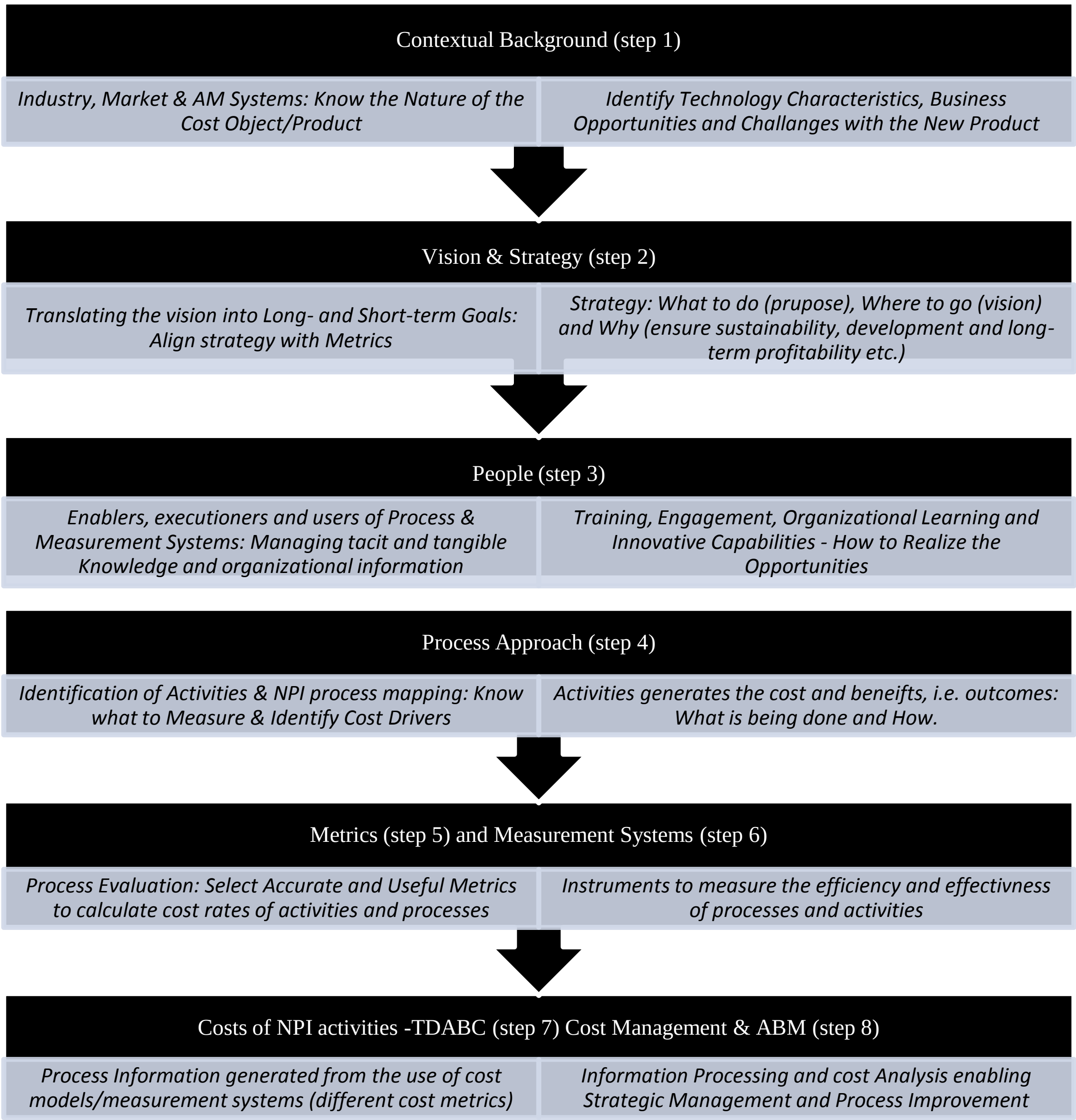


Figure 22. Summary of the literature review. Own developed model.

3. Method

This chapter explains the research design, methods & research plan used to collect, process and analyze the data enabling this research project. This aims to make the research methods replicable and the conclusions and measurements valid.

3.1. Research Design

The research design is the framework for the generation of evidence that is suited for the research question in which the researcher/investigator is interested in. It focuses on the end-product, what type of study that is being planned and what kind of results that are aimed at. This is closely related to the research strategy which can be viewed as the general orientation to conduct a business research (Bryman and Bell, 2011). The design/framework used in this research is a single case-study of TRUMPF. The research strategy has been used to generate both qualitative and quantitative data. The qualitative data has been gathered through interviews of employees at TRUMPF Maskin AB for deeper understanding of the activities in the NPI process in TRUMPF Maskin AB. Quantitative data has been gathered to estimate the cost and time of these activities. In addition, descriptive statistics of the company and the market for *TruPrint 1000* has been gathered to allow for more generalizable conclusions and benchmark. The descriptive statistics regard industry and product characteristics and the performances of the corporations in the industry. The benchmark includes conclusions drawn from the product characteristics and how they influence the NPI process.

The research strategy used in this study is what Ghauri (2004) refers to as the *abductive reasoning* approach, which is a mix between the *deductive* and *inductive reasoning* approaches. Bryman and Bell (2011) defines deductive approach as the theory being used to guide the research and the opposite; the inductive approach as the research guiding the theory. The deductive approach starts by analyzing theory that provide the researcher with knowledge and ideas about what to study empirically (direct or indirect observation and experience) and how to approach that research objective. The inductive approach starts with empirical studies such as explorative and unstructured interviews, discussions of a phenomenon at the organization of interest and participant observations to explore the social context at the organization etc. This then guides the collection of theoretical data and information related to the phenomenon that caught the researcher's interest.

The empirical data has mainly been collected at TRUMPF Maskin AB consisting of interviews with employees and observations. Also, observations have been conducted at the Headquarter of TRUMPF Group in Ditzingen, Germany. The initial part of this study started with several explorative discussions with top managers in TRUMPF Maskin AB regarding what issues the company needed to solve and what researcher needed to – and are interested in studying. Thus, the initial part of the study has an inductive approach consisting of qualitative studies to explore the overall research topic. As the discussions continued more aspects of the company, its business, and issues became clear to the point that it became evident that it was possible to conduct the case-study at the company. However, the research site was not explicitly concluded in this phase since TRUMPF is a multinational corporation (MNC) with many sites in different countries and locations. Thus, making it difficult to locate where to conduct the case-study beforehand and what research participants to include. The location for the case-study and the research participants were instead selected as the research evolved and as more information and data was collected, particularly after the explorative and inductive part of the study.

The research proposal was developed through investigation of literature related to the research topic to create an understanding of how the problem can be encountered given the specific time-frame for this study. The research question was then specified according to the increased understanding of the problem through the literature review. From this point on, the research was deductive, meaning that theory was systematically reviewed to approach the problem and develop solutions.

In this research, the specified research design consists of the single case study of TRUMPF. A case study is according to Bryman and Bell (2011) a detailed and intensive analysis of a single case which is concerned with the complexity and particular nature of the case in question. Thus, the case study of TRUMPF Maskin AB is a study of a single organization, based in Alingsås in Sweden, but with particular emphasis on the NPI process of *TruPrint 1000*. It is an intensive examination of the cost generated from the NPI process in TRUMPF Maskin AB, which in-turn affects the overall performance of TRUMPF Group. This is to provide an in-depth elucidation of the cost of activities in the NPI process. As the company and the NPI process is unique in itself the case study is not set to represent a larger population but rather to elucidate the unique features of the case, also known as the idiographic approach (Bryman and Bell, 2011). In this sense TRUMPF Maskin AB can be viewed as a unique agent with a unique history and with properties that sets the organization apart from other organizations.

TRUMPF has been chosen for the case-study because it is a very innovative multinational company, a pioneer in laser-manufacturing and one of the leader in the industry. Furthermore, the manufacturing industry is moving towards Industry 4.0 and the market size for 3D-printers is expanding. TRUMPF can be considered a driving force of both cases. However, TRUMPF Maskin AB requested improved cost information in the NPI process of their 3D-printer *TruPrint 1000* to improve strategic and operative decision-making. Since the cost of the NPI process is caused by the activities that consume resources, the problem arrived at developing a cost model that can measure these cost. A challenge with this is to make the model as detailed and accurate as possible so that it reflects the actual costs and enables effective use, while it is simple enough to be easy and cost-efficient to develop and maintain.

The deductive part of the study allowed the explicit research sites to be concluded and the problem to be defined in detail. This mix of the inductive and deductive approach is what Ghauri (2004) refers to as the abductive approach. This approach allows for subjective logic analysis as the parameters included in the data input (in this case the time and cost of activities in the NPI process) are allowed to include a degree of uncertainty about their accurate values. This makes it possible to conduct subjective logic analysis in the presence of missing or incomplete input evidence. Consequently, this usually results in certain degrees of uncertainty in the output conclusions which in this case is the cost of the NPI processes in TRUMPF Maskin AB. Furthermore, all costing techniques are estimates that include different degrees of uncertainty. However, the time-driven Activity Based Costing (TDABC) system are arguably one of the most promising techniques to accurately estimate the cost of activities, both to provide useful information for strategic and operative management (Turney, 2005), while minimizing the risk of using the wrong metrics and measures (Kaplan and Anderson, 2003, Kaplan and Anderson, 2004).

3.1.1. Research Design: Case-study details

According to Bryman and Bell (2011), a case-study is a case, e.g. a single person, a single event, a single organization or a single location that is being studied over time. In addition, case-studies are appropriate to get in-depth knowledge of a particular phenomenon in an organization and to elucidate its complex nature. This case-study includes qualitative research consisting of both unstructured- and semi-structured interviews at TRUMPF Maskin AB to get further cost information of the NPI process within the company and how it relates to the performance of the company. Additionally, this explorative case-study consists of quantitative data in the form of descriptive statistics of TRUMPF and the additive manufacturing market. TRUMPF is a multinational family business from Germany founded in 1923 by Christian Trumpf in Stuttgart. It ranks among the world's leading manufacturers of production technology and industrial lasers with 11 181 employees as of 2016 (TRUMPF annual report, 2015/16).

Yin (1994) argues that case study research is to investigate contemporary phenomena within real-life contexts especially when the boundaries between phenomena and contexts are not clear. This task consists of a description of an explorative study of the NPI process of additive manufacturing technologies in TRUMPF Maskin AB as part of the current industrial trend: Industry 4.0. Since the current phenomena of introducing new additive manufacturing machines to the Swedish market doesn't have clear boundaries and is complex processes in their nature, a single detailed case-study is deemed appropriate. The case study is centered around the evaluation of the cost to introduce new additive manufacturing technology from the R&D within TRUMPF Group to the Swedish market.

Case-study researchers tend to argue that they aim to generate an intensive examination of a single case, in relation to which they then engage in a theoretical analysis. The central issue of concern is the quality of the theoretical reasoning in which the case study researcher engages (Bryman and Bell, 2011). This regards how well data support the theoretical arguments that are generated, and if the theoretical analysis is incisive, e.g. does it demonstrate connections between different conceptual ideas that are developed out of the data, is there a match between the data and theory? This case study aims to examine and explain the relationship between the theory and data collected from TRUMPF Maskin AB to investigate the cost in the NPI process of *TruPrint 1000* to the Swedish market. Thus, emphasis will be put on developing measures, i.e. activity cost drivers, used to accurately measure and link the cost of the NPI process to the activities conducted and the product. This is used to support the arguments and conclusions regarding the cost of the NPI process. However, the cost model developer and users should be aware that the more detailed, accurate and complex the cost model is, the more effort and time needs to be invested in the model (Drury ,2012). Thus, this motivates the development of the TDABC model instead of more traditional costing techniques as previous research shows that it involves less complexity while successfully achieving greater and more accurate cost transparency (Kaplan and Anderson, 2004).

Bitektine (2008) argues that the case study can have a role in the testing of hypotheses by conducting what he calls a 'prospective case study design'. It is the development of hypotheses that relate to an ongoing process (for example, the introduction process of a new technology in a particular kind of organization), which are then tested at some point in the future by collecting qualitative or quantitative data that allow the researcher to determine whether the hypothesized patterns correspond to the findings. This case study has been conducted in order to test hypothesis regarding the ongoing process of introducing the new 3D printers from TRUMPF Group and TRUMPF Maskin AB to the Scandinavian market which then has been tested based on the qualitative data collection. The hypothesis has mainly been involved in the processing of previous studies of similar cases. For example, the findings from the case study by Bukovinsky et.al (2000) of a robotic company in the U.S showed that the ABC model generated more transparent information regarding the magnitude of expenses in the firm. Thus, they concluded that that ABC is as helpful in the administrative and marketing areas as in the manufacturing area. This generated the hypothesis that the TDABC model can be helpful in generating more transparent information for the NPI process in TRUMPF Maskin AB. This hypothesis can later be tested by qualitative interviews with the users of the cost model. Furthermore, case studies describe real occurrences, which gives the researcher in-depth knowledge of the origin and interval of a certain event (Yin, 2009). Since this study aims to describe the real cost impact of introducing the new 3D printer *TruPrint 1000*; to give in-depth knowledge of the origins of cost in the NPI process; and to illustrate the interval of this event, a case study is well suited.

3.1.2. Research Design: The process of the case-study

The development process of the case study consists of eight stages that enables the development of the cost model: (1) Context, (2) Cost objects, (3) Strategy, (4) People, (5) Process, (6) Metrics, (7) Costs and (8) the measurement system: the time-driven Activity Based Costing model.

The aim of the context (1) is to provide a more detailed contextual background to this study, based on established literature. This includes a general description of the industry the market and general characteristics of technological innovations.

Then, the cost objects (2) are described which are the products and services that are the final outcomes of the New Product Introduction (NPI) process. These are the Additive manufacturing machines (*TruPrint 1000/ TruPrint Series*) for metal processing that is the focus of the case study.

The role of strategy (3) is then described to include the strategic goals that employees want to achieve with the cost model and then form the model to achieve these goals. This is essential for determining the purpose of the costing model. Similar as metrics and measures enables performance management, the strategy and goals enables them to be used to pursue and achieve these goals by aligning them with each other (Kahn et.al, 2005).

The people (4) are described as both the internal and external stakeholders of the company that enables both the strategy, process and the activities of a firm. The people are the users of the cost model and have the most insight into the NPI processes for which the model is to be used for. They provide information both about the operative and strategic aspects of the NPI process. This makes it essential to involve them in the development of the cost model in order to make it useful. As argue by Tun et.al (2010), the effectiveness of performance measurement systems (PMS) is highly influenced by internal customers, especially by managers and their support towards measurement systems.

The process (5) is described as the activities that are done to facilitate the introduction of the new products. This include modeling the NPI process from start to finish in order to include all NPI activates in the cost model of significant importance to the process, known as a process mapping (Franceschini et.al, 2007, pp.4-5). A hypothesis for this study is that the process map and cost model will make it easier to see the contribution each function is expected to make to the process and can be extended to reflect the goals of each function that contributes to the NPI process as motivated by the arguments of Rummler and Brache (2013, p. 306). Additionally, this includes a more specific description of the activities, how they are linked to the products (*TruPrint 1000, etc.*) and how the activities inputs and outputs are linked with each other. This what Kaplan and Copper (1998, pp. 79-99) calls the activity dictionary.

Metrics (6), in this case the activity cost drivers, are developed based on the process maps and the information provided by the internal stakeholders (employees) of TRUMPF Maskin AB for the cost model. These drivers are aligned with the strategic aspects of the NPI process of *TruPrint 1000* provided by the involved managers from the company. This is to ensure that the metrics reflect the company's operative process and strategic objectives. If neither reflect the operative nor the strategic levels, they well be of no use for the company (melnyk et.al, 2004).

> *"A useful metric is both accurate (in that it measures what it says it measures) and aligned with your goals. Don't measure anything unless the data helps you make a better decision or change your actions." – Seth Godin*

The basis of costs (7) is described to identify relevant cost for the cost model. In this case, overhead or indirect costs are the focus of the study which has been provided by the firm's employees, general ledger and annual report. These are assigned to the activities of the NPI process according the information provided by the internal stakeholders which are the essence of the cost system, needed for two primary reasons (Kaplan and Cooper (1998, p. 2):

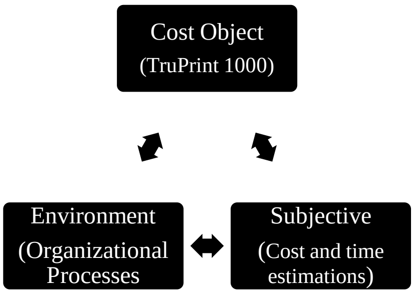
1. *Estimation of cost of activities, products, services, and customers; and*
2. *Providing economic feedback to managers and operators about process efficiency.*

Finally, the aggregation of activity cost drivers (metrics/indicator) forms a measurement system (8), which is the TDABC model for the NPI process. When developing the model, three levels of usage have been taken into consideration (A) *Organization level, (B) Process level,* and (C) *Job/Performer level,* developed by Rummler and Brache (2013). This cost model aim to provide a framework to identify and analyze cost drivers in the NPI process in TRUMPF Maskin AB which later are expected to generate more transparent and accurate cost information. The aim of these eight steps is to provide a framework that can guide the development of a useful cost model for strategic management support and operative improvement in the NPI process. When used, the cost model aim to provide information (activity cost driver rates of the NPI process) that enables decision making that move the NPI process in the firm's desired direction of improved short-and long term performance.

"The key concept is that the metrics are chosen so that actions and decisions which move the metrics in the desired direction also move the firm's desired outcomes in the same direction."

3. *(Hauser and Katz, 1998, p. 520)*

Furthermore, three dimensions have been considered during the design of the case-study. These are (1) subjective perceptions (e.g. subjective cost and time estimations); (2) the study (cost) objects (objective perceptions, e.g. TruPrint 1000); and (3) the (surrounding) environment (TRUMPF Maskin AB organization and NPI processes).



Model 1. The Three dimensions of the research design. Inspired by: Tagemark (2014). Own developed model.

3.2. Research Methods

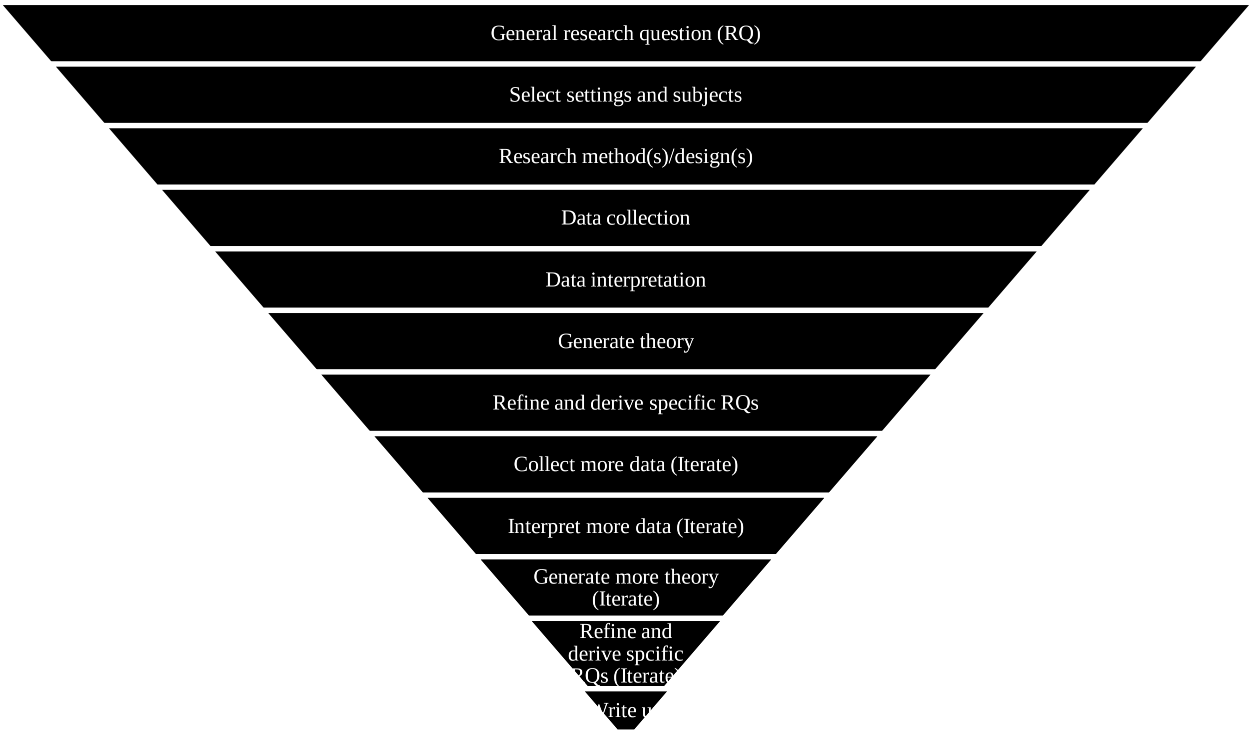
The research method is according to Bryman and Bell (2011) the techniques for collecting data and can involve a specific instrument such as unstructured and semi-structured interviews and interview schedules. It focuses on the research process and the tools and procedures to be used. This study uses mixed research methods, i.e. quantitative and qualitative methods. The researcher has initially used unstructured (qualitative) interviews to explore the research question (RQ) and research topic. Then, as the topic narrows and the final research question is specified, semi-structured (qualitative) interviews are being used to provide a deeper understanding of the topic of the research. The semi-structured interview includes a predetermined interview guide to cover the RQ and research topic explored through the unstructured interviews. These interviews have been complemented with questionnaires to collect quantitative data regarding the time and cost of the activities in the NPI process of *TruPrint 1000.* According to Bryman and Bell (2011), semi-unstructured interviews allow the research to guide the interviews to have focus on the specific research question/topic, while at the same time including open questions that enable the respondents to freely share all information they consider important. The quantitative research process consists of questionnaires to collect quantitative data regarding the cost and time of the activities in the NPI process and descriptive statistics collected from annual reports, the general ledger, and reports of *TruPrint 1000*, the AM market, TRUMPF and its industry (context).

The difference between a semi-structured and an unstructured interview is that the latter is more similar to a common conversation or discussion with a specific topic in mind. The former has a list of questions and a specific topic to be covered, often referred to as the interview guide. However, the questions may not be asked according the interview guide and new questions may evolve during the conversation (Bryman and Bell, 2011) a fashion of which this study followed during the semi-structured interviews. The more detailed data was obtained through questionnaires to enable the cost model.

The participant observations continued throughout the research process which included close contact with the people at the organization and participation in the same activities as the members of the organization and its social setting being studied. This provides a better understanding of the social reality of the organization so that links between behavior and context can be forged. It also allows the researcher to collect information about how decisions evolve as part of the social process at the organization by participating in it for a longer period of time, compare to interviews who are performed during a shorter period of time (Bryman and Bell, 2011). Another benefit with observations is that the researchers doesn't have to rely on a third party's retelling, but collects the empirical information directly by themselves (Esaiasson et.al. 2012). Thus, it is suitable to use observations when it is useful to get a general understanding of a practice, in this case how the NPI process of *TruPrint* in TRUMPF Maskin AB are performed and the resources consumed by its activities. The participant observations evolve during the researcher's performance of tasks and activities from the period of 01-01-17—30-04-17. The tasks include accounting, logistics and after-sale services. In addition, passive observations have been conducted at new product events in TRUMPF Maskin AB in which *TruPrint 1000* was illustrated. Passive observation was also conducted at the Headquarter of TRUMPF in Ditzingen, of product lines in the MNC's laser-machine portfolio including additive manufacturing machines.

3.2.1. The Qualitative research process

The initial phase of this study is qualitative, unstructured and flexible to provide room for different suggestions for research topics, and to allow broader perspectives of research participant. This generated a contextual understanding of TRUMPF Maskin AB, its industry in relation to its NPI process and the problems it faces. The participants in this phase of the study shared their perspectives of what the company needs to explore in relation to innovation management. This eventually resulted in a general research suggestion to explore how the innovations generated from within the company affects their domestic subsidiary TRUMPF MASKIN AB in Sweden. The innovations are mainly generated from TRUMPF's R&D facilities across the world, and the directives comes from its headquarter in Ditzingen, Germany. The general research question that emerged was how to convert the innovations, industrial changes and directives into revenues and advantages for TRUMPF Maskin AB and subsequently for TRUMPF Group. The inductive part/qualitative research process of this study is illustrated by model 2.



Model 2. The Qualitative research process. Source: Bryman and Bell (2011). Own developed model.

The general research question was developed together with TRUMPF Maskin AB: how the innovations created by TRUMPF group affect its Swedish subsidiary TRUMPF Maskin AB. Thus, it is a very general RQ regarding industrial innovation management in a large (>11 000 employees) MNC. However, the selected settings for the study: TRUMPF Maskin AB in Alingsås, Sweden was decided upon in this phase of the research project.

The general research questions were then refined based on the new knowledge about the selected settings and subjects of the case-study and theory about the research topic. The process of data collection and theory were then repeated until the researcher and the initial research participants where clear on-and agreed upon the research question, topic and research design/method.

The qualitative (initial) part of this study consists of unstructured research which is the typical form of qualitative research. It is used to increase the chances of getting the research participants' meanings and concepts emerging out of the data collection (Bryman and Bell, 2011).

A problem with qualitative research is the lack of transparency regarding what the researcher did, how he or she arrived at the study's conclusion and how the process of the qualitative study looked like. The researcher of a qualitative study is sometimes not clear on how respondents were chosen, and it is often not clear of what the researcher were doing when the data were analyzed. Thus, it is difficult for the reader to know how the researcher arrived at a certain conclusion (Bryman and Bell, 2011). This study addresses these issues by thoroughly describing the decision-process of selected the research participants for observations and interviews, and motivate why they were selected. It also illustrates the qualitative analysis process by describing the process of interviews and what was been done during the process of analyzing the data, e.g. how the respondents' answers were illustrated, compared and summarized. The unstructured interviews are performed in closed and quite rooms, through telephones and e-mail. The dialogue is recorded through software-program and notes were taken during the dialog. The answers are illustrated in tables and written dialogs in the appendix.

The qualitative data is processed, illustrated and analyzed in an iterative process as illustrated in Model 1, that means that it is a repeated interplay between the collection and analysis of the data. The data was coded while being collected. The coding consisted of labeling, separating, compiling and organizing the data from interviews and observations.

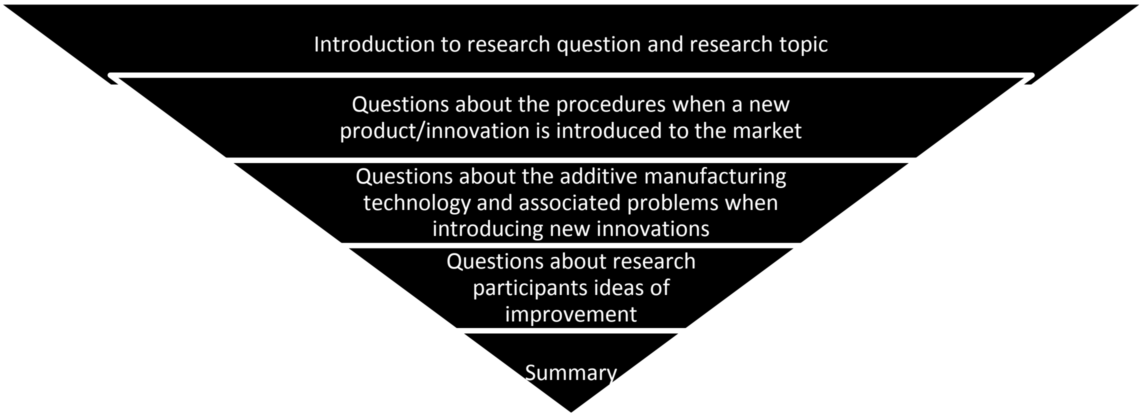
3.2.2. An Overview of the Semi-Structured Interview Guide

The main objective of the interviews is to get insight into the cost of the activities in introducing new products to the Swedish market in TRUMPF Maskin AB with emphasis on *TruPrint* 1000. Another main objective is to get sufficient data of the activities', of their characteristics and function. This data will be used to develop measures and metrics to enable accurate measurement and provide useful information for strategic and operative decision-making.

Since the centrality of the interviews is to highlight the current cost impact of the firm's NPI process, three different interviews were conducted in three different departments, namely: the marketing department, laser-machine sales department, and the after-sales service department. The finance department aims to provide the financial fact-based data of the costs of introducing new innovations to the Swedish market. Further information was requested to complement these interviews and provide a more holistic view of the new technological innovations/products and their impact on the company. This is necessary to provide information that eventually can be used to suggest of how the company can be affected by technological innovations more holistically in terms of cost, to increase the cost awareness and increase chances for improving overall performance.

These interviews aim to expose the company's current NPI process of new technological innovations and provide useful information that can guide later studies and determine what methods that can be used to expose and exploit them further. The interviews aim to provide information that can be used to critically analyze the NPI process of the new technological innovations and its impact on the company's capabilities, resources and business performance. Eventually this led to suggestions of ways to improve the NPI process in terms of effectiveness and efficiency. The new products' current impact and the view of the research participants (the employees from respective department and customers) are essential to determine what methods to use to improve their impact accordingly.

The interviews aim to get a deeper knowledge about the current cost of introducing new product to the innovations to the Swedish market and what cost-drivers and dimensions that needs to be incorporated into the cost model. Thus, in order to expose the research participants' view, there will be flexibility in the conduct of the interviews. Hence, the questions are initially open and general. As the interviews evolve more specific questions were asked related to the subject and research question.



Model 3. The structure of the initial interviews. Own developed model

Types of questions and their order:

1. Introductive questions - Please tell me about the current cost impact of new products on your company. Please tell me about the activities of new product introductions to the Swedish market.
2. Follow up questions - Could you say something more about how technological innovations affect your capabilities and resource? Could you say something about of how the cost developments in the company have changed with the introduction of new technological innovations over time? Could you say something about how the developments of technological innovations will affect your company in the future?
3. Specifying questions – Pleas provide cost data of the activities of introducing *TruPrint 1000* from your department. Have you come across any problem associated with the NPI of technological innovations? How do you think that your current resources and capabilities are matched with the objectives of TRUMPF Group and the demands of customers? How does the NPI process of technological innovations interfere with your regular tasks? Do you think that you have too many projects at the same time to introduce new products? What impact does *TruPrint 1000* have on the resources of TRUMPF Maskin AB when introduced to the Scandinavian market relative to other products?
4. Exemplify – Could you give examples of challenges with the introduction of technological innovations associated with the company and potential disadvantages?
5. Indirect questions – How do most of the people here think that an increased rate or the current continuous introduction of technological innovations will affect the company's overall performance?
6. Interpretation – Do I get this right when...
7. Come back to – Earlier you said…
8. Summarize – Use the notes to summarize what has been discussed so far.
9. Closing question – 'catch all' – Something more you would like to add?

3.2.3. The chosen Respondents and why

The respondents are knowledgeable and experienced people from respective department with deep insight into their respective business processes. Thus, each respondent can provide essential information of the business processes, contribute to insight of the tasks performed, communication channels, competence, visions etc. The problems associated with each department and how they are related can contribute to a holistic insight into the cost of introducing new innovations in TRUMPF Maskin AB and perhaps be to support for future decision making. Table 2 illustrates the semi-structured interviews of the research project. Additional unstructured interviews have been conducted but not included as they were informal.

Date	Interviewees	Job title	Form	Length	Place	Language
TBA	*Mr Hubert Wilbs*	*CEO*	*Face-to-Face*	*2 hours*	*Alingsås*	*Swedish*
2013-03-08	*Mr Mikael Olsson*	*Laser-Machines Sales Manager*	*Face-to-Face*	*1 hour*	*Alingsås*	*Swedish*

2017-03-01	*Ms Karin Gustafsson*	*Marketing Coordinator*	*E-mail*	*N/A*	*Alingsås*	*Swedish*
2017-03-08	*Mr Henning Kristensen*	*After Sales Service Group Leader*	*Face-to-face*	*2 hours*	*Alingsås*	*Swedish*
2017-03-20	*Ms Benitha Benjaminsson*	*After Sales Service Manager*	*E-mail*	*N/A*	*Alingsås*	*Swedish*

Table 2. The Overview of the semi-structured interviews. The respondents of the semi-structured interviews.

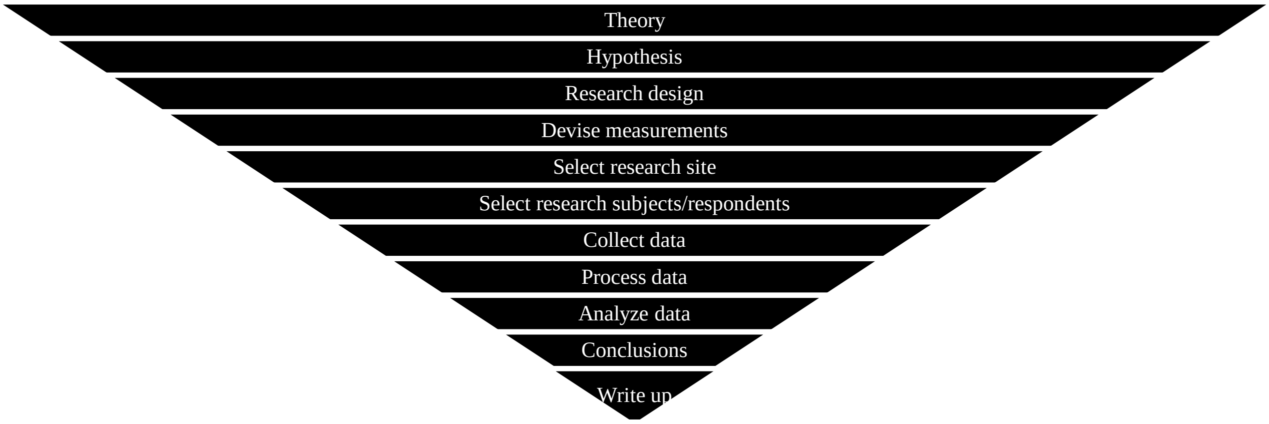
The interviews conducted through email consisted of a mix of both standardized/quantitative and open/qualitative questions. The standardized questions were developed to collect detailed data of activities in the NPI process, and their consumption of time and costs. The open questions were developed to allow room for ideas of how to make the cost model both strategically and operatively useful, and to highlight departmental problems derived from the NPI process.

3.2.4 Description of the Interview Set-up

- The interview questions were first mailed to each respondent along with a description of the research project to make them acquainted with the topic.
- The face-to-face interviews were conducted in TRUMPF Maskin AB in a quiet room around a table.
- The respondents are interviewed one at a time.
- The interviewer takes notes and questions are asked in a pre-determined order. .

3.3. The Quantitative research process

When the research question, topic and focus of the study had been generated from the initial qualitative phase of this study, the deductive approach has been used to explore the related theory of this study and conduct further data collection. The data are then processed and analyzed along with the theory from which conclusions are drawn. The deductive part/quantitative research process of this study is illustrated by model 4.



Model 4. The quantitative research process. Source: Bryman and Bell (2011), Own developed model.

The later part of the study is deductive and mainly quantitative except from the qualitative data collection (unstructured and semi-structured interviews). It starts with the collection of relevant and interesting theory from literature, lectures, films, radio etc. The theory is the contemplative and rational abstract of industrial NPI management; overhead cost measurement; strategy; cost models cost management; and metal 3D-printers. This process follows the eight steps developed in the process of the case-study. Hypothesis are according to Bryman and Bell (2011) informed speculations about the possible relationship between two or more variables which is set up to be tested. The hypotheses drawn from the theory of the thesis reflects the purpose of the cost model and its aim to improve the effectiveness and efficiency of the NPI process in TRUMPF Maskin AB. The main variables that is studied and integrated into the cost model are the time and cost consumed by each activity in the NPI process.

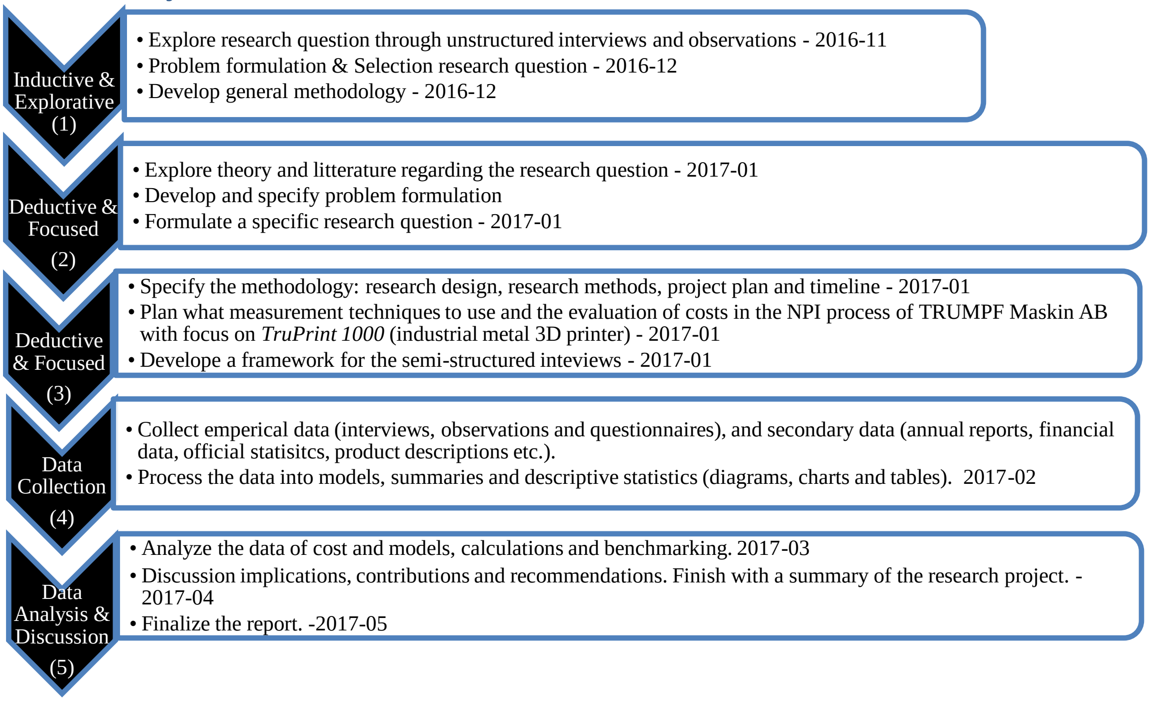
3.3.1 The Quantitative Methods

The quantitative data are collected through official statistics, secondary data (annual reports, product documents, market reports etc.) questionnaires, and processed through descriptive statistics. The theory generated act as a guide for the collection of descriptive statistics (deductive approach). The quantitative data is processed, illustrated and analyzed in tables, diagrams, models and figures in relation to established theory in the topic. Eventually conclusions are made based on the analysis and the research project is summarized and reflected upon. These techniques and tools are used to gather and analyze quantitative data motivated by the fact that they reduce the amount of data collected and ensures that variation in answers is not caused by the qualitative interview context (Bryman and Bell, 2011). More specifically, the quantitative methods are used to collect the data (time and cost of NPI activities) which involves a quite high level of details, to generate measures (activity cost rates) for the cost model that provides useful information for management.

According to Merriam-webster.com (2017), a measure is the dimensions, capacity, or amount of something ascertained by measuring. Indicators are any statistical values that taken together give an indication, i.e. the sign, symptom or index of something (Merriam-webster.com, 2017). A measurement method is, according to businessdictionary.com (2017), the technique or process used to obtain data describing the factors of a process or the quality of a process. Furthermore, Bryman and Bell (2011) describes measures as quantities that allows us to define differences and relationship between concepts. In addition, they define concepts as being the building blocks of theory representing the facts and ideas around which business research is conducted. Thus, a measure is the value of any variable of a unit. Byrne (2002), argue that it exists two frames of measurements within science: the survey measurement and experiment measurement. The survey measurement measures the world as it is, e.g. a case-study of a NPI process. The experiment measurement carries out measurement in a world created by the experimenter by abstraction of the world as it is, e.g. an isolated experiment of cells. This study uses survey measurement in the case-study of measuring the cost of introducing new product innovations within the NPI process of TRUMPF Maskin AB to the Scandinavian market. Thus, quantitative measures are the fundamental blocks of the cost model and this study.

According to Bryman and Bell (2011), the most important advantage of quantitative or quantifiable data like the cost rate of different NPI activities or descriptive statistics is that it provides the researcher with a consistent benchmark. Benchmarking can be defined as a mark on a permanent object serving as a reference in surveys and tidal observations (merriam-webster.com, 2016-12-25). Thus, the descriptive statistics collected about TRUMPF Maskin AB is used for benchmarking performances regarding costs of introducing new products to the Swedish market on a product, process and activity level. An index is developed to capture the cost evolution of introducing new products to the Swedish market in a simplified cost model (TDABC model). As experience and data are accumulated the cost model users in TRUMPF Maskin AB can predict the cost similar events more accurately and manage similar events in the future more effectively and efficiently.

3.4 Summary of the Abductive Research Process



Model 5. The research project process summary: The Abductive approach. Own developed model.

3.5 The framework for the development of process map and the cost model

The framework used to develop the cost model and interview questions is a modification of the six major steps for developing the time-driven activity based model by Turney (2005). This has been combined with the five main moments when building the TDABC model as suggest by Kaplan and Anderson (2004). The six major steps to assist the completion of a useful TDABC model is (Turney, 2005, p.285):

1. *Identify activities*
2. *Reconstruct the general ledger*
3. *Create activity centers*
4. *Define resource drivers*
5. *Determine attributes*
6. *Select activity drivers*

The five main moments when building the TDABC model are to: (1) *Estimate the cost per time unit of capacity;* (2) *Estimate the unit times of activities;* (3) *Drive cost-driver rates*, (4) *Analyze and reporting costs;* and (5) *Update the model.*

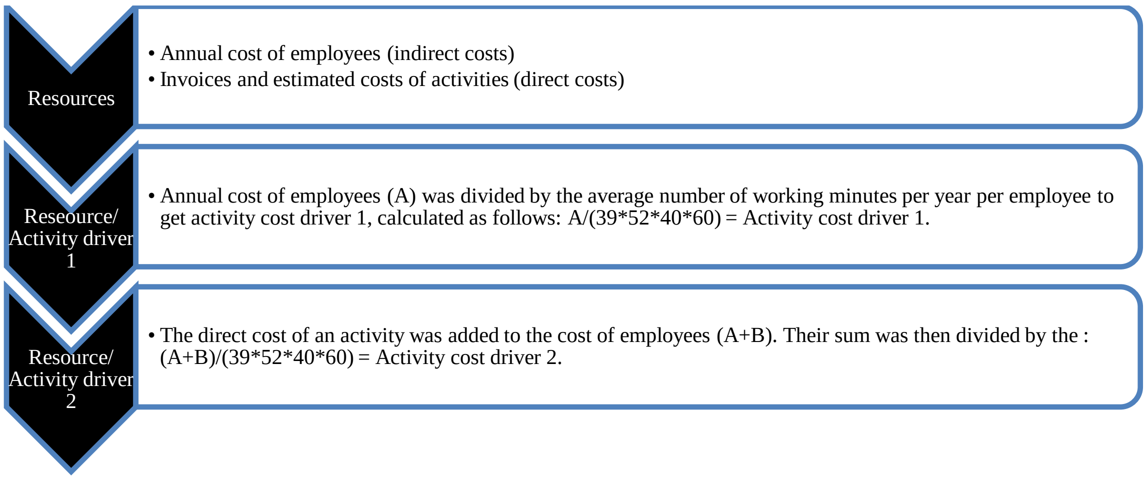
The modified version is adapted to the NPI process of the company and consists of the following seven steps:

1. Identify the characteristics of the new product;
2. Identify the activities of the NPI process for that specific product. Depending on the product characteristics (such as product complexity, price, uniqueness etc.) the activities necessary for the NPI process are identified. Consequently, the NPI process characteristics may vary from product to product;
3. Determine direct costs (invoices);
4. Define indirect costs (reconstruct the general ledger);
5. Create activity centers (departments and major event (Tech-Days/tech-days));
6. Estimate the unit times of activities;
7. Drive cost-driver rates, i.e. calculate activity cost driver rates;
8. Usage (including updating the model, analyzing and reporting costs).

3.5.1 How the cost model for the NPI process was developed

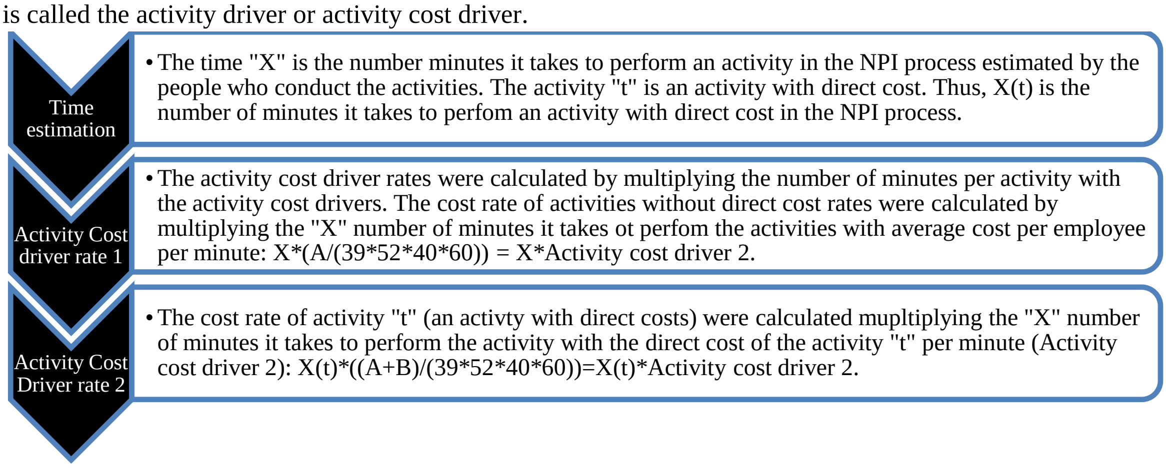
The cost model has been developed by using the direct cost of activities and the own developed modified framework for building the TDABC system. The model was developed in the following 13 steps:

1. *Identify the cost object: TruPrint 1000* which is subject to the NPI process in TRUMPF Maskin AB.
2. *Identify activities in the NPI process,* which has been done through face-to-face interviews and questionnaires. The activities of the NPI process were linked to the cost object (*TruPrint 1000)* in the first step as the NPI process looks different depending on product characteristics.
3. *Determine direct costs,* direct costs were collected from invoices at the financial department at TRUMPF Maskin AB.
4. *Define indirect costs,* which mean that the resources used to estimate the indirect cost of activities are selected. This consists of the annual cost of employees from the company's latest annual report (2016-06-30). In addition, direct cost for departmental activities in the NPI process such as cost of staff training, preparing service, material, and documents was estimated by employees who conduct the activities.
5. *Create activity centers:* the selected activity centers were the *departments* in which activities had most similar functions.
6. *Define activity drivers.* Two resource drivers have been used. The first was defined by using the cost of employees divided by the average number of annual working minutes per employee to get the average annual cost per employees per minute. The second resource driver was defined by dividing the direct cost for departmental activities in the NPI process with the average number of annual working minutes.
7. *Estimate the theoretical and practical cost of capital*. The theoretical *cost* of capital is the total cost of employees and the additional direct cost of activities in the NPI process. The theoretical *time* is the total average number of minutes of work per week per employee. The total number of weeks per year is estimated to be 52 and the average number of hours per week is estimated to 40 hours. The practical time is the estimated proportion of total time per week/year that each employee uses to conduct tasks related to work performance. Hence, the practical time excludes the cost of employees associated with vacation, breaks etc. It is determined as a proportion of theoretical time which is 85%. Thus, 15% of the total work-time and cost of employees are estimated to be related to non-performance related work.
8. *Determine the time to finish each activity*. The employees from each department have estimated the time (days/hours/minutes) it takes to finish each NPI activities for respective department. In this thesis, some the activity driver used is the number of minutes it takes to develop advertisement, prepare documents, and to train staff.
9. *Determine activity cost driver measures*. The cost of activities has been calculated using time-equations. This involves the use of *activity drivers* to calculate the cost rate per activity in the NPI process. Two activity drivers were used: (1) *average cost per employee per minute* and (2) *the direct cost of activity "t" per minute* where t represent an activity with direct costs, such as cost of staff training for a new product. Similarly, two *resources* were used: (A) annual total *cost of employees* (received from the annual report 2016-06-30), and (B) the *direct cost of activity "t"* (collected from invoices). First, the average cost per employee per minute was simply calculated by dividing the annual cost of employees per year, by the number of employees (39) in the company, by the number of payed weeks (52) per year, by the number of working hours (40) per week and by the number of minutes per hour. In other words, the annual total cost of employees (resource driver A) was modified to the average cost per employee per minute (activity cost driver 1) by dividing it with the average annual number of minutes of work per employee. Costs that are unique for an activity, such as cost of staff training, was estimated by employees that conduct the activities. The direct cost of activity "t" per minute (activity cost driver 2) was calculated in two steps. First by adding resource driver A to B, and then by dividing their sum (A+B) with the average number of working minutes per year per employee. However, the activities that did not have direct cost were allocated with average cost per employee per minute.



Model 6. The formula for calculating the activity cost drivers. Own developed model.

10. *Calculate the activity cost driver rates*. The activity cost drivers were used to calculate the cost rate per activity by multiplying them with the number of minutes it takes to finish each activity. The proportion of minutes to finish each activity multiplied by the total cost of resources (the total average cost per employee) gives the cost of each activity linked to the cost object (the 3D printer *TruPrint* 1000). The link is called the activity driver or activity cost driver.



Model 7. The formula for calculating the activity cost driver rates. Own developed model.

11. *Determine the cost of the NPI process per product.* This has been done by using the combined data of activity cost rates per department. The departments are used as cost centers to which resources and costs are allocated according to the activity cost drivers (SEK per minute).
12. *Process and analyze the information generated from the cost model to create reports.*
13. *Use the feedback and information from the reports as strategic and operative decision support, and update the cost model.*

3.6. The Project Analysis methods

Bryman and Bell (2015), discribes an analysis method called iterative approach, which means that the researcher repeatedly goes back and forth between the collected data and analysis. This is a central part of the qualitative study because the research topic is considered unexplored and thus the primary data is of importance to guide the analysis. The theoretical framework was already established before the semi-structured interviews took place, thus the primary data collection in the quantitative part of this study is guided by the theory and secondary data.

The central methods used to analyze the costs of introducing new products to the Swedish market are:

- The process approach; the process approach is used to map the NPI process and identify its activities.

- The four perspectives of the Balanced Scorecard (BSC) model; used to incorporate non-financial aspects of the NPI process into the costing model so that the metrics developed take these into consideration (Turney, 2005).

- The Time-Driven Activity Based Costing (TDABC) model; this framework is used to develop the costing model based on previous studies done by Kaplan and Anderson (2004), Turney (2005) and other researchers. Previous studies of factors that affect the development and usefulness of the cost model has been taken into consideration to prepare for the empirical data collection. These factors include the time and costs for development (Max, 2007, Kaplan and Anderson, 2004, etc.), the business context (Jänkälä and Silvola, 2012) and for what purpose it is developed, i.e. strategic or operational/process improvement purposes (Turney, 2005).

- The choice to select the TDABC model is motivated based on previous researchers' arguments. Velmurugan (2010) argue that the ABC model is appropriate to develop for pilot studies due to the small scale of the study which results in less complexity and costs. Since the TRUMPF Maskin AB is a relatively small company it motivated the selection of the TDABC model. Furthermore, since the TDABC model is argued to demand less time and effort to develop and maintain, the TDABC model was chosen instead of the traditional ABC model. The model's ability to reflect the cost of activities linked to cost objects in processes like NPI processes more accurate than traditional costing methods supported the chose. Indeed, the model's ability to provide effective and useful information for process improvement and strategic management was also important when selecting the model.

The majority of the fundamental information needed to develop the TDABC model are provided from experts on the NPI process in TRUMPF Maskin AB. Thus, a qualitative research strategy and semi-unstructured interviews has been deemed appropriate for this purpose. Bryman and Bell (2011) argues that qualitative interviewing methods provide more information for in-depth analysis of the research subjects. Hence, the new products (e.g. *TruPrint 1000*) from TRUMPF Group and the impact they have on TRUMPF Maskin AB can be analyzed more in-depth as they make room for free elaboration upon the questions and not restricted to the interviewers expected answers. This approach also highlights how employees of TRUMPF perceive how technological innovations currently influence the company and their work. For example, their work tasks and routines, the company's service level, investments in new product preparations etc. Furthermore, this study uses scenario analysis based on three-different contribution margins (CM) derived from three-different gross profit margins (GPM). This is to show how the company's NPIs can influence future business performance depending on what sales price that are negotiated with customers. The unstructured interviews also aim to collect data on what extent technological innovations influence the company's financial performance, what the cost drivers are and estimated to be in the future, what type of activities they invest in and how they will use them in the future. Thus, the unstructured interviews aim to provide information that can problematize the current state of the costs of introducing innovations to the Swedish market. Furthermore, it aims to reveal a clear overview of the costs in the NPI and highlight possible conflicting goals/wishes amongst the departments and other associations. This provides information on how the activities and costs can be managed to create more value for the company and improve its performance. Furthermore, since the initial phase of the study aim to explore a more general view of what to study rather than a clear focus and to see things from the perspective of the respondents, unstructured interviews are appropriate (Bryman and Bell, 2011).

3.7. Reliability, Replicability & Validity

Bryman and Bell (2011) argues that the most prominent criteria for the evaluation of business and management research are *reliability*, *replicability* and *validity*. Reliability concerns whether the results of a study are repeatable. Replicability is very close to this criterion, but instead of being concerned with the repeatability of the results from a study, it is concern with the capability of replicating the methods used to conduct a study. Hence, in order for a study to be repeatable, it needs to be replicable so that the results generated are compared with the results generated from the same research methods. Validity is concerned with the integrity of conclusions that are generated from a piece of research and is arguably the most important criterion. Thus, validity is concerned whether a measure or argument of cause and effect really explains the concept that it is supposed to be denoting.

3.7.1. External reliability

Bryman and Bell (2011) argues that the external reliability of a qualitative research is weak due to the complexity of a social setting which is hard to replicate. For example, it is much harder to replicate a social setting of a semi-structured or unstructured interview compared to a quantitative research survey based on standardized questionnaires. However, although the complexity of this study's social setting are harder to replicate than standardized and closed questions, the interview guide and interview analysis for the qualitative interviews aim to increase their replicability. Furthermore, the qualitative research is complemented with quantitative data collected from official data regarding TRUMPF and its industry which aims to increase the replicability of the case-study as a whole. Thus, this research aims to use the advantages of both quantitative and qualitative data by using the abductive approach as a research strategy.

3.7.2. Internal reliability

The internal reliability, i.e. the consistency of the indicators that make up a scale or index, is usually high in a qualitative research due to the goal of reaching a common understanding and shared interpretations amongst the participants and researcher(s). Thus, there is a high probability of having indicators that relates to the same thing, i.e. high level of coherence when conducting a qualitative research because the researcher can ensure that the respondents understand the subject of the research by asking questions, explain it, summarize their interpretations etc. (Bryman and Bell, 2011). Hence, the majority of the empirical data are collected through interviews. The initial interviews are unstructured in order to allow spontaneity in respondents' answers and thus increase the chances for them to provide interesting replies that are not covered by the fixed answers from more specific and standardized questions (structured interviews). Furthermore, the unstructured-and semi-structured interviews includes questions of this study are open and explorative (and fewer than the later interviews) in order to allow for rich and explorative answers while at the same time being connected to the research question (Bryman and Bell, 2011).

3.7.3. Replicability

Replicability concerns the procedures of the study that the researcher spells out in great detail to make replication of the study as good/similar as possible. Thus, if the methodology and methods of data collection (not only what and where but also how much data) is not explicitly stated, then the replicability of the study becomes impaired. Furthermore, if the replicability is bad then reliability usually also is bad. This is because other researchers that want to test the reliability of the study would not be able to because they do not know the processes of the study (Bryman and Bell, 2011).

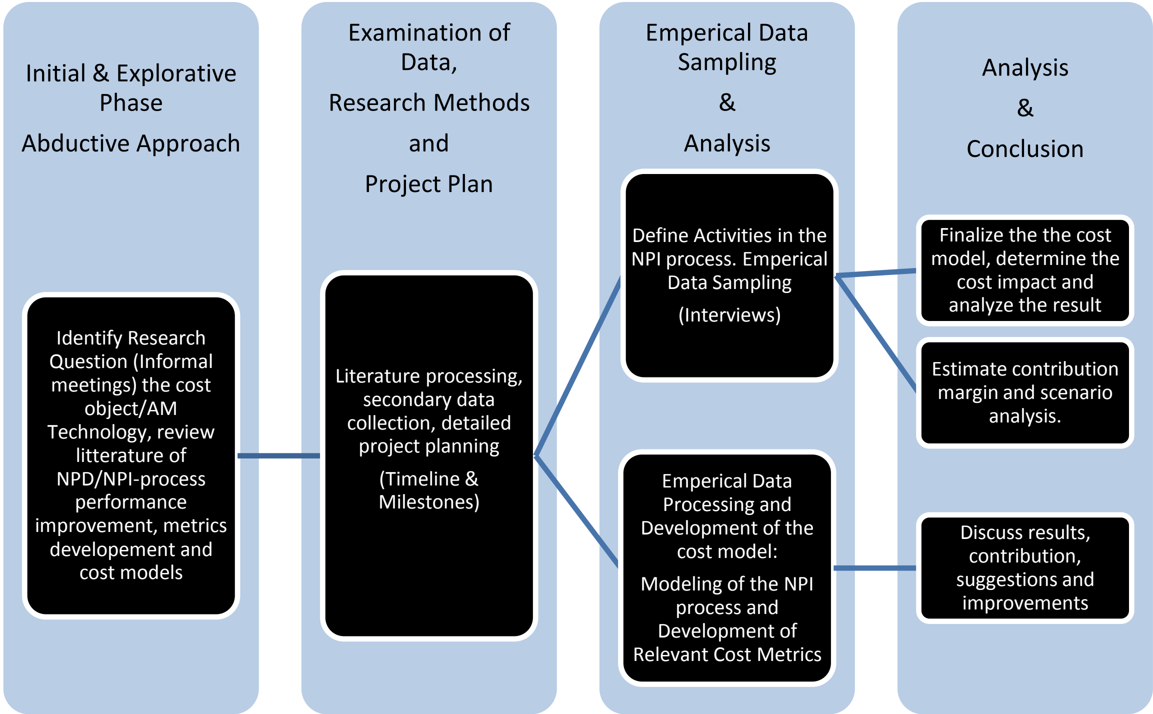
3.7.4. Internal validity

The internal validity regards whether or not there is a match between the researchers' observations and the theoretical ideas they develop. A high internal validity indicates that there is a good match. The internal validity of a qualitative study is argued to be high and consistent due to the closeness between empirics and theories (Bryman and Bell, 2011). The (initial) qualitative parts of this study are aimed to provide a closeness of theory and empirics to form a clear RQ and topic that guides the selection of theory and provides a consistent focus of the quantitative/deductive part the study.

3.7.5. External validity

The external validity is a measure to which degree research findings can be generalized across social settings. It tends to be low in qualitative studies due to the relatively low volume of responses (data) and the uniqueness of each case and case-study (Bryman and Bell, 2011).

3.8. The methodology framework of the research project



Model 7. The theoretical methodology framework of the research project. Own developed model.

4. Results

This chapter provides a background of the characteristics and applications of technological innovations from TRUMPF Group, the implications of its technology on businesses. Furthermore, a description of Industry 4.0 and its relation to TRUMPF Group is provided. The AM technology, its market, its growth rate and characteristics are also described. This is to provide an overview of the cost implications of the activities necessary to realize the introduction of innovations and strategies of TRUMPF Group to its customers and industry in Sweden.

4.1. Secondary data

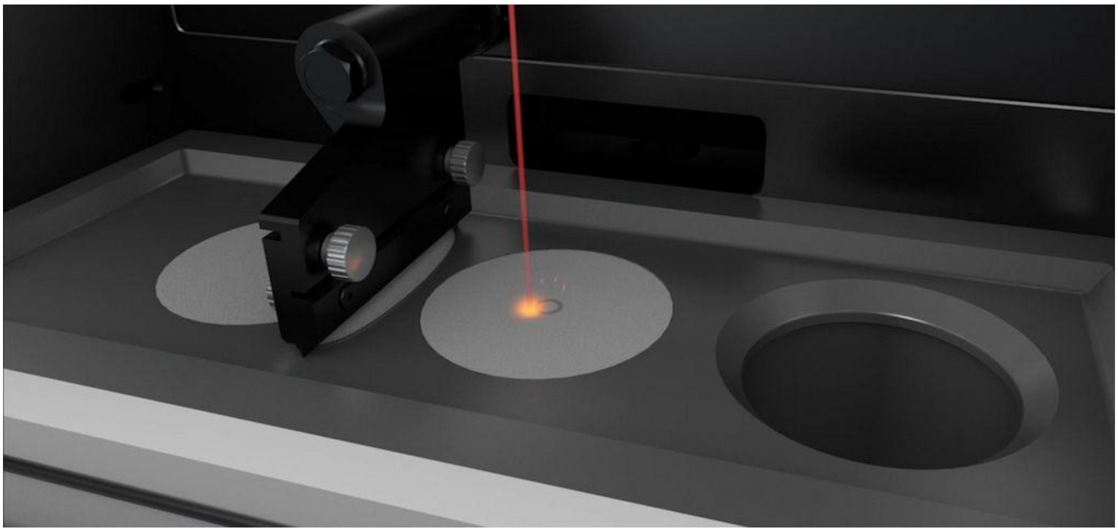
The following text consists of descriptive statistics about the manufacturing industry, TRUMPF Group and TRUMPF Maskin AB. This provides more insight into the research topic and a summary of the samples and observations that have been made in order to provide more detailed, and generalizable answers to the research questions.

4.1.1. Contextual background: TRUMPF Group and its industry

TRUMPF Group was founded in 1923 by Christian Trumpf in Stuttgart, Germany. It entered the laser manufacturing industry with its own Co2 laser in 1985. Today, TRUMPF Group is a global world leading supplier of advanced manufacturing system and laser technologies, and a pioneer of Industry 4.0. The MNC has 71 subsidiaries world-wide and TRUMPF Maskin AB, is one of its marketing, sales and service subsidiaries. TRUMPF Maskin AB can be considered as a SBU of TRUMPF Group that enables approximation to the Scandinavian market. TRUMPF Masking AB offers AM systems, laser systems, IT-systems etc., with an integrated approach for the metal manufacturing industry. AM-technologies for metal manufacturing can be viewed as a sustaining technology for the company.

The laser industry is a science-driven industry that has existed since the 1960s. The first laser device occurred in 1958. The first US companies in the business of producing and selling lasers started in the early 1960s with companies like Korad, Coherent and Spectra-Physics. The laser industry was then characterized of discontinuous rather than continuous innovation and for many years it was a solution searching for a problem. Eventually, other techniques were discovered that made high-powered pulses possible at a variety of wavelengths (Radziemski, 2002). This resulted in lasers being applied in cutting, welding, and various other processes in the steel manufacturing industry. In the period of 1996-1999, the worldwide laser revenue grew from $2,8 billion to $4.9 billion and were estimated to be $6.3 billion in 2000. Diode lasers accounted for 69% of that revenue and the CO2 laser was among the top 4 best sellers. The most prominent applications were in materials processing and medical therapeutic areas, such as metal-processing, microlithography and ophthalmology (Kudic et.al 2015). However, revenues gained from CO2 lasers have declined by -5% in 2015 and -11% in 2016, while fiber lasers have increased their revenues by 16% and 11% respectively. This have resulted in an increased market share for fiber laser by 54% ($1713,7 million) in 2015 while CO2 lasers are down -5% ($656,7 million). The advantages of fiber lasers compared to CO2 lasers is mainly related to better efficiency (higher electrical efficiency, less maintenance and operating costs), applicable to cut copper, brass and aluminum without problems and higher speed when cutting thin material (1-3mm). The advantages of CO2 laser mainly related to the cutting speed when cutting thicker materials (>5mm) where it cuts faster in a straight line and faster piercing times at the start of the cut. The cuts by CO2 laser also have a smoother surface finish when cutting thick materials Along with this, one of the fastest emerging and growing field within the laser industry is additive manufacturing which had an impressive 71% revenue growth rate in 2015 ($64,8 million) and 37% in 2016 ($88,8 million) for micro-processing application (Industrial-lasers.com 3, 2016, Industrial-lasers.com 4, 2016, Industrial-lasers.com 5, 2016).

Today, TRUMPF has one of the company's fastest growing technologies is additive manufacturing equipment such as laser metal deposition (LMD) which has emerged as a prominent additive technique for industrial application (TRUMPF annual reports 2011/12-2015/16, TRUMPF.com, 2016). They also manufacture and sell Laser Metal Fusion (LMF) systems and 3D printers which are expected to have a huge impact in the future of the manufacturing industry. In 2000 TRUMPF Group made entrance with its first 3D printer TrumaForm which was one of the first AM technologies used for industrial production of metal objects. In 2003, TRUMPF Group presented its TrumaForm LF and TrumaForm DMD 505 machines at EuroMold. The LF machine uses the same technique that is built on today's upgraded 3D printer TruPrint 1000, known as Laser Metal Fusion (LMF). However, TRUMPF Group stopped to produce TrumaForm 3D printers due to an immature market. In 2016, TRUMPF reentered the market with *TruPrint 1000* and *TruPrint 3000*, and has announced that its newest metal 3DP, *TruPrint 5000*, will be introduced in late 2017. All three uses LFM for industrial application and can be used to produce complex metal components of virtually any geometric shape. 3000 can produce larger complex metal parts and 5000 is suitable for large-scale production/mass production (optics.org, 2014, TRUMPF-Laser.com, 2017, wholersassociates.com, 2008, TRUMPF.com, 2017).



Picture 3 and 4. TruPrint 1000 (on top) is one of TRUMPF Group's 3D-printers using Laser Metal Fusion (below) when manufacturing. Source: TRUMPF.com (2017).

TRUMPF Group is as of 2016 the largest industrial laser/system supplier with an impressive record of continuous growth during the period of 2001-2016. The world leading provider of fiber laser manufacturing systems is the MNC IPG Photonics from Russia founded in 1991. Other competitors in the industry are the MNC Coherent Inc from US founded 1966, and Han's Laser Technology Co., Ltd established in 1996 in China. Coherent has a strong portfolio of laser sources which expanded even more when they acquired Rofin Sinar in March 2016. This more than doubled Coherent's market share in material processing from $111 million to about $311 million with a $200 million boost in macro processing sales. Han's Laser is a publicly owned company and the fastest growing laser-system provider in China with sales of $452 million in the first half of year 2016 and with an annual growth rate of 22.7 % which is faster than TRUMPF and IPG (Industrial-lasers.com 3, 2016, Industrial-lasers.com 4, 2016, Industrial-lasers.com 5, 2016, Industrial-lasers.com 6, 2016).

4.1.2. TRUMPF Maskin AB – Contextual background

TRUMPF Maskin AB was established in 1984 in Alingsås, Sweden, and is the Swedish subsidiary of TRUMPF Groupp. It can be described as a Strategic Business Unit (SBU) responsible for sales, marketing and services for the Swedish market. The core value of TRUMPF Group is to be driven; the will and motivation to innovate and create. Thus, innovation is a part of the core value of TRUMPF Group. The company's attributes/characteristics are being convincing, open/transparent, strong (strategy, assets and capabilities), and independent (everything from research & development to the manufacturing of its product portfolios and service packages are done within TRUMPF Group). Its brand positioning is divided into two main categories. The first is customer insight, i.e. to work close with its customers, to integrate them in a mutually beneficial relationship (e.g. connected manufacturing) and offer them the benefit of products and services provided by TRUMPF Group in an open relationship. The second one is the innovation promise, i.e. the promise to continue to innovate and provide new creative solutions for its customers, e.g. the newest and best technology, so that they can gain/maintain/retain a competitive edge in the industry and improve business performance. The customer insight/knowledge is necessary to have in order to develop and create value according to customers' needs. The innovation promise is a promise to continue to innovate advanced technology for industrial manufacturing that provides innovative, superior and reliable, solutions for its customers. By being creative and innovative they can exceed the customers' expectations and even provide solutions to problems that customers yet are to become aware of (se.Trumpf.com, 2017, Trumpf.com, 2016).

TRUMPF Maskin AB has approximately 40 employees of which 50% work with after sales services (se.TRUMPF.com, 2017). The departments of TRUMPF Maskin AB are:

1. *Administration* (managing services across several departments including contracts, invoices, orders, negotiations, bookings etc.)
2. *After Sales Services* (service level management, customer service, preparation of product services and material/spare-parts, execution of product services).
3. *Finance and accounting* (budgeting, prepare and manage resources, assets, liabilities, invoicing, capital accounting, financial transactions from investments, documentation etc.)
4. *IT Sales Management and Technical support* (sub-department of tool-machines sales department and experts on the IT products, monitoring systems and responsible for sales and programming of software, IT-product training and customer education services etc.)
5. *Marketing* (planning, coordinate, and executing advertisements and new product campaigns, events, trade-shows, product news, and various communication channels; promotion activities, meetings, registration and tracking of customers, responsible for the customer relationship management system, CRM system, etc.)
6. *Logistics (*order administration & logistics coordination, inventory management, preparation and sale of material and spare-parts, administration of delivery notes, documentation, case registration etc.)
7. *Laser-machine sales* (laser-machine sales management, planning NPI and sales processes, laser-machine sales negotiations, contracting, internal and external customer meetings, execution of sales of laser machines).
8. *Technical services* (sub-department of the after-sales service department and responsible for technical training of new product, product programming, installation & technical customer education services, technical maintenance, repairs, machine monitoring services & education etc.).
9. *Tool-machines sales* (tool-machine sales management, planning NPI and sales processes, tool-machine sales negotiations, contracting, internal and external customer meetings, execution of sales of tool-machines).

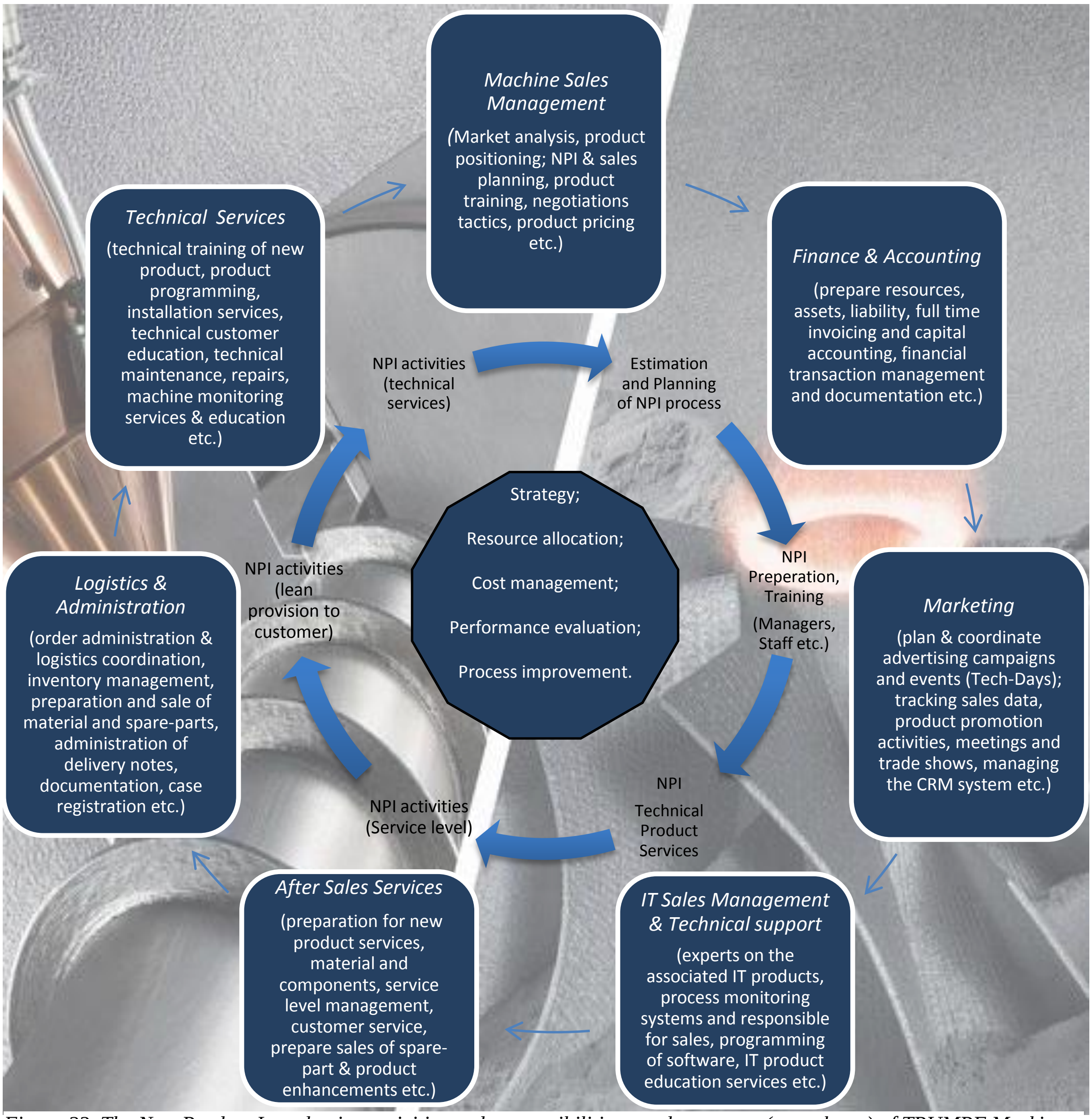


Figure 23. The New Product Introduction activities and responsibilities per department (outer layer) of TRUMPF Maskin AB and the activities of the NPI process (inner layer). Own developed model.

4.1.3. The product portfolios in TRUMPF Maskin AB

The products from TRUMPF Maskin AB are categorized into five product portfolios: *machines & systems*, *lasers*, *power electronics*, *power tools*, and *software*. Within each category exists the product lines of TRUMPF, listed in figure 24. Besides the products, TRUMPF Maskin AB offers its customers many services around the life cycle of its machines. In addition, TRUMPF has two service categories: *Services* and *Smart factories*. The services category includes a wide range of services such as technical services, financial services, training courses and process optimization services. The category smart factories include *TruConnect* which offers a number of consulting services to create a continuous production flow. TruConnect is TRUMPF's concept for connected manufacturing to enable more transparent, flexible and cost efficient production within the framework of Industry 4.0 (se.Trumpf.com, 2017).

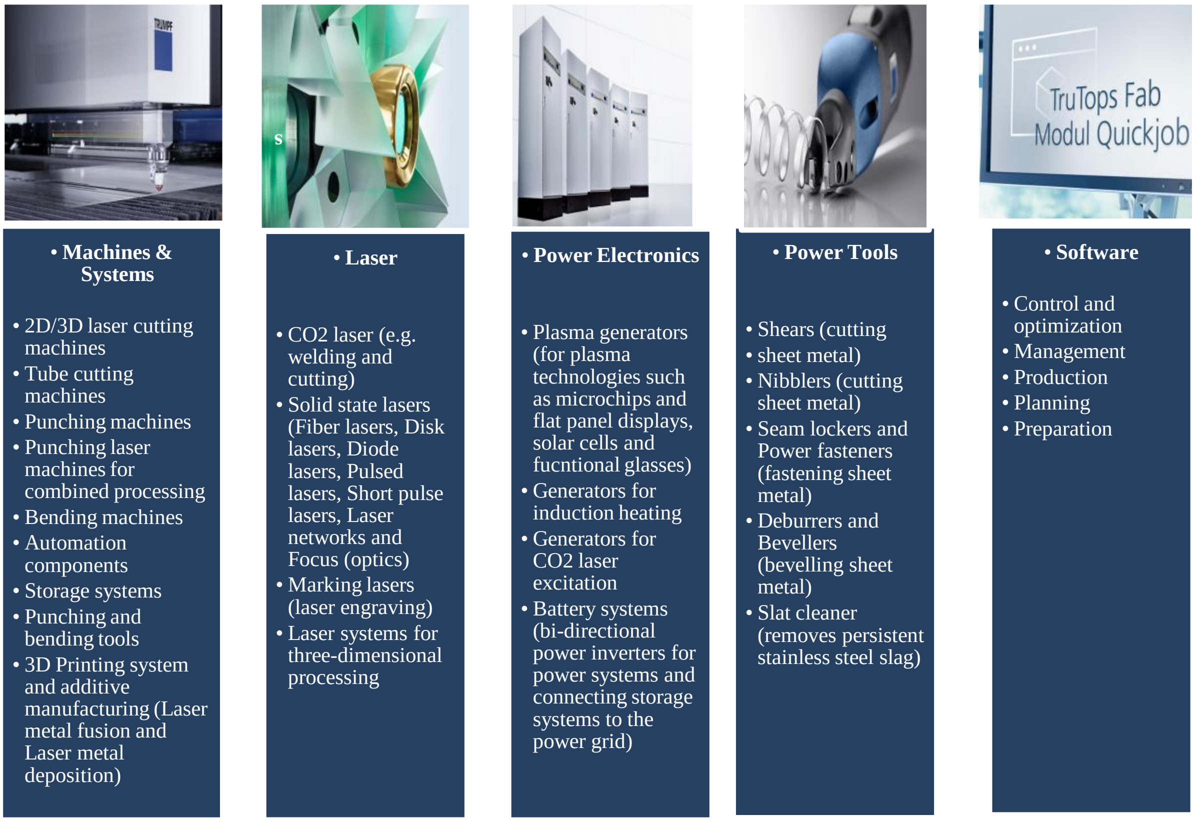


Figure 24. An overview of TRUMPF Group's product portfolio. Source: Trumpf.com (2017). Own developed model

4.1.4. 3D-lasers and 3D printers

The 3D laser technology of TRUMPF is divided into 3D laser processing systems and 3D printing systems. The laser systems for 3D laser processing includes the TruLaser Cell series (1000, 3000, 7000 and 8030 (L60)), TruTops Cell and TruLaser Robot 5020. These machines perform separate tasks regarding laser processing of 3D components. TruLaser Cell series 1000 weld 3D components such as coils, tubes, and profiles. It can also be used to strip and weld rotationally symmetrical components. TruLaser Cell series 3000 can be used for three-dimensional cutting, welding and laser metal deposition. It is can produce both prototypes and large series efficiently and productive. This applies especially to the production of small to medium components with optimum quality. TruLaser Cell Series 7000 can be used to cut or weld metal parts and change surfaces with Laser Metal Deposition (LMD), also known as laser cladding or direct energy deposition. The process of laser metal deposition includes filler material which is applied to a surface and molten with a laser beam to form a strong bond with the substrate, which is also melted, and then solidifies, leaving behind a small raised area. The process continues in this fashion, spot by spot, line by line, layer by layer until the desired shape and results is achieved. TruLaser Cell 8030 (L60) is used for productive, efficient, fast, and accurate 3D cutting of hot-formed components, providing high product safety. TruLaser Robot Series 5000 welds the housing to the air scoop by full penetration welding (se.Trumpf.com, 2017).

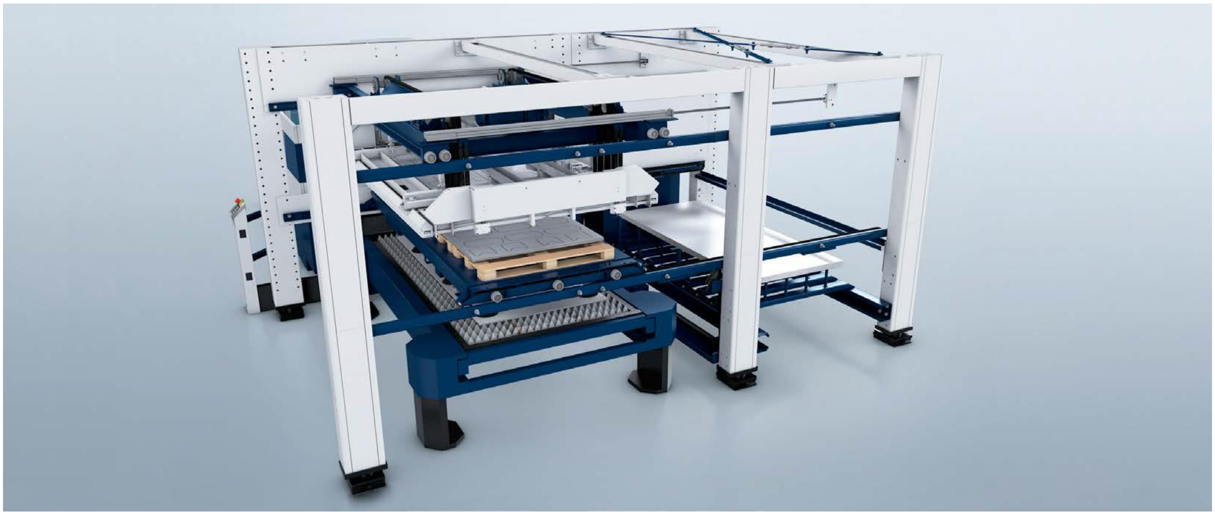
Picture 5. TruLaser Cell 3000. Source: TRUMPF.com (2017-04-06).

The first 3D-printer developed and manufactured by TRUMPF Group was TrumaForm, introduced in year 2000. The TrumaForm LF machine uses a 250-watt laser and fiber optic cable to direct the light onto a bed of pure powder metal. However, the project was shot down in 2004 due to an immature market (Pw-review.com, 2014). Today, the 3D printing systems provided by TRUMPF Groups is divided into two categories: one is the product line TruPrint Series which performs Laser Metal Fusion (LMF) and the second one is the laser machines TruLaser Cell 3000 and TruLaser Cell 7000 used for Laser Metal Deposition. The 3D printers used for LMF processing are: TruPrint 1000 and TruPrint 3000. TruPrint 1000 is a 3D-printer used for the production of small metal components by powered bed-based-laser melting (LMF). This enables the creation of new workpieces from melting powder with laser, and building them up layer by layer. The combination of metal powder and laser light are able to create virtually any geometric shape. Complex shapes can be transformed from the CAD design into real components. So far this has been advantageous in the production of prototypes, on-offs and small series. The TruPrint 3000 is also a 3D-printer using the laser metal fusion process but has a larger build volume which offers greater flexibility in terms of size, part number and geometry of respective application. The other form of additive manufacturing, Laser Metal Deposition (LMD) is also known as laser cladding and direct energy deposition. LMD uses the laser to create a melt pool on the component's surface in which metal powder is continuously added and melted as filler material. This produces welded-together beads which can form structures on existing base or entire components. The method can be used for coating, repairs, to generate complete components and joining processes such as bridging of gaps (Trumpf-laser.com, 2017).

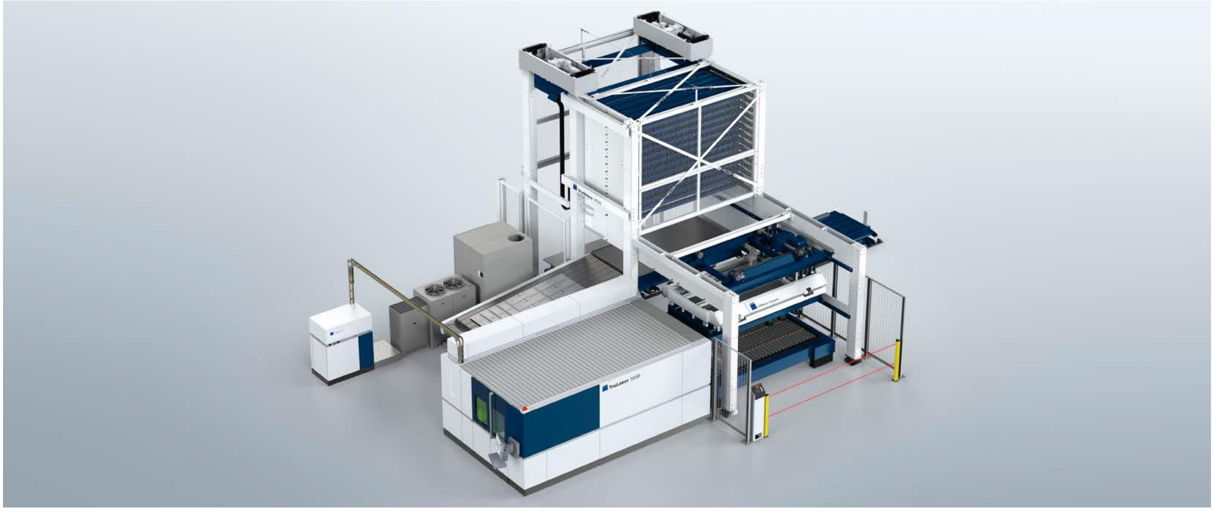
Picture 6. TRUMPF TruLaser Cell 7040. Source: TRUMPF.com (2017-04-06).

4.1.5. Product enhancements

TRUMPF Maskin AB offers product enhancements. The product enhancements offered have a large variety. For example, standard enhancements such as TRUMPF CoolLine is provided to cool materials during laser processing and allows up to 30% more parts to be produced from a single sheet. Automation components such as LiftMaster Compact allows automatic parallel loading and unloading for many TruLaser machines that eliminates the throughput time in Laser cutting by its short cycle time of less than 90 seconds. Another example is the customized solutions such as automatic storage connections which could for example be a fully-automated TruLaser 5030 fiber with the LiftMaster Compact combined with the TRUMPF TruStore 3030 storage system (Trumpf.com, 2017).



Picture 7. The LiftMaster Compact. Source TRUMPF.com (2017-04-07).



Picture 8. TRUMPF TruStore 3030 storage system. Source: TRUMPF.com (2017-04-07).

Picture 9. TRUMPF TruLaser 5030 fiber/ 5040 fiber. Source: TRUMPF.com (2017-04-06).

4.1.6. Digital business platforms

A company's motives determine what it offers and to promote solutions for smart factories TRUMPF Group also provides an online platform for digitally connected manufacturing through AXOOM GmbH, which TRUMPF founded in 2015. AXOOM is designed to connect systems, machines and workplaces to provide a complete view of production. The Managing Director of AXOOM, Florian Weigmann describes it as follows: "*AXOOM is designed as an open and modular platform to enable end-to-end solution for our customers which includes the integration of industry-leading applications from our partners and service providers".* AXOOM is an open platform that encompasses the entirety of the value chain, open to customers and users, their logistics and service providers and to mutual partners of AXOOM. It provides several solutions such as order management, resource management, automatic optimization of the Shop Floor, automatic preparation of orders for shipping, provides a clear overview over the shipping and data, optimizes the selection of logistics providers and full transparency in everyday business. For example, the digital end-to-end solution enters orders digitally in the online shop which replaces consulting and inquiring done through phones, fax and e-mails. Resource management are supported by automatic reorders of material, automatic reports of missing material needed for an order, and the provision of

Logo: AXOOM. Source: axoom.com (2017).

full transparency about material and suppliers (TRUMPF.com, 2016, axoom.com, 2017, Laserfocusworld.com 1, 2017).

4.2. Empirical data

This chapter describes the data collected from empirical findings. The data has been collected from the following departments: marketing, sales, after-sales service and finance department. The activities that has been identified in each department are performed in the NPI process and linked to TruPrint 1000. This data lays the foundation for the NPI process map, the cost model (the time driven ABC model), the contribution margin and scenario analysis of the NPI processes.

4.2.1. The overall steps of the NPI process methodology at TRUMPF Maskin AB

The main departments involved in the NPI process of TruPrint 1000 in TRUMPF Maskin AB are Machine Sales, Marketing, logistics & administration and After-Sales Services. The overall steps of the NPI process methodology at TRUMPF Maskin AB have been summarized in figure 25. The NPI process of TRUMPF Maskin AB can be defined as all the activities that are involved in preparation and execution of the initial sales, marketing and after sales service activities of a new product. This includes preparing and executing activities that enables a desired service level for the new product, i.e. after sales services.

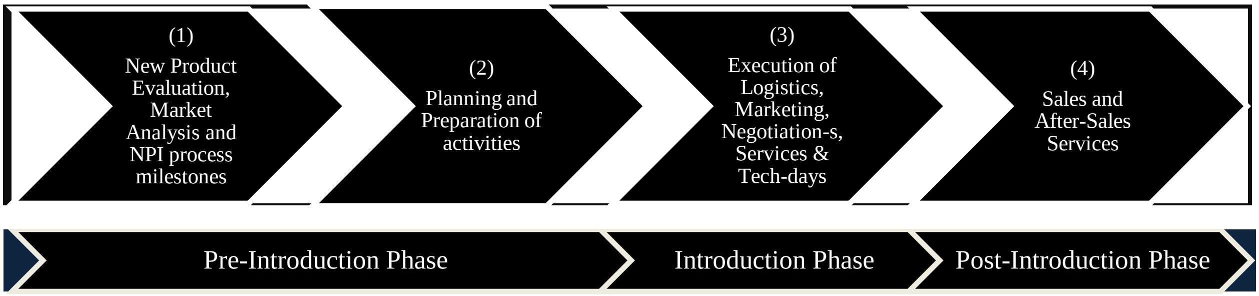


Figure 25. The overall NPI process approach in which TRUMPF Maskin AB applied to TruPrint 1000. Inspired by: Tang and Collar (1992, pp. 23-26); Andrew et.al (2008); Rummler and Brache (2013, p. 267, p. 287); Dombrowski and Malorny (2016). Own developed model.

In the first step (1), in the pre-introduction phase, the project manager and project team from TRUMPF Maskin AB are informed about the new product. The project manager for TruPrint 1000 is from the Laser-machine sales department and conduct analysis of domestic market, customers and competitors together with the team. The market analysis is usually performed by 4 people with complementary market knowledge. The project manager then attends to the new product training program provided by TRUMPF Group. This is followed by new project meetings with the project team at TRUMPF Maskin AB to plan the NPI process. This step also includes new product positioning and pricing which is conducted by the project manager in consensus with the CEO and through reconciliation with TRUMPF GmbH/ TRUMPF Group Headquarter. This is to cover earlier costs in the NPD process and plan profit margins. The communication plan is then developed to reach target audience through various marketing channels. The milestones of the NPI process are then set which guides the preparation activities in the next step. Thus, a product positioning plan, distribution plan, and initiatives for process management and process improvement are developed (Andrew et.al, 2008). This step is the pre-introduction phase which should include the development and use of metrics to measure performance through the whole NPI process (Cooper and Edgett, 2008).

The next step (2), in the pre-introduction phase, consist of preparation activities, including sales training and uploading of new product information to the website. Customer Relationship Management (CRM)-, and quotation systems are updated. Sellers train product arguments and the staff of the after-sales service department prepare technical service and material documents. Technicians are being trained (to provide installation and maintenance services/support) and customer education programs are being prepared/developed or adopted. The marketing channels are prepared through the marketing department, such as digital advertisement, press releases, new product shows, Public Relationship (PR) management and customer invitations. Information is passed to the logistics department to prepare logistics activities, material/spare-part supply, available suppliers, partners and third-part logistics firms. This step is in the grey zone in-between the pre-introduction and introduction phase. It is the phase where the majority of purchases take place. This includes purchase of marketing material, services, equipment, spare-parts; order administration; and warehouse management (performed by all departments but mainly by the logistics and administration department).

The third step (3), the introduction phase, is the execution of the preparations activities in the different departments. Advertising campaigns, press releases and new product shows are executed and coordinated. The marketing department have most responsibility of CRM and PR activities. The CEO, sellers, technicians and marketing coordinator are meeting customers and the public. Sellers perform initial product presentations face-to-face with customers and negotiations.

The final step (4), the post-introduction phase, is when the sellers conduct the majority of sales and technician conduct machine installation for customers, customer education and other technical services. After-sales service activities are related to service level management which include product maintenance and technical consultation, product enhancement and supply of spare-parts/material etc.

4.2.2. The data needed and its potential for the NPI process in TRUMPF Maskin AB

According to the interviewed persons at TRUMPF Maskin AB (table 2) there is no clear cost system at place that can provide sufficient cost information of their NPI processes. This undermines their ability to plan and manage the activities in the NPI process and the activities thereafter such as sales and after-sales services. Hence, the company needs better cost information for both strategic and operational process management.

The interviewed persons desired the following information to enable improved process management:

I. Updated product documentation
II. Clear illustration of those NPI activities regarded as important and as detailed as possible to the extent it makes sense and is economically feasible. These processes should be linked to specific products, in this case *TruPrint 1000,* so that the product characteristics (complexity, size, function, relative uniqueness etc.) are reflected in the required resources to the process.
III. Estimations (approximations) of the time consumption per activity and their relevant costs (e.g. cost of personnel, training of staff etc.) need to be included in the cost model. These estimations provide the basis for improved strategic and operational decision-making. For example, more accurate contribution margin calculations, budgeting, resource allocation and activity management.
IV. There is a need for financial data that link both direct and indirect costs with activities.

This information has been incorporated into the cost model and used to estimate time and cost of the NPI processes of *TruPrint 1000*. These estimates are then used to calculate contribution margin per number of units sold. The cost model aims to enable both operational and strategic Activity-Based-Management. According to Kaplan and Cooper (1998) and the Chartered Institute of Management Accountants (CIMA) in UK (2001), this could enhance the company's ability to:

1. Reduce time and effort required by activities;
2. Signal where either continuous or discontinuous (re-engineering) improvements in efficiency (costs), time (speed) and quality (effectiveness) are needed;
3. Eliminate unnecessary activities;
4. Select low-cost activities;
5. Share activities wherever possible;
6. Redeploy unused resources;
7. Guide product mix and investment decisions;
8. Choose among alternative suppliers;
9. Negotiate about price, product features, quality, delivery and service with customers;
10. Employ efficient and effective distribution and service processes to target market and customer segments;
11. Improve the value of an organization's products and services;
12. Correction of the activities, improve preparations, effectiveness and efficiency in the NPI process.

4.2.3. The direct- and indirect costs linked to the NPI process

Direct cost has been identified for each activity whose costs can specifically and exclusively be attributed to the production of a specific service or good, e.g. staff training, installation and advertisement. These costs have been collected from invoices in the financial system of TRUMPF Maskin AB.

The latest annual report from 2016-06-30 has been used to derive indirect cost to the activities in the NPI process of TRUMPF Maskin AB. The company had 39 employees and an operating revenue of 39 045 438 USD (approximate 331 455 331 SEK) as present in the database Orbis (2017). Table 3 illustrated the key-account chosen as resource driver for the TDABC model which is the total cost of employees and average cost per employee. The cost of employees includes salaries for managers and shareholders, salaries to employees, employer social fees, pension and job insurance etc. The total and average cost of employees is divided into two categories: *Theoretical cost of employees* and *practical cost of employees*. Theoretical cost of employees includes both non-performance related time of work, i.e. travels, breaks, internal meetings and other work unrelated to actual work performance. Practical cost of employees discard the time and cost spent on no-performance related time of work. Hence, practical cost of employees only includes the performance related time of work and is estimated to account for 85% of the theoretical work time per year.

Resource drivers	USD	Average	SEK	Average
Annual report ***Key-Account***	*2015-07-01—2016-06-30*	*USD per employee (39 employees)*	*2015-07-01—2016-06-30 (SEK/USD: 0.11780)*	*SEK per employee (39 employees)*
Theoretical cost of employees	4 169 425	106 908	35 394 100	907 541
Practical cost of employees (85%)	3 544 011	90 872	30 084 985	771 410

Table 3. Cost of resources from the annual report (2016-06-30) of TRUMPF Maskin AB. Source: Orbis (2017).

The indirect cost drivers are the average annual cost (SEK) per employee divided by the average number of minutes of work per year. The theoretical working time is 52 weeks per year and the estimated full-time work per employee per week is 40 hours (2400 minutes). As follows, the average practical working time is 2040 minutes per week per employee (85% of 2400 minutes). The average cost per minute of work (both theoretical and practical) is illustrated in table 4 columns 6.

Resource driver	Average	Per week	Per hour	Per minute
Annual report ***Key-Account***	*Average annual cost (SEK) per employee (39 employees, SEK/USD: 0.11780)*	*Average cost (SEK) per employee per week*	*Average cost (SEK) per employee per hour.*	*Average cost driver measures (SEK) per employee per minute*
Theoretical cost per employee (100%)	907 541	17 452,7	436,32	7,27
Practical cost per employee (85% of theoretical cost and 2040 minutes per week)	771 410	14 835	436,32	7,27

Table 4. Average cost (SEK) of resources from the annual report (2016-06-30) of TRUMPF Maskin AB per week, per hour and per minute of work. Source: Orbis (2017 and TRUMPF Maskin AB.

4.2.4. Cost Allocation to Activity Centers

Direct costs linked to activities per department has been collected from invoices and estimated by experts from each department involved in the NPI process of *TruPrint 1000*. Each department and major event represents an activity center which consists of related NPI activities. The costs per NPI activity are aggregated in each activity center. The departments involved are (1) *the marketing department*, (2) *the laser-machine sales department*, and (3) *the after-sales service department*. In addition, one major product promotion and customer relationship event is included (4) *Teach-Days*. This event was the Tech-Days, i.e. the new product show at TRUMPF Maskin AB during the period of 2016-11-30 – 2016-12-02. The task-specific direct costs are allocated to the activities that exclusively cause the costs. The indirect costs are only allocated to the activities that are performed by the employees at TRUMPF Maskin AB.

4.2.5. Estimation of the Activity Cost Driver Measures

Three different cost driver measures have been estimated when calculating the activity cost rates for each cost center: *minimum (min.) activity costs driver measures*, *maximum (max.) activity cost driver measures* and *average activity cost driver measures*. These estimates are the number or inputs (units of work), either in minutes, pieces (pcs), kilograms (kg) or liters (l) per activity. The minimum and maximum cost driver measures for activities with only indirect costs is based on the range of inputs per activity estimated by the respondents. The cost driver measures for activities with direct costs have been estimated using the actual costs form invoices as the minimum cost driver measures. The maximum cost driver measures are calculated based on an 50% increase in units of work/input per activity per cost center. However, due to the large proportion of some direct costs, they have remained the same for minimum, maximum and average cost rates. The *average* activity cost driver measures are the costs in-between minimum- and maximum cost driver measures: minimum cost driver measures + (maximum cost driver measures-minimum cost driver measures). However, the minimum cost driver measures for the Tech-Days have been determined by allocating the direct costs per machine according to the invoices. The maximum cost driver measures are based on a 100 % increase in units of work/input per activity except for the activities with the largest cost proportion. Their maximum costs are based on a 50 % increase of the minimum cost driver measures.

4.2.6. The Marketing Department

The marketing coordinator at TRUMPF Maskin AB was chosen to provide information about strategic planning of marketing activities and marketing operations at the company. Operative marketing management include appropriation and classification of data regarding company and product image, updating of the website; advertisement; release in trade press; Tech-Days; customer relationship management in the form of receiving and administrating customer inquiries, verbal customer communication etc. Strategic planning includes Customer Relationship Management (CRM) in the form of analyzing the collected data regarding new product and firm-related phenomena and planning communication of product characteristics and benefits. This is for example when information about *TruPrint1000* was retrieved, the marketing department started to plan Tech-Days event in which customers was invited to review the product and get educated by the staff of TRUMPF. This means that the marketing department is in charge for planning room and location for machines and people in those events. In addition, press and media is managed by the marketing department.

The main tasks of the marketing department associated with NPI processes are executed when enough preparation for the new product and NPI process has been done (in the laser-machine department, after sales service department etc.), such as staff training, product material, spare-parts and service preparation. The main tasks include uploading new product information the company’s website, followed by booking of advertisements, product promotions, press releases, customer invitations to new product events etc.

The market department has 1 employee that approximately works 32 hours (1920 minutes) each week (80 % of full-time), which is the theoretical work time. The estimated practical work time is approximately 85 % of theoretical working hours (i.e. available working hours, excluding vacation, breaks, internal meetings and work unrelated to actual work performance). Thus, the marketing employee’s practical hours per week are 27 hours (1620 minutes per week).

The cost per marketing employee is based on the annual average cost per employee (table 3, column 5). The estimated practical hours of work per week are 85% of 32 hours (27.2 hours). The estimated average and annual theoretical cost per marketing employee is 726 033 SEK (0.8*907 541 SEK (table 4, column 2, row 2)). Similarly, the annual practical cost per marketing employee is 617 128 SEK per marketing employee per year, i.e. 80 % of average practical full-time cost per employee (0, 8* 771 410 SEK (table 4, column 2, row 3)).

The direct cost of marketing activities consists of product promotions through advertisement in newspaper and through emails. The approximate cost for advertisement in newspaper for one product is 65 000 SEK. The estimated cost for mailing through the digital business platform and industrial hub called “Industritorget.se” is about 5 000 SEK. Their cost driver rates per minute are shown in table 5 columns 5.

Resource driver	Per year	Per week	Per hour	Per minute

Indirect costs for the marketing department	*Annual indirect practical cost (SEK) per activity (1 employee) 80% of full-time (0,8*(table 4, column 2, row 2))*	*Indirect cost (SEK) per employee per week (52 weeks per year)*	*Indirect cost (SEK) per employee per hour (theoretical time: 32 hours per week and 27.2 practical hours).*	*Indirect cost driver measures (SEK) per employee per minute: Indirect cost driver*
General practical cost of activities per employees (practical time & 80% of full-time)	617 128	11 867.85	436.32	7.27
Number of employees per activity	1	1	1	1

Table 5. Average cost (SEK) in the marketing department of TRUMPF Maskin AB per minutes of work (activity cost drivers) Source: Orbis (2017, and TRUMPF Maskin AB.

The direct costs of the marketing department are illustrated in table 6.

Marketing Activities with direct costs	*Direct costs (SEK)*	*Minimum and maximum number of minutes per activity*	*Minimum and maximum costs per activity*	*Direct Cost driver measures (SEK) per marketing activity per minute (cost drivers)*
Product promotion in newspaper (80% of full-time)	65 000	480	65 000	135,42
Product promotion in e-mail (80% of full-time)	5000	480	5000	10,42
Marketing activities with direct costs including indirect costs	*Indirect + Direct Costs (SEK)*	*Minimum & Maximum number of minutes per activity*	*Min-Max costs*	*Direct Cost driver measures (SEK) per marketing activity per minute (cost drivers)*
Practical Cost & time for promotion in newspaper.	68 489,6 - SEK	480 – 720 Minutes	68 489,6 – 102 734 SEK	142,69 (135,42+7,27)
Practical cost & time for promotion in e-mail.	8 489,6 - SEK	480 – 720 Minutes	8 489,6 – 12 734 SEK	17,69 (10,42+7,27)
Variable costs & time for marketing activities with direct costs	**76 979 SEK**	**960 Minutes**	**76 979 SEK**	**160,38 SEK**

Table 6. Direct costs (SEK) in the marketing department of TRUMPF Maskin AB per minutes of work (activity cost drivers) Source: Orbis (2017, and TRUMPF Maskin AB.

The time and cost to finish respective task of the marketing department was approximated by the marketing coordinator illustrated in table 7. The marketing department is considered to be one cost center in the cost model and the activities performed by its employees are represented row by row. The cost drivers are the number of minutes per activity (table 7, column 3) and the minimum-maximum cost drivers for *TruPrint 1000* represented in column 4 and 6 respectively in table 7. The Indirect cost rate per marketing activity are calculated based on the Indirect cost of marketing activities per employee per minute in table 5, multiplied by the general number of minutes it takes to finish each activity (table 7, column 3). The cost rate for new product promotion activities in newspaper and email are based on the activity cost drivers for total direct cost of activities in table 7.

Marketing activities	*Descriptions of each activity in the marketing department of the NPI*	*Minimum units of work per NPI*	*Maximum units of work per NPI*	*Minimum costs per activity:*	*Maximum costs per activity:*	*Activity cost driver*

during the NPI process of TruPrint 1000	*process*	*activity and proportion of practical work per week (%)*	*activity and proportion of practical work per week (%).*	*Indirect costs + direct cost, i.e. the activity cost driver rates.*	*Indirect costs + direct costs, i.e. the activity cost driver rates.*	*measures in SEK per minute (min)*
Updating Website	*Updating product and technical information*	240 minutes	600 minutes	1 744,8 SEK	4 362 SEK	7.27 SEK/ Min
Adding to Website	*Adding extra information to the Website*	60 minutes	120 minutes	436 SEK	872 SEK	7.27 SEK/ Min
Advertise Booking	*Advertise Booking/communication & collaboration with advertising agencies/providers*	60 minutes	120 minutes	436 SEK	872 SEK	7.27 SEK/ Min
Press releases	*Write press releases, distribute press material (e.g. pictures) & analyze post-press release.*	480 minutes	480 minutes	3 490 SEK	3 490 SEK	7.27 SEK/ Min
Create advertisement/product promotion in newspaper	*Create ads in collaboration with advertising agencies, includes design, translation and corrections.*	480 minutes	720 minutes	68 490 SEK	102 734 SEK	142,69 SEK/ Min
Create digital advertisement/product promotion through e-mail	*Create ads in collaboration with advertising agencies, includes design, translation and corrections.*	480 minutes	720 minutes	8 490 SEK	12 734 SEK	17,69 SEK/ Min
Planning of Tech-Days and events	*Customer reconciliations and meetings, protocols and checklists, communication with head quarter etc.*	960 minutes	1200 minutes	6 979 SEK	8 724 SEK	7.27 SEK/ Min
Marketing of Tech-Days	*Marketing of Tech-Days and product shows.*	960 minutes	1200 minutes	6 979 SEK	8 724 SEK	7.27 SEK/ Min
Administration	*Customer inquiries, invitations to agencies, ordering of marketing material etc.*	1440 minutes	2160 minutes	10 469 SEK	15 703 SEK	7.27 SEK/ Min
Planning and coordinating preparations to Tech-Days and CRM	*Customer service, space and location management, Public Relationship (PR marketing) management, coordination etc.*	1200 minutes	1800 minutes	8 724 SEK	13 086 SEK	7.27 SEK/ Min
Total indirect and direct costs	**Aggregated time and costs**	**6360 minutes**	**9120 minutes**	**116 238 SEK**	**171 302 SEK**	
The number of employees dedicated	*The number of marketing employees.*	1	1	1	1	

Table 7. The activities and cost drivers of the marketing department during the NPI process. Own developed table.

The three-different activity cost driver measures in the NPI process of TruPrint 1000 are illustrated in table 8 for the marketing department.

Activities	Minimum cost driver measures	Maximum cost driver measures	Average cost driver measures	Cost driver rates in SEK
Update Website	1 745 SEK	4 362 SEK	3 053 SEK	7,27 SEK
New Product information system upload	436 SEK	872 SEK	654 SEK	7,27 SEK
Advertise Booking	436 SEK	872 SEK	654 SEK	7,27 SEK
Press releases	3 490 SEK	3 490 SEK	3 490 SEK	7,27 SEK
Advertisement in newspaper	68 491 SEK	102 737 SEK	85 614 SEK	142,69 SEK
Digital advertisement (email)	8 491 SEK	12 737 SEK	10 614 SEK	17,69 SEK
Planning Tech-Days	6 979 SEK	8 724 SEK	7 852 SEK	7,27 SEK
Marketing of Tech-Days	6 979 SEK	8 724 SEK	7 852 SEK	7,27 SEK
Administration	10 469 SEK	15 703 SEK	13 086 SEK	7,27 SEK
Preparation of Tech-Days and CRM	8 724 SEK	13 086 SEK	10 905 SEK	7,27 SEK
Total	**116 240 SEK**	**171 307 SEK**	**143 774 SEK**	

Table 8. The three-activity cost driver measure rates of the marketing department during the NPI process of TruPrint 1000.

The largest cost driver rates in the marketing department for the introduction of *TruPrint 1000* is advertisement in newspaper as illustrated in diagram 2. The diagram is based on table 8.

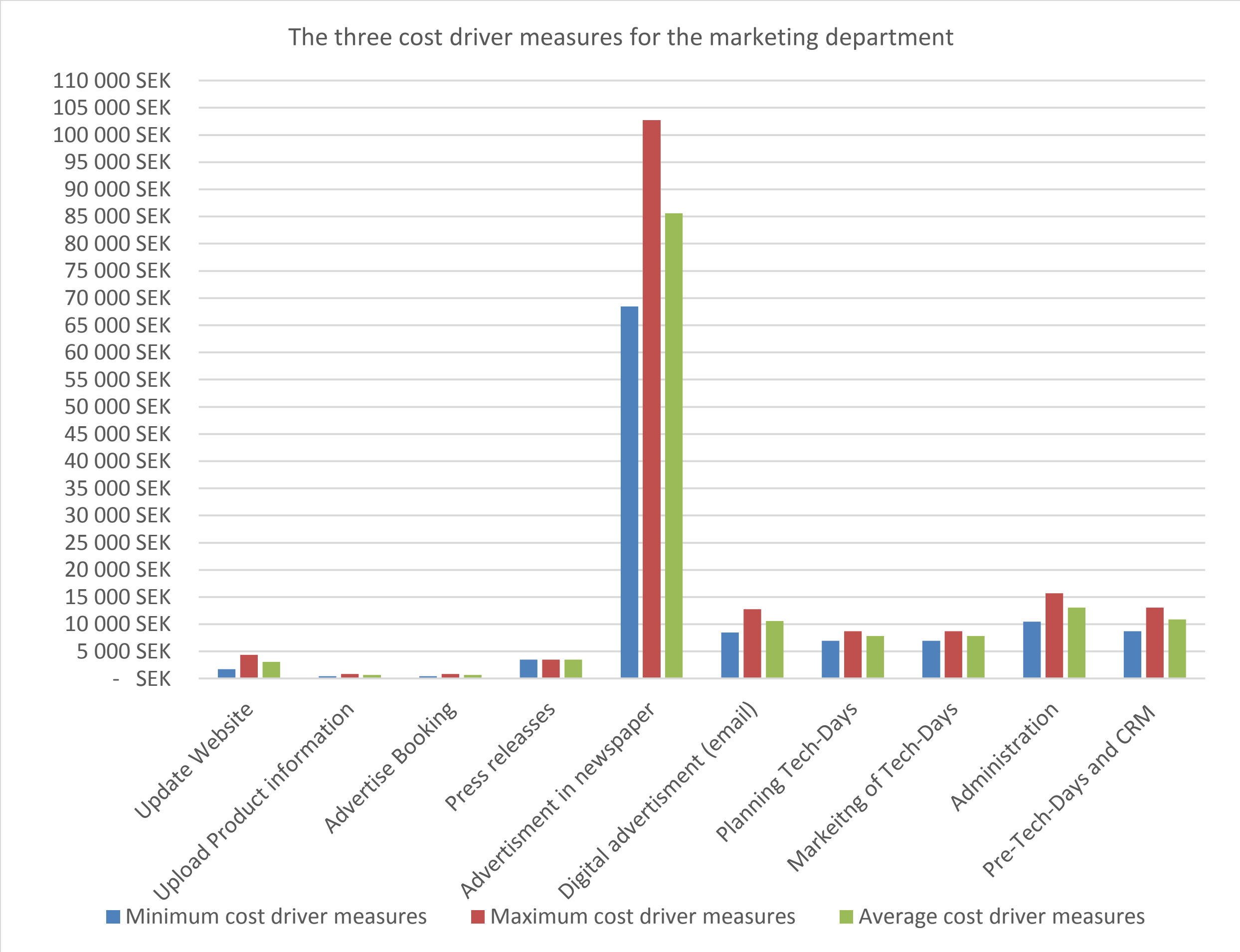


Diagram 2. The three cost driver measures for the marketing department. Own developed diagram.

4.2.7. The Laser-Machine Sales Department's Activity Drivers

The two sales departments of TRUMPF Maskin AB are (1) the laser-machine sales department and (2) the tool-machine sales department. The cost object *TruPrint 1000* is included in the laser-machine sales department's product portfolio. Thus, the laser-machine sales manager was interviewed to understand the NPI process of *TruPrint 1000*. The manager's main activities consist of project management and sales of laser machines. He is also a member in the board of directors of TRUMPF laser-group. The department has two employees (including the laser-machine sales manager) but many activities are conducted cross-sectional across different departments and with different people. For example, the CEO is involved in the planning and execution of the NPI process. The laser-machine product manager's main tasks are to manage sales projects of laser-machines from start to finish, inspect customer inquiries and purchase activities. Additional tasks include seminar meetings, events, report preparation and article writing.

The sales department for laser-machines conducts services for other departments. For example, when the customer needs to upgrade its machine (retrofit) the department prepare documents of what components, material and spare-parts that should be ordered. This includes specifications of the functions they fulfill and the services for the machine. These documents are sent to the logistics department that performs the orders, purchase and administration of receipts and deliveries for the retrofit.

The laser-machine sales manager works approximately 60 hours per week (3600 minutes per week) which is the theoretical time of work per week for the laser-machine department. Hence, this is 150% of weekly full-time work (40 hours). The estimated practical work time is approximately 85 % of theoretical working hours (i.e. available working hours, excluding vacation, breaks, internal meetings and work unrelated to actual work performance). Thus, the practical work time per week is 51 hours (3060 minutes per week). The average cost per employee of laser-machines sales department is 7, 27 SEK per minute (table 4) and the average work time per laser machine employee are 150% of weekly full-time work per employee illustrated in table 8. The laser-machine sales department did not have any direct costs related to the NPI process of *TruPrint 1000*. For example, the new product training for the laser-machine sales manager was free to TRUMPF Maskin AB according to our interview.

Resource driver	**Per year**	**Per week**	**Per hour** (hours per week)	**Per minute**
Laser-machine sales department for TruPrint 1000	*Indirect annual Practical cost (SEK) per Laser-machine sales activity 150 % of full-time (1,5*(table 4, column 2, row 2))*	*Indirect cost (SEK) per laser machine sales employee's weekly work (60 hours).*	*Indirect cost (SEK) per laser machine sales employee per hour*	*Indirect cost driver measures (SEK) per laser machine sales employee per minute*
Average indirect Practical cost of laser-machine employees (150% of full-time)	1 157 000	26 172	436,2	7,27

Table 9. The average practical cost of resources from the annual report (2016-06-30) assigned to the Laser-machine sales department per week, per hour and per minute of work. Source: Orbis (2017) and TRUMPF Maskin AB.

The sales manager of laser-machines highlights a communication and information problem regarding the documentation of new products. The documented product information can deviate from how the final product characteristics look. Problems arrive when the information deviate to a larger extent, i.e. when the new products are not completely represented in the documents. When this happens, large cost occurs for correcting the mistake after a sale when the product does not meet the needs and expectations by customers.

The indirect activity cost driver rates (with activity cost driver measure of 7,27 SEK per minute) for the Laser-machine sales department are illustrated in table 9. Direct costs did not exist in this cost center related to the NPI process of TruPrint 1000. Hence, since this cost center only includes indirect costs, the cost driver measures range (minimum to maximum cost driver measures) have been estimated by the respondents.

Laser-Machine Sales activities during the NPI process of TruPrint 1000	*Descriptions of each activity in the marketing department of the NPI process*	*Number of employees per activity*	*Minimum units of work per NPI activity (activity driver linked to product)*	*Maximum units of work per NPI activity (activity driver linked to product)*	*Minimum costs per activity: Indirect costs*	*Maximum costs per activity: Indirect costs*
Market Potential Analysis	Identify and analyze market developments, opportunities and threats	4	720 Minutes	1 440 Minutes	5 234 SEK	10 469 SEK
Product positioning	Positioning of product in product portfolio	1	60 Minutes	120 Minutes	436 SEK	872 SEK
Competitor analysis	Analysis of competitor	2	480 Minutes	960 Minutes	3 490 SEK	6 979 SEK
Customer analysis	Analysis of customer segment and approximation to local market	2	480 Minutes	960 Minutes	3 490 SEK	6 979 SEK
Market Pricing	Determine product price	1	120 Minutes	240 Minutes	872 SEK	1 745 SEK
Sales Budgeting	Set sales goals and estimate expected	1	120 Minutes	240 Minutes	872 SEK	1 745 SEK

	income and costs					
New product price lists	Create new product price lists and product offer documents	1	120 Minutes	240 Minutes	872 SEK	1 745 SEK
New Product Training	Staff training (product manager) for the new product	1	2 400 Minutes	4 800 Minutes	17 448 SEK	34 896 SEK
Sales Training	Training with Product Manager	4	Minutes	1 440 Minutes	5 234 SEK	10 469 SEK
Sales Arguments	Develop sales arguments for local market	4	240 Minutes	480 Minutes	1 745 SEK	3 490 SEK
Market plan	Communication plan to the market	3	720 Minutes	1 440 Minutes	5 234 SEK	10 469 SEK
Adopting CRM system	Adopt the CRM system to the new product	1	120 Minutes	240 Minutes	872 SEK	1 745 SEK
Adopting Quotation System	Adopting the Quotation System	1	120 Minutes	240 Minutes	872 SEK	1 745 SEK
Marketing material	Adopting marketing material to the new product	1	120 Minutes	240 Minutes	872 SEK	1 745 SEK
Update website	Upload & translate new product information	1	240 Minutes	480 Minutes	1 745 SEK	3 490 SEK
Local Advertising	Local advertising Translation	2	240 Minutes	480 Minutes	1 745 SEK	3 490 SEK
Local Prospectus	Local prospectus Translation	3	720 Minutes	1 440 Minutes	5 234 SEK	10 469 SEK
Total Indirect costs (no direct costs)	**Aggregated time and costs**	**1-4**	**7 749 Minutes**	**13 080 Minutes**	**56 270 SEK**	**112 540 SEK**

Table 10. The activities and the cost drivers of the laser-machine sales department in the NPI process for TruPrint 1000. Source: Orbis (2017) and TRUMPF Maskin AB. Own developed table.

The three-different Tech-Days activity cost driver measures have been used to calculate the minimum, maximum and *average* activity cost driver rates. These are illustrated in table 11 and diagram 3.

Laser-Machine Sales Activities	Minimum Activity costs in SEK	Maximum Activity costs in SEK	Average Activity costs in SEK	Cost driver measures
Indirect costs:				
Market Potential analysis	5 234 SEK	10 469 SEK	7 852 SEK	*7,27 SEK/Minute*
Product positioning	436 SEK	872 SEK	654 SEK	*7,27 SEK/Minute*

Competitor analysis	3 490 SEK	6 979 SEK	5 234 SEK	*7,27 SEK/Minute*
Customer analysis	3 490 SEK	6 979 SEK	5 234 SEK	*7,27 SEK/Minute*
Market pricing	872 SEK	1 745 SEK	1 309 SEK	*7,27 SEK/Minute*
Sales budgeting	872 SEK	1 745 SEK	1 309 SEK	*7,27 SEK/Minute*
New product price list	872 SEK	1 745 SEK	1 309 SEK	*7,27 SEK/Minute*
Sales training	17 448 SEK	34 896 SEK	26 172 SEK	*7,27 SEK/Minute*
New product training	5 234 SEK	10 469 SEK	7 852 SEK	*7,27 SEK/Minute*
Sales argument	1 745 SEK	3 490 SEK	2 617 SEK	*7,27 SEK/Minute*
Market plan	5 234 SEK	10 469 SEK	7 852 SEK	*7,27 SEK/Minute*
Adopting CRM system	872 SEK	1 745 SEK	1 309 SEK	*7,27 SEK/Minute*
Adopting quotation system	872 SEK	1 745 SEK	1 309 SEK	*7,27 SEK/Minute*
Market material	872 SEK	1 745 SEK	1 309 SEK	*7,27 SEK/Minute*
Update website	1 745 SEK	3 490 SEK	2 617 SEK	*7,27 SEK/Minute*
Local advertising	1 745 SEK	3 490 SEK	2 617 SEK	*7,27 SEK/Minute*
Local prospectus	5 234 SEK	10 469 SEK	7 852 SEK	*7,27 SEK/Minute*
Total variable costs:	56 270 SEK	112 540 SEK	84 405 SEK	

Table 11. The three-different Laser-Machine Sales activity cost driver rates in the NPI process of TruPrint 1000.

The largest cost driver rates in the laser-machine sales department for the introduction of *TruPrint 1000* is new product training, i.e. staff training with for the new product, as illustrated in diagram 3. The diagram is based on table 11.

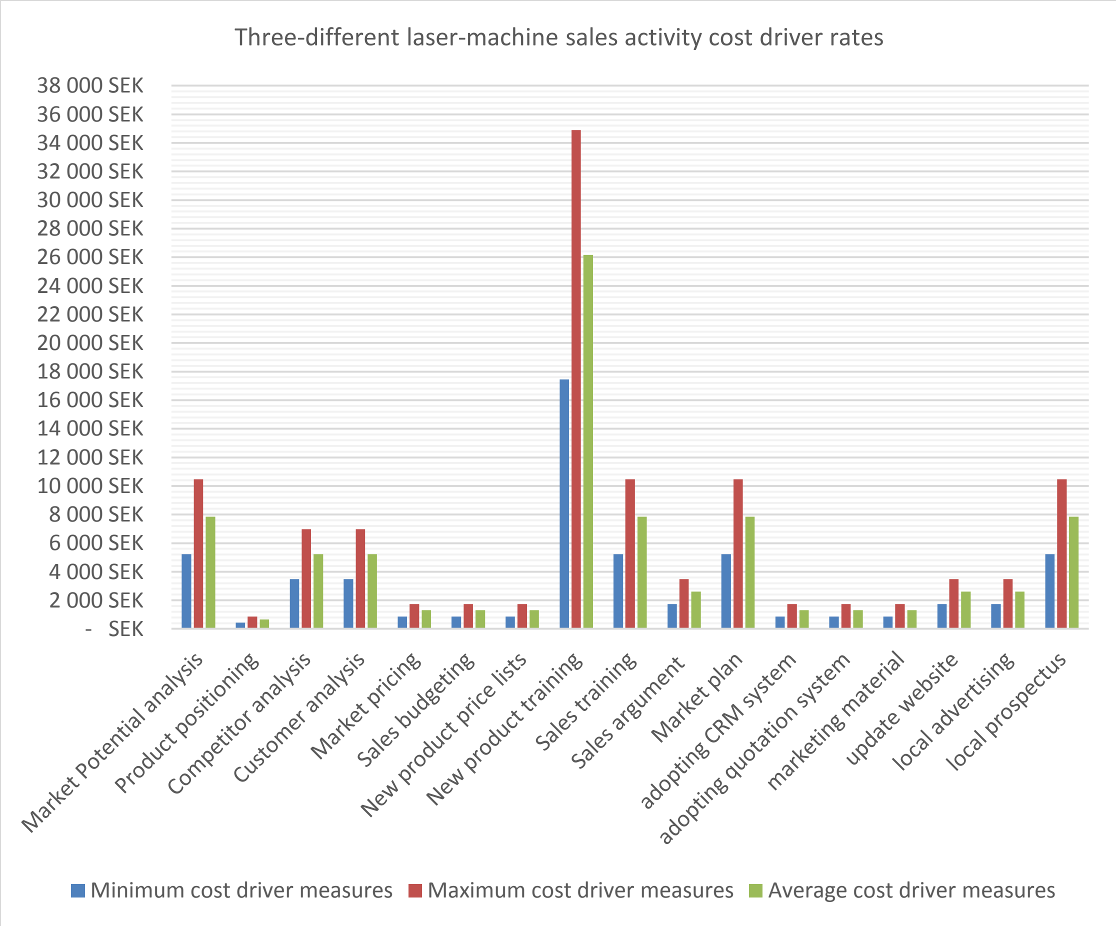


Diagram 3. Three-different laser-machine sales activity cost driver rates. Own developed diagram.

4.2.8. The After-Sales Service Department

The after-sales service department has 26 employees and consists of three groups: the laser-machine group (14 employees, including 7 external service technicians/workers), punching (6 employees) and press break/machine tool (6 employees). Each group has a group leader and the laser-machine group is involved in the NPI process of *TruPrint 1000.*

Department activities specific for the NPI process of *TruPrint 1000* includes:

1. Preparation of material documents for the machine. It takes 16-24 hours (960-1440 minutes) to prepare and costs approximately 25 000 SEK to perform (direct and indirect activity cost).
2. Preparation and generation of service specifications for the new product, estimated to take 40 hours (2400 minutes). Estimated cost of service preparation is 25 000 SEK (direct and indirect activity cost).
3. In-house support (preparing repair and maintenance services, customer machine error inquiries etc.). This takes 40 hours (2400 minutes) to finish and the estimated cost is 55 000 SEK (direct and indirect and indirect activity cost).
4. Staff training takes 40 hours in Germany and 40 hours in Sweden, totally 80 hours (4800 minutes). The training in Germany and Sweden costs 55 000 SEK per week and per employee each (direct and indirect activity cost), totally 110 000 SEK.
5. Installation of *TruPrint 1000* takes 3 hours (180 minutes).
6. Customer education services take approximately 56 hours (3360 minutes) for *TruPrint 1000.*

These activities are described in table 12.

After-Sales Service activities in the NPI process of *TruPrint 1000 & Cost driver*	Descriptions of each activity in the after sales department during the NPI process of TruPrint 1000
Prepare material	Preparation of material, components, tools and equipment for the machine
Prepare services	Preparation and generation of services and specifications for the new product
In-house support	Preparing repair and maintenance services (customer machine error inquiries).
Staff training in Sweden	Staff training of technicians and product specialists in Sweden
Staff training in Germany	Staff training of technicians and product specialists in Germany
Installation services	Product installation services
Customer education services	Product specific customer education services

Table 12. Activity Center, i.e. descriptions of the after-sales service activities in the NPI process for TruPrint 1000. Own developed table.

The theoretical working time per week is strictly 40 hours (2400 minutes). The estimated practical work time is approximately 85 % of theoretical working hours (i.e. available working hours, excluding vacation, breaks, internal meetings and work unrelated to actual work performance). Thus, the practical work time per week is 34 hours (2040 minutes per week). Staff training and creating documents has been included as a separate resource drivers (in table 10) due to their magnitude of importance in terms of cost and benefits to the NPI process.

The activities, activity driver rates and activity cost drivers for the NPI process of *TruPrint 1000* are illustrated in table 13. The activity driver rates specific for *TruPrint 1000* has been calculated based on the time-unit estimates by the experts from the after-sales department. The indirect activity cost driver rates have been calculated using the annual costs per employee per minute. This has been allocated to installation services and customer education services. The activities with direct costs are assigned with the indirect costs only when the activities have been conducted by the employees of TRUMPF Maskin AB.

Resource Driver	**Per Year**	**Per Week** (52 weeks per year)	**Per Hour** (40 hours per week)	**Per Minute**
After Sales Service resource drivers for TruPrint 1000	*Indirect cost (SEK) per after sales service activity 100% full-time (table 2, column2))*	*Indirect cost (SEK) per after sales service weekly work*	*Indirect cost (SEK) per after sales service hours of work*	*Indirect cost driver measure, i.e. indirect cost (SEK) per after sales service employee's minutes of work*
Indirect practical cost of activities per employee (100% of full-time)	771 410	14 835	436,32	7,27

Table 13. The indirect cost drivers of the After Sales activities during the NPI process of TruPrint 1000. Source: Orbis (2017) and TRUMPF Maskin AB.

The indirect- and direct activity cost drivers of the after-sales service department are illustrated in table 14. The indirect cost and direct cost of installation services are illustrated in separate rows.

Indirect cost per after sales service activity	*Minimum units of work per activity (times the number of employees)*	*Maximum number units of work per activity (times the number of employees)*	*Minimum cost (SEK) per activity*	*Maximum cost (SEK) per activity*	*Indirect cost driver measures, i.e. indirect costs (SEK) per Minute per activity*
Customer education services	3 360 Minutes	5 040 Minutes	24 427 SEK	36 641 SEK	7, 27 SEK/Minute
Installation Services	180 Minutes	270 Minutes	1 309 SEK	1 963 SEK	7, 27 SEK/Minute
Prepare material offers	2 400 Minutes	3 600 Minutes	17 448 SEK	26 172 SEK	7, 27 SEK/Minute
Total indirect costs	5 940 Minutes	8 910 Minutes	43 184 SEK	64 776 SEK	
After Sales Service Activities with direct costs in the NPI process of TruPrint 1000	*Minimum units of work per activity*	*Maximum units of work per activity*	*Minimum cost (SEK) per activity*	*Maximum cost (SEK) per activity*	*Direct cost driver measures, i.e. direct costs (SEK) per Minute per activity (including indirect costs per activity)*
Prepare/purchase material offers	14 Pcs	21 Pcs	31 856 SEK	47 785 SEK	2 275 SEK/Pcs
Prepare service offers	2400 Minutes	2400 Minutes	25 000 SEK	25 000 SEK	10, 41 SEK/Minute
In-house support (technical support system)	2400 Minutes	2400 Minutes	55 000 SEK	55 000 SEK	22,92 SEK/Minute
Staff training in Germany	2400 Minutes	2400 Minutes	55 000 SEK	55 000 SEK	22,92 SEK/Minute
Staff training in Sweden	2400 Minutes	2400 Minutes	55 000 SEK	55 000 SEK	22,92 SEK/Minute
Installation Services	180 Minutes	270 Minutes	1 500 SEK	1 963 SEK	8,33 SEK/Minute
Total direct costs	9 780 Minutes	9 870 Minutes	223 350 SEK	241 428 SEK	
Total cost of all activities	15 540 Minutes	18 531 Minutes	266 534 SEK	306 204 SEK	
The number of employees per activity	The number of after sales service employees working with the NPI process	N/A	N/A	N/A	N/A

Table 14. The cost drivers of After Sales activities during the NPI process of TruPrint 1000. Source: Orbis (2017) and TRUMPF Maskin AB.

The laser service group conducts several activities for other departments including: technical advising, fault diagnosis, technical support, creating documents for spare-parts, components and material etc. The resource consumption per activity conducted by the laser-machine group in the NPI process varies by product size, complexity and other product characteristics. For example, it takes approximately 240 hours (14400 minutes) to train staff in the NPI process of the laser machine *TruLaser Cell* 3000 which is three times as much as for *TruPrint 1000 (4800 minutes).* The installation of *TruPrint 1000* takes 4-8 hours (240-480 minutes) while the installation for *TruLaser Cell* takes 11-22 hours (660-1320 minutes). In addition, the customer education services take approximately 56 hours (3360 minutes) for *TruPrint 1000* while it takes approximately twice as much time (6 720 minutes) for *TruLaser Cell*.

The three-different after-sales service activity cost driver measures have been used to calculate the activity cost driver rates. These are illustrated in table 15 and diagram 4.

After-Sales Service Activities	Minimum Activity costs	Maximum Activity costs	Average Activity costs	Cost driver measures
Indirect costs				
Customer education	*24 427 SEK*	*36 641 SEK*	*30 534 SEK*	*7,27 SEK/Minute*
Installation services	*1 309 SEK*	*2 617 SEK*	*1 963 SEK*	*7,27 SEK/Minute*
Prepare product material	*17 448 SEK*	*26 172 SEK*	*21 810 SEK*	*7,27 SEK/Minute*
Direct costs				
Prepare/purchase product material	*31 848 SEK*	*47 772 SEK*	*39 810 SEK*	*2 275 SEK/Pieces*
Prepare product Services	*25 000 SEK*	*25 000 SEK*	*25 000 SEK*	*10,42 SEK/Minute*
In-house support	*55 000 SEK*	*55 000 SEK*	*55 000 SEK*	*22,92 SEK/Minute*
Staff-training Germany	*55 000 SEK*	*55 000 SEK*	*55 000 SEK*	*22,92 SEK/Minute*
Staff-training Sweden	*55 000 SEK*	*55 000 SEK*	*55 000 SEK*	*22,92 SEK/Minute*
Installation Services	*1 499 SEK*	*2 999 SEK*	*2 249 SEK*	*8,33 SEK/Minute*
Total variable costs:	***266 500 SEK***	***306 200 SEK***	***286 400 SEK***	

Table 15. The three-different after-sales service activity cost driver rates in the NPI process of TruPrint 1000.

The three largest cost driver rates in the after-sales service department for the introduction of *TruPrint 1000* are staff training in and in-house support for the new product, as illustrated in diagram 4. While the smallest cost driver rates are installation services (1300-2700 SEK). The diagram is based on table 15.

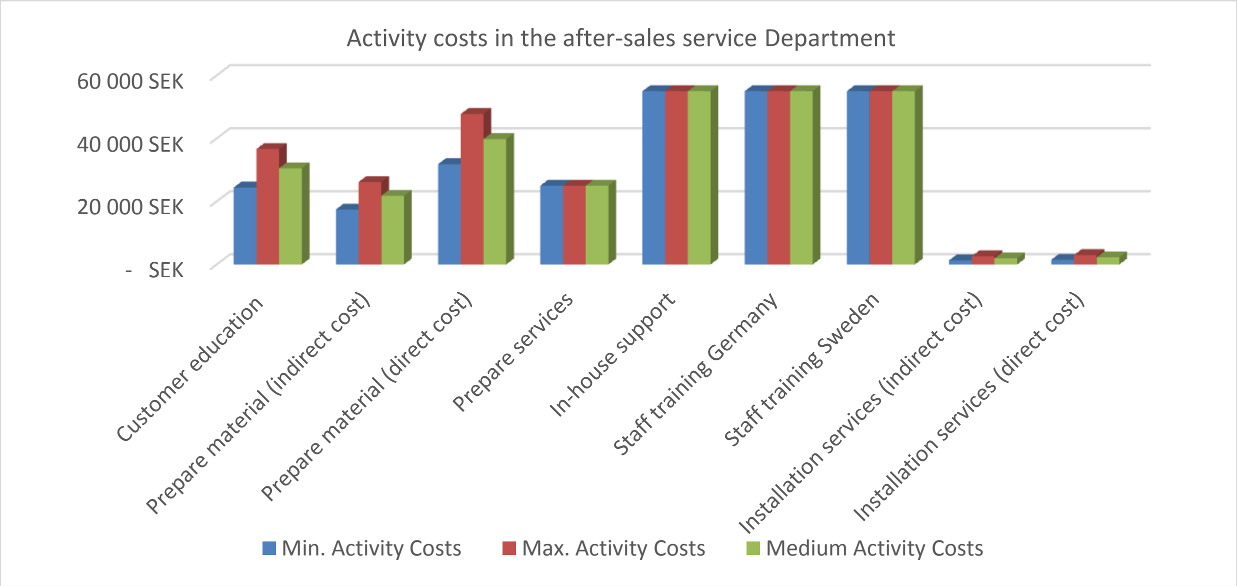


Diagram 4. Minimum-, maximum- and average after-sales service activity cost rates in the NPI process of TruPrint 1000.

4.2.9. Tech-Days

The indirect cost driver for the Tech-Days (Additive Manufacturing show) at TRUMPF Maskin AB is shown in table 16.

Resource Driver	Per Year	Per Week	Per Hour	Per Minute
Tech-Days resource drivers for TruPrint 1000	*Yearly indirect cost (SEK) per employee 100% full-time (table 2, column2))*	*Indirect costs (SEK) weekly work*	*Indirect costs (SEK) per hour of work*	*Indirect cost driver measures, i.e. indirect cost (SEK) per after sales service employee's minutes of work*
Indirect practical cost of activities per employee (100%)	771 410	14 835	436,32	7,27

Table 16. The costs of Tech-Days activities for the NPI process of TruPrint 1000 at TRUMPF Maskin AB. Own developed model.

The activities with indirect costs and direct costs during the Teach-Days are shown in table 17. The majority of the Tech-Days activities with direct costs are external services such as shipping, installation and marketing.

Costs per Tech-Days activities with only indirect costs	*Minimum units of work per activity*	*Maximum units of work per activity*	*Minimum cost (SEK) per activity*	*Maximum cost (SEK) per activity*	*Cost (SEK) per unit of work per activity*
Start-up meeting (6 people & 2 hours	*360 Minutes*	*720 Minutes*	*2 617 SEK*	*5 234 SEK*	7,27 SEK
Reconciliation with Headquarter	*120 Minutes*	*240 Minutes*	*872 SEK*	*1 745 SEK*	7,27 SEK
Project Meetings (6 people & 2 hours)	*720 Minutes*	*1 440 Minutes*	*5 234 SEK*	*10 469 SEK*	7,27 SEK
Tech-Day/New Product Show Event internal work (6 people & 24 hours)	*2 160 Minutes*	*4 320 Minutes*	*15 703 SEK*	*31 406 SEK*	7,27 SEK
Energy Consumption for TruPrint 1000	*360 Minutes*	*720 Minutes*	*108 SEK*	*216 SEK*	0,3 SEK
Total cost of activities with only indirect costs			*24 535 SEK*	*49 070 SEK*	
Costs per Tech-Days activity with direct- costs	*Minimum units of work per activity*	*Maximum units of work per activity*	*Minimum cost (SEK) per activity*	*Maximum cost (SEK) per activity*	*Cost driver measures in (SEK) per unit of work per activity*
External Marketing Services for TruPrint 1000	637,5 Minutes	1 275 Minutes	20 875 SEK	41 750 SEK	32,75 SEK/Minute
Marketing Material (advertisement) for TruPrint 1000	2pcs	4pcs	2 000 SEK	4 000 SEK	1 000 SEK/pcs
Shipping and loading costs of TruPrint 1000	8 680kg	17 360kg	18 870 SEK	37 740 SEK	2, 17 SEK/kg
Installation of TruPrint 1000	240 Minutes	480 Minutes	3 400 SEK	6 800 SEK	14,17 SEK/Minute
Dismantling of TruPrint	180 Minutes	360 Minutes	2 550 SEK	5 100 SEK	14,17 SEK/Minute

1000					
Installation Material for TruPrint 1000	3pcs	6pcs	3 000 SEK	6 000 SEK	1 000 SEK/pcs
Application support by TRUMPF Group employee (External services)	720 Minutes	1 440 Minutes	16 800 SEK	33 600 SEK	22,33 SEK/Minute
Metal Powder	2,5kg	5kg	15 855 SEK	31 709 SEK	6 342 SEK/kg
Metal Powder shipping	2,5pcs	5pcs	300 SEK	600 SEK	120 SEK
Rent Gas: Helium (99% discount), Nitrogen (99% discount) and Argon (including shipping, packing & container)	25 L	50 L	2 670 SEK	5 330 SEK	106,7 SEK/L
Catering	1pcs	2pcs	1 625 SEK	3 250 SEK	1 625 SEK/pcs
Energy Consumption for TruPrint 1000	360 Minutes	720 Minutes	58 SEK	116 SEK	0,16 SEK/Minute
Total direct costs			88 000 SEK	130 250 SEK	
Total variable costs			**112 505 SEK**	**225 011 SEK**	

Table 17. Direct costs of Tech-Days activities in the NPI process of TruPrint 1000. Own developed table.

The three-different Tech-Days activity cost driver measures have been used to calculate the minimum, maximum and *average* activity cost driver rates. These are illustrated in table 18 and diagram 5.

Tech-Days Activities	Minimum Activity costs	Maximum Activity costs	Average Activity costs	Cost driver measures
Indirect costs:				
Start-up meeting	***2 617 SEK***	***5 234 SEK***	***3 926 SEK***	*7,27 SEK/Minute*
Reconciliation	***872 SEK***	***1 745 SEK***	***1 309 SEK***	*7,27 SEK/Minute*
Project Meetings	***5 234 SEK***	***10 469 SEK***	***7 852 SEK***	*7,27 SEK/Minute*
Tech-Days internal work	***15 703 SEK***	***31 406 SEK***	***23 555 SEK***	*7,27 SEK/Minute*
Energy Consumption	***108 SEK***	***216 SEK***	***162 SEK***	*0,3 SEK/Minute*
Direct costs:				
External Marketing Services	***20 900 SEK***	***41 800 SEK***	***31 300 SEK***	*32,75 SEK/Minute*
Marketing material	***2 000 SEK***	***4 000 SEK***	***3 000 SEK***	*1000 SEK/pcs*
Shipping and loading of TruPrint 1000	***18 800 SEK***	***37 700 SEK***	***28 300 SEK***	*2,17 SEK /kg*
Installation of TruPrint 1000	***3 400 SEK***	***6 800 SEK***	***5 100 SEK***	*14,17 SEK/Minute*
Dismantling of TruPrint 1000	***2 550 SEK***	***5 100 SEK***	***3 800 SEK***	*14,17 SEK/Minute*
Installation material for TruPrint 1000	***3 000 SEK***	***6 000 SEK***	***4 500 SEK***	*1000 SEK/pcs*

Application support for TruPrint 1000	***16 100 SEK***	***32 200 SEK***	***24 100 SEK***	*22,33 SEK/Minute*
Metal Powder	***15 900 SEK***	***31 700 SEK***	***23 800 SEK***	*6342 SEK/kg*
Metal Powder shipping	***300 SEK***	***600 SEK***	***450 SEK***	*120 SEK/kg*
Rent for gas	***2 700 SEK***	***5 300 SEK***	***4 000 SEK***	*106,7 SEK/L*
Catering	***1 600 SEK***	***3 300 SEK***	***2 400 SEK***	*1 625 SEK/pcs*
Energy Consumption	***58 SEK***	***115 SEK***	***86 SEK***	*0,16 SEK/Minute*
Total variable costs:	***12 505 SEK***	***225 000 SEK***	***168 800 SEK***	

Table 18. The three-different Tech-Days activity cost driver rates in the NPI process of TruPrint 1000.

The single largest cost driver rate in the Tech-Days cost center for the introduction of *TruPrint 1000* is Tech-Days internal work, i.e. the implementation of the new product show event at TRUMPF Maskin AB. While the smallest cost driver rate is energy consumption. This is illustrated in diagram 5. The diagram is based on table 18.

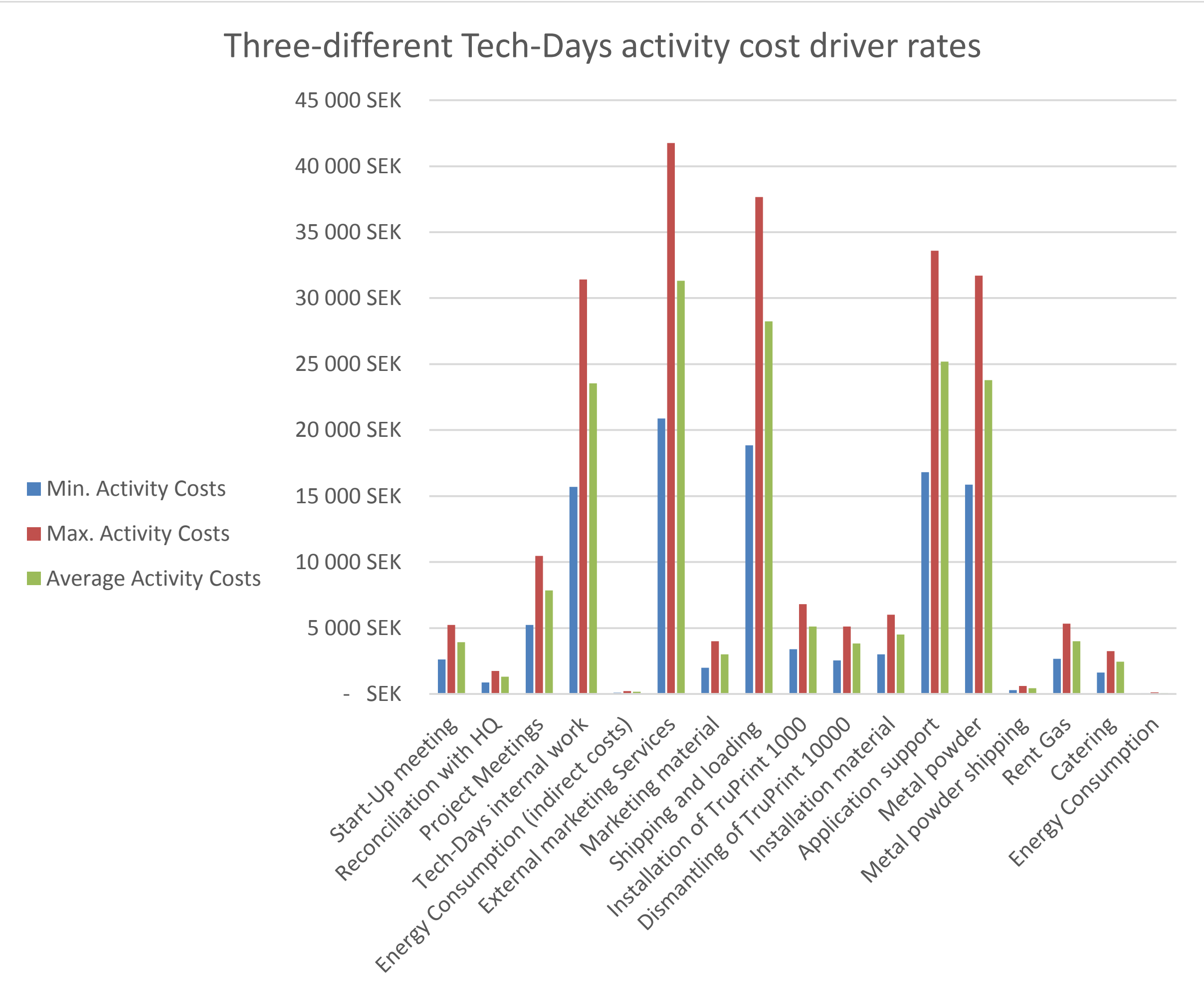


Diagram 5. Three different Tech-Days activity cost rates. Own developed diagram.

4.2.10. Total cost of activities in the NPI process of *TruPrint 1000*

The total cost of activities in the NPI process of TruPrint 1000 are the combined total cost per cost center (the marketing-, laser-machine sales-, after-sales service department and Tech-Days event). This are illustrated in table 19.

Cost centers	Minimum Costs	Maximum Costs	Average Costs
The Marketing Department:	116 237 SEK	171 302 SEK	143 774 SEK
The Laser-Machine Sales Department:	56 270 SEK	112 540 SEK	84 405 SEK
The After-Sales Service Department:	266 540 SEK	306 200 SEK	286 400 SEK
The Tech-Days/New Product Show Event:	112 505 SEK	225 011 SEK	168 758 SEK
Total indirect and direct costs:	**551 552 SEK**	**815 053 SEK**	**683 303 SEK**

Table 19. The total cost of activities in the NPI process for TruPrint 1000. Own developed table.

The cost center that consumed most resources during NPI process of TruPrint 1000 is the after-sales service department as illustrated in diagram 6.

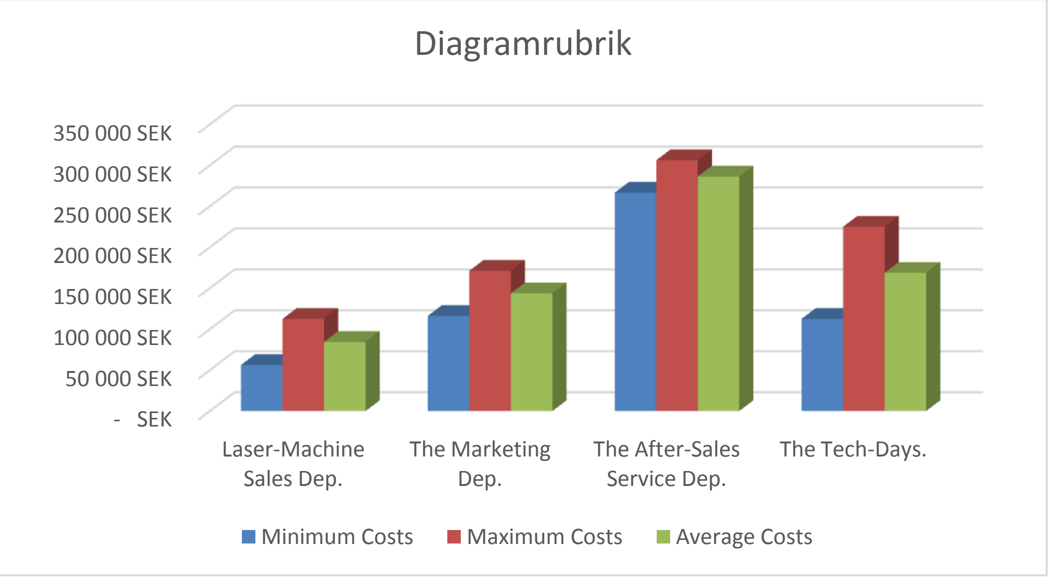


Diagram 6. The three-different cost rates per cost center in the NPI process of TruPrint 1000 in TRUMPF Maskin AB.

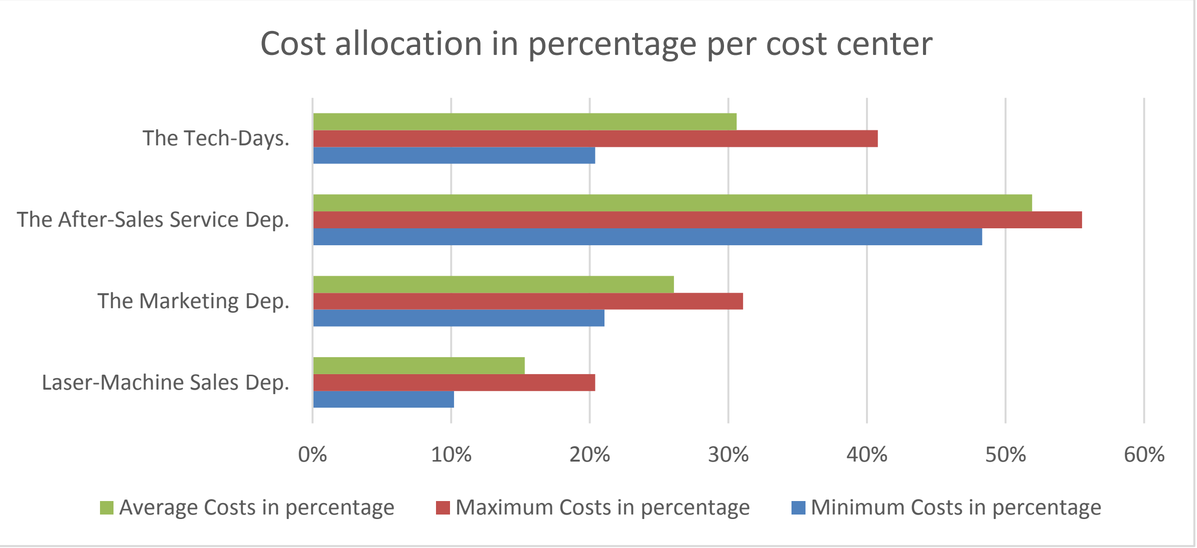


Diagram 7. The Three-different cost rates in percentage per cost center in the NPI process of TruPrint 1000 in TRUMPF Maskin AB.

The difference between the minimum indirect and actual total direct costs (according to the ERP system in TRUMPF Maskin AB), the maximum Variable costs and average costs are illustrated in diagram 8. The diagram is based on table 19. Diagram 9 illustrates the original total direct costs (minimum costs) and the original indirect costs (minimum cost) in the blue stack. The red stack illustrates a total cost increase of approximately 65 % and the green stack illustrates an approximate cost increase rate of 30 %. This is due to the fact that the maximum direct cost of activities in each cost center have been increased by 50 % except from Tech-Days where the majority have been increased with 100% from the original minimum values of direct costs. The green stack illustrates the cost in-between minimum and maximum Variable costs.

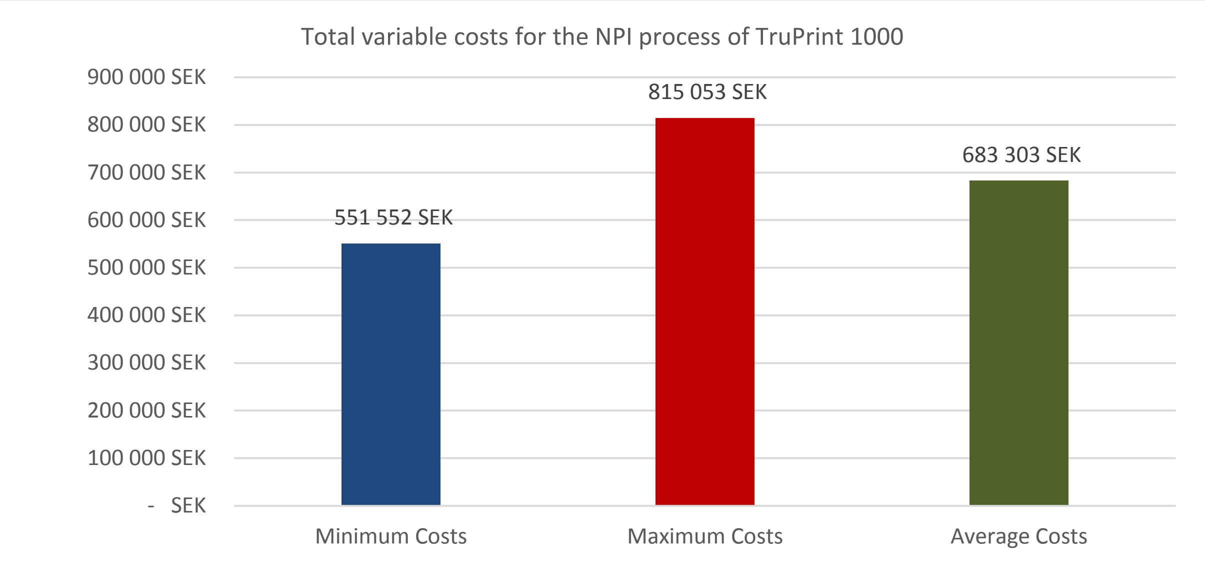


Diagram 8. The total variable costs for the NPI process of TruPrint 1000 in TRUMPF Maskin AB.

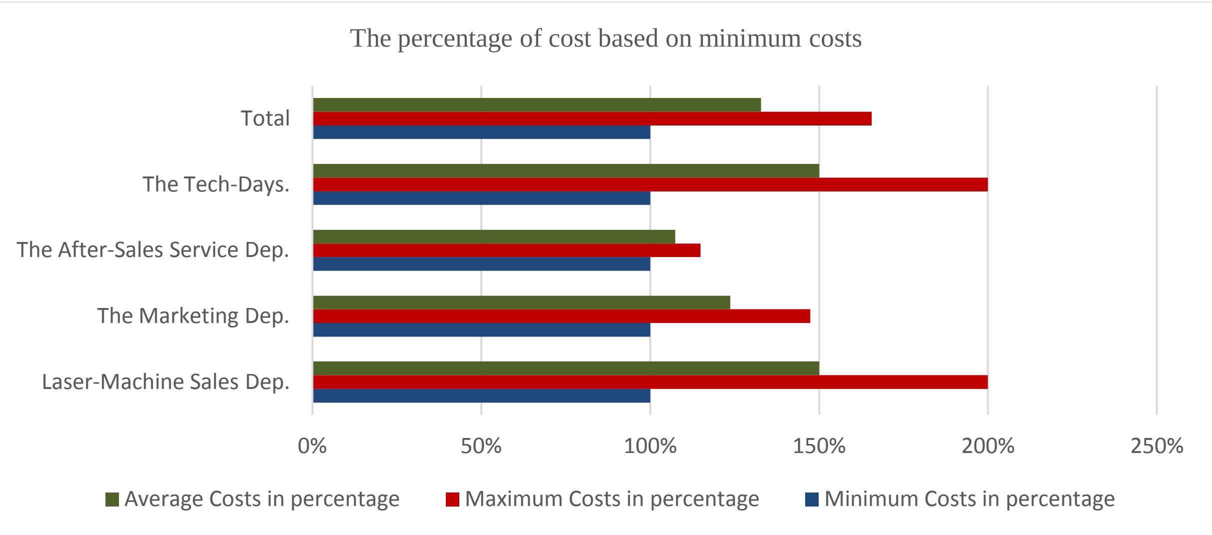


Diagram 9. The percentage of the three-different cost estimates based on minimum costs per cost center.

4.2.11. High frequency of NPD processes in TRUMPF Group and high costs in the NPI process in TRUMPF Maskin AB

The high rate of NPD processes in TRUMPF Group and its impact on the NPI costs of TRUMPF Maskin AB were highlighted during the interviews with the five research participants (table 2). TRUMPF's new product development (NPD) process is happening frequently. New product versions are developed during the release year of older versions which puts pressure on the resources in TRUMPF Maskin AB. This involves installation, training, new product marketing, customer education etc. These resources are consumed by the activities included in the NPI process which needs to be measured and documented to allow process improvement. Today TRUMPF Maskin AB do not have metrics (Key Performance Indicators) developed for their NPI processes to document their performance. However, there is a strong desire is to get better cost information of activities during the NPI process so that operative procedures can be improved, support management and be more aligned with strategic objectives. More specifically, one desire highlighted by the company's CEO, Hubert Wilbs, was to use the cost information to calculate marginal contributions, break-even points, budgeting, etc. Furthermore, the cost estimations for the NPI process of a new product need to be done before the initial sale. This would increase the understanding of what minimum price should be negotiated to reach the marginal profit goal (profit per unit sold).

During the cost data collection, it became evident that much of the costs of activities in the NPI are contributed to after-sales service activities (2/4) whose primarily goal is to provide a high service level to a minimum cost. However, a high service level demands investments in activities that consume more resources. Thus, the level of costs derived from after sales service activities increases as the volume of products sold increases. For example, regarding *TruPrint 1000*, the estimated number of desirable service technicians is one on two machines. This means that each odd sales number of *TruPrint* 1000 increases the cost for educating one additional service technician. However, if the service level is higher than the level of income generated from that product then this will result in short-term losses for the company. In contrast, a low service level would result in poorer customer satisfaction which minimizes income due to lost goodwill, sales and long-term profitability. Hence, there is a strong need for indicators that can illustrate the equilibrium of costs and short-term profit per product sold.

Further, if these levels are consistent over time, the sale will result in systematic loses over a longer period of time. The company may never be able to catch up with these costs through the income generated from sales of this product (if they remain constantly below the critical level for marginal profit) before the next version is released. The new version is likely to cannibalize the sales of the old version since it is upgraded and usually superior in some aspects of functionality. At the same time the new version demands new investments in the NPI process prior to and after its first sale. Experts in the company argues that this problem arrive due to the small size of the Scandinavian market compared to other larger markets of TRUMPF Group, i.e. central Europe, U.S. and China. The small market size can't absorb the new product as fast as larger markets. Thus, the development rate in TRUMPF's NPD process, which is determined by the parent company in Germany, do not always fit the size of its smaller subsidiaries responsible for smaller market. However, TRUMPF Group can still of course choose which products to promote for what regions and markets.

The NPI process in TRUMPF Maskin AB is planned based on the product documentation that is provided. TRUMPF Group provides a wide range of different products which means that the NPI processes in TRUMPF Maskin AB differs a lot. Therefore, it is essential to have a correct product documentation that accurately reflects its complexities, technical characteristics and functions, so that TRUMPF Maskin AB can plan the NPI activities that prepare material and services for the product introduction and after sales services. If the product specification is incorrect, the company is likely to suffer from unnecessary costs imposed due to misalignment between process and product. Further, if the product is sold to the customer based on incorrect product specification, larger costs will be imposed on TRUMPF to correct those mistakes. This especially happens when problems occur during the guarantee period of the product, when the major responsibility is TRUMPF and when customers do not have to pay for the services provided to solve these problems (trouble shooting, repair, upgrading, etc.).

A cost model that can be used to accurately measure and communicate the cost of the NPI process is needed so that the planning of the NPI processes becomes more effective based on accurate costing of its activities. The factors influencing the performance outcomes in terms of cost and time estimates derived from the cost model is not only determined by product characteristics but also the NPD rate in the parent company in Germany. If a new version of the product is expected within a shorter period of time, then the current version needs to be introduced as fast as possible (while the NPI process is effective and efficient). This is so that the critical sales volume per product can be achieved to balance the cost of investments before the new version starts to cannibalize its sales. Increasing sales of a new product during a shorter period of time is more likely when marketing and other activities of the NPI processes are done more extensively which demands more resources per activity.

4.3. Marginal contribution data

The desired contribution margin (CM) levels, also known as the profit-volume ratios, for *TruPrint 1000* are 2%, 3% and 4% according to the interviews at TRUMPF Maskin AB. The contribution margin is the selling price per unit minus the variable cost per unit. The variable costs include both direct- and indirect costs. The products sold by TRUMPF Maskin AB are first purchased from TRUMPF Group. The purchase price covers the cost for R&D and manufacturing. This means that the cost of product purchase needs to be included when estimating the profit-volume ratio and to enable cost-volume-profit analysis.

The product price is set to cover the cost of new product purchase from TRUMPF Group and the Variable costs of the company, including the variable costs from the NPI process. As illustrated in table 19, the total minimum variable cost in the NPI process of *TruPrint 1000* is approximately 600 000 SEK while the maximum cost is about 972 000 SEK. The number in between those costs estimates is 785 500 SEK which is used to calculate the profit-volume ratio. During the interviews at TRUMPF Maskin AB, three different gross profit margin levels: 11 %, 12% and 13% was considered per product. In addition, the goal is to sell at minimum four *TruPrint 1000* and be far into the negotiation process with 2 additional *TruPrint 100* machines during the fiscal budget year 2017/18.

5. Analysis

This chapter includes analysis of the cost of activities in the NPI process and how they affect the marginal contribution rates of TruPrint 1000. The usefulness and limitations of the cost model, its metrics and data are being analyzed as well as the possibilities to implement the cost model, Activity Based Management, and their contributions. In addition, three scenario analyses have been conducted to suggest possible outcomes when using the cost model. These possibilities include NPI process improvement in terms of operational efficiency, strategic implications, process effectiveness and productivity. Previous studies have been analyzed and compared with the results.

5.1. TRUMPF NPI process analysis – The process approach

Johnson (1980, 44-5) argues that cost information does not allow for process improvement. It needs to be complimented with information that provides a proper understanding of the activities encompassing the process and how they are related to cost and performance. Hence, it is therefore appropriate to map activities of the NPI process and allocate costs to the activities according to their estimated resource consumption levels. This process approach allows managers to identify specific activities, responsibilities and measure the effectiveness and efficiency of the process. The NPI process can be viewed as a system of activities that uses resources to transform inputs into outputs. The inputs can simply be defined as the cost and time consumed by each activity in the NPI process. The outputs can be defined as the quality generated by the inputs (Atkinson, 1999; Franceschini et.al. 2007). Franceschini et.al. (2007) argues that the process approach is a strong tool to manage activities and related resources which enables organizations to be more efficient. Since the TDABC model allow the analyst to track costs to activities and the cost object (Kaplan and Anderson, 2004), the TDABC model goes hand in hand with the process approach.

According to the literature review (Tang and Collar, 1992; Andrew et.al, 2008, Stump et.al, 2002; Dombrowski and Malorny, 2016; Rummler and Brache, 2013), the NPI process can be divided into three stages: pre-introduction, introduction and post introduction. This applies to TRUMPF Maskin AB as well. The NPI process of TruPrint 1000 can be divided into the same three major stages as illustrated by figure 26.

Figure 26. The overall NPI process approach in which TRUMPF Maskin AB applied to TruPrint 1000. Inspired by: Tang and Collar (1992, pp. 23-26); Andrew et.al (2008); Rummler and Brache (2013, p. 267, p. 287); Dombrowski and Malorny (2016). Own developed model.

The first step, the pre-introduction, is where the activities in the laser-sales department dominate. This step includes the establishment of goals (what) and planning of activities (how) to achieve those goals. It can be of help to use Doran's (1981) SMART criteria to ensure that the goals are specific, measurable, assignable, realistic and time-bound. As he argues, SMART can be considered a general framework for setting meaningful goals and make them useful. As he stated: "*The establishment of objectives and the development of their respective action plans are the most critical steps in a company's management process"* (Doran, 1981, p.35).

According to company's CEO, the overall strategy is clear, to introduce new products at minimum costs (efficiency) while delivering unique and desirable value to customers (effectiveness). However, the strategy is useless without correct management tools; as Melnyk et.al (2004, p. 209) explicitly stated "*Strategy without* *metrics is useless; metrics without a strategy are meaningless".* This is in line with Doran's (1981) argument that goals/targets or metrics are essential to provide quantitative support and expression of managers' beliefs. Thus, metrics are fundamental tools to realize strategies and process improvement but not all metrics are meaningful:

"Not everything that can be counted counts and not everything that counts can be counted."
– Albert Einstein, Source: Hillman (2014)

The second step, the introduction, is where the marketing and the Tech-Days/new product show activities dominates. This is the phase where marketing preparations can be measured based on the number of respondents and customers attending to the Tech-Days. In addition, sellers are now starting to introduce customers to the products and the initial customer negotiations may start in this step.

The third step, the post-introduction, is dominant by sales activities and after-sales service activities. This step includes the majority of customer negotiations; new product sales and after-sales service activities (customer education, product installations, maintenance, supply of spare-parts etc.).

In addition, a more detailed illustration of the NPI process are illustrated in four steps (A-D) shown in figure 27.

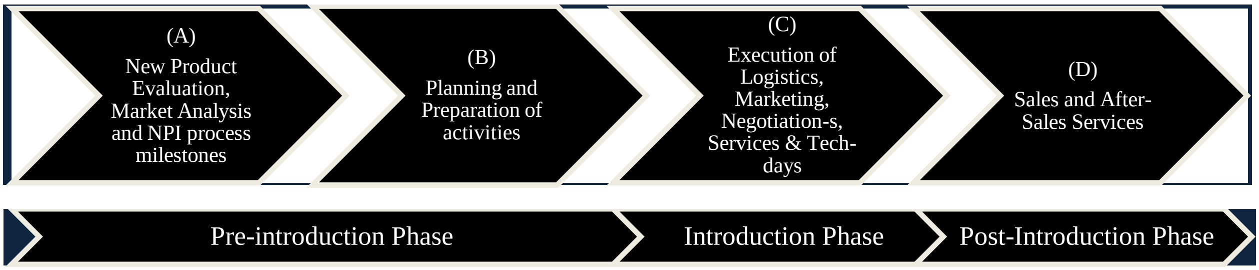


Figure 27. The detailed NPI process of TruPrint 1000. Inspired by: Tang and Collar (1992, pp. 23-26); Andrew et.al (2008); Rummler and Brache (2013, p. 267, p. 287); Dombrowski and Malorny (2016). Own developed model.

In the first step (A), the pre-introduction phase, as argued earlier, this step includes the market potential analysis, product positioning plan, distribution plan, and development of initiatives for process management and process improvement (Andrew et.al, 2008). This step is the pre-introduction phase which should include the development and use of metrics to measure performance through the whole NPI process (Cooper and Edgett, 2008).

The next step (B), the pre-introduction phase, consist of preparation activities, including material and service preparations/purchases, sales training, logistics services (third-part-logistics) and uploading of new product information to the website etc. Liao et.al (2015) argues that this is the most investment-intensive for the execution of marketing, sales and distribution activities of the new product, which should align with the strategic and tactical plans developed in step 1. This is reflected in diagram 2-7 which shows the proportion of costs per activity per activity cost center. Hence, activities such as preparation/purchase of marketing, sales, after-sales services, staff-training are ranked highest in each cost center except for the Tech-Days cost center where internal work during Tech-Days is the highest cost driver.

The third step (C), the introduction phase, is the execution of the preparations activities in the different departments. This is the phase in which the company makes initial contact with many customers interested in their new product(s). It is a very important phase since the first customer impression is crucial for the reputation of the company and its products. Hence, the needs and the demands of the customers must be fulfilled for them to spread a positive word of mouth (Dombrowski and Malorny, 2016). This step is the introduction phase which should also include measurement and continuous improvement of the process by the use of metrics that explains what factors (sources of cost and revenue) that influence the value delivered to customers and the business performance (Andrew et.al, 2008, Tang and Collar, 1992). The cost model of this thesis provides data from accounting and financial activities used to generate quantitative metrics that can guide this process improvement (Kaplan and Anderson, 2004).

The final step (D) is the post-introduction phase. This is when the sellers conduct the majority of sales and after-sales service activities are conducted. Here, non-financial measures can be used to guide improvement of processes. For example, customer satisfaction measures can be used to reflect and improve the customer service performance (Kaplan and Norton, 1996). In addition, quantitative metrics generated from the cost model can be used to guide decision making processes regarding sales-prices of the new product and additional services (e.g. process management systems, storage/loading systems, and other product enhancements). This is to enable more efficient and effective strategic management, and process improvement (Franceschini et.al, 2007).

According Kaplan and Norton (1996) argues that the key successful financial and non-financial measures are to link them to the strategy. The Balances Scorecard (BSC) is a framework they developed to build this link. The key elements in the BSC are commonly argued to be the four perspectives: (1) the financial perspective, (2) the customer/stakeholder perspective, (3) the learning and growth perspective, and (4) the internal business process perspective (Kaplan and Norton, 1996). The cost model developed in this thesis based on the TDABC system is suggested to enable primarily the internal business process perspective that includes information on business process performance and what processes to improve to satisfy internal-and external customers (Kaplan and Anderson, 2004). However, it also contributes with information to the other three perspectives since it provides data to conduct contribution margin analysis which can be integrated into budgeting and strategic decision-making. The following sections will provide information of how the cost model data can be processed and used for these purposes.

5.2. Cost Model Data Analysis – What was generated from the cost model?

The data generated from the cost model shows that the largest cost center is the after-sales service department accounting for approximately 50 % of the total NPI process costs as illustrated in diagram 10-12.

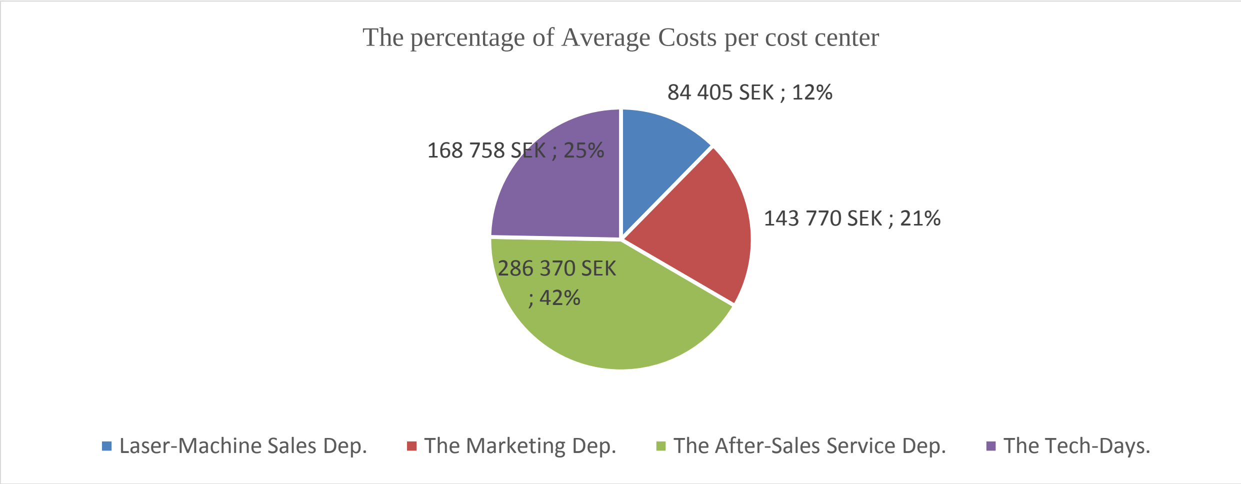


DIAGRAM 10. THE PERCENTAGE OF AVERAGE COST PER COST CENTER. OWN DEVELOPED MODEL.

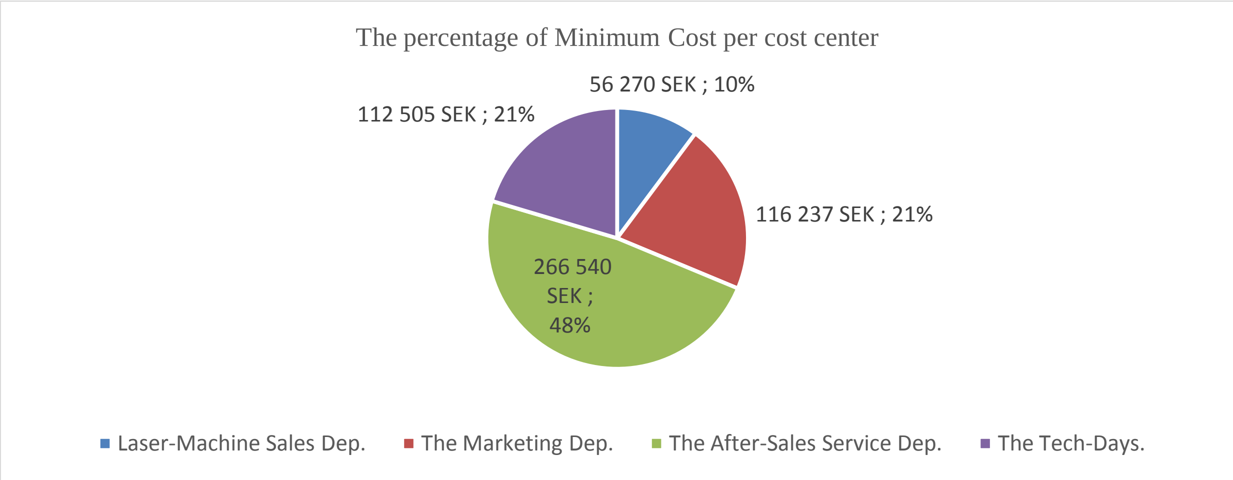


DIAGRAM 11. THE PERCENTAGE OF MINIMUM COST PER COST CENTER. OWN DEVELOPED MODEL.

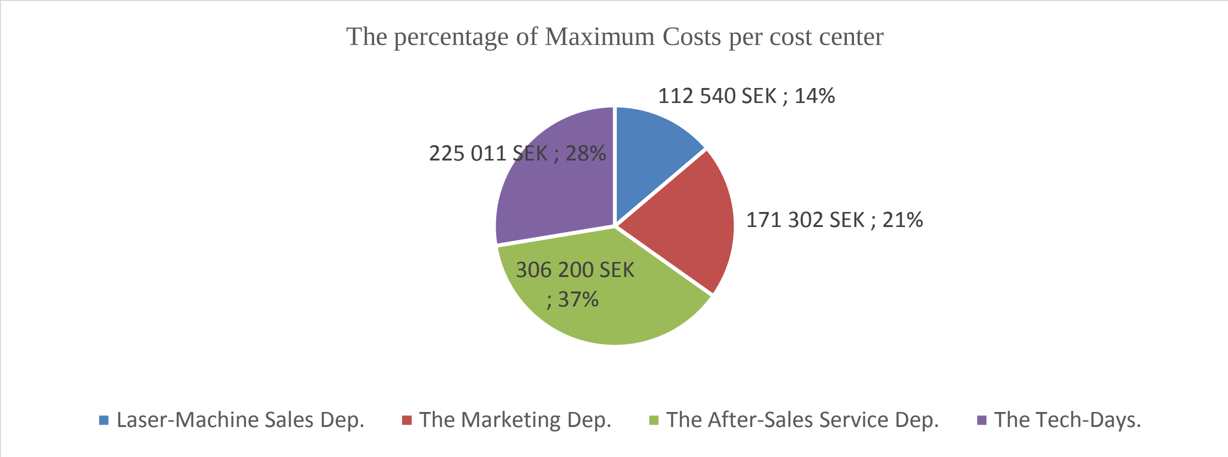


DIAGRAM 12. THE PERCENTAGE OF MAXIMUM COST PER COST CENTER. OWN DEVELOPED MODEL

The proportion of costs in the after-sales department is in the range of approximately 40-50% of Variable costs. This is in proportion to its size in the company since the after-sales service activities accounts for approximately 50 % of the total activities conducted in TRUMPF Maskin AB.

The activities with the highest costs have been illustrated per cost center. While some may be of fundamental importance for the NPI process such as staff training, other activities necessity may be analyzed in terms of cost and benefit for the NPI process. For example, the cost of newspaper advertisement is the activity with the highest costs for the marketing department. However, its relative benefits may be analyzed compared to digital advertisement to determine its relative importance to the NPI process. As suggested by Kaplan and Anderson (2004) the TDABC model can be used to determine how activities can be conducted and which to improve process efficiency and performance. Hence, the cost-information generated from the cost model can assist management of what activities to improve in terms of cost-efficiency since the costs can be traced to activities and cost objects. The feature that TDABC can be traced to activities allows to (Turney, 2005; Phan et.al, 2014):

- Reduce the time and effort required to perform activities.
- Eliminate unnecessary activities.
- Select low-cost activities.
- Share activities wherever possible.
- Redeploy unused resources.

The feature that TDABC can be traced to the cost object allows for product-mix decision-making support (Kaplan and Anderson, 2004; Phan et.al, 2014). This is what Kaplan and Cooper (1998) refers to as operational ABM, *doing things right*, which means that organizations should run their processes to accomplish their goals through minimum waste (efficiency), lower costs and high asset utilization. It also refers to the internal business process perspective (Kaplan and Norton, 1996) since the cost model allows the users to trace costs back to activities and identify cause and effect relationships (Drury, 2012). This allows business process monitoring on an activity based level in which bottlenecks can be identified where utilization, costs, speed and quality do not meet business targets. However, before making decisions of how to make the activities more cost-efficient it is important to understand how the decision may affect the efficiency of other activities and the time it takes to perform them.

The proportion of time per activity/cost center is illustrated in diagram 13, 14 and 15. The other units of inputs used as cost driver measures generated from the cost model such as kilograms (kg), pieces (pcs) and liter (l) have been converted into a realistic proportion of minutes in order to accurately reflect the cost proportions in diagram 8 and 9. For example, one kilogram is equal to 0.2 minutes.

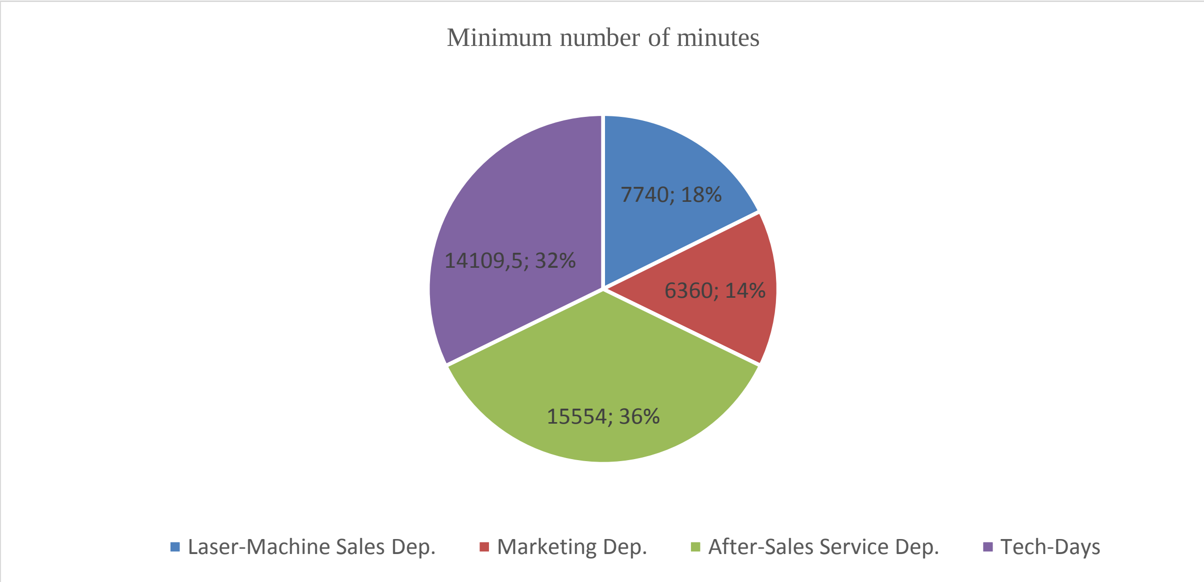


DIAGRAM 13. THE PROPORTION OF TIME PER ACTIVITY COST CENTER BASED ON THE MINIMUM NUMBER OF MINUTES.

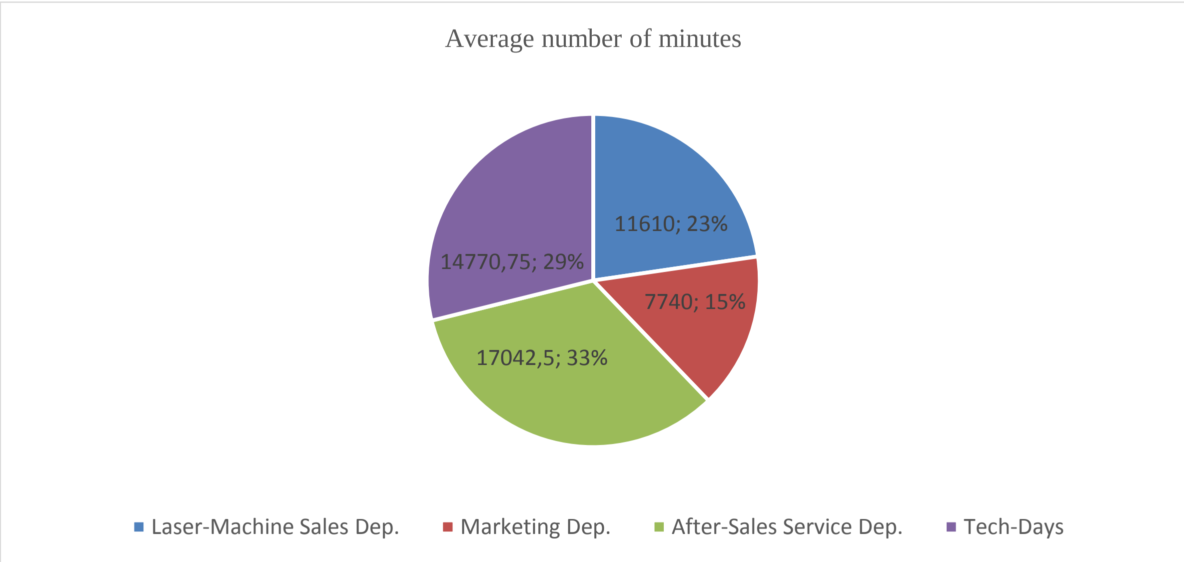


DIAGRAM 14. THE PROPORTION OF TIME PER ACTIVITY COST CENTER BASED ON THE AVERAGE NUMBER OF MINUTES.

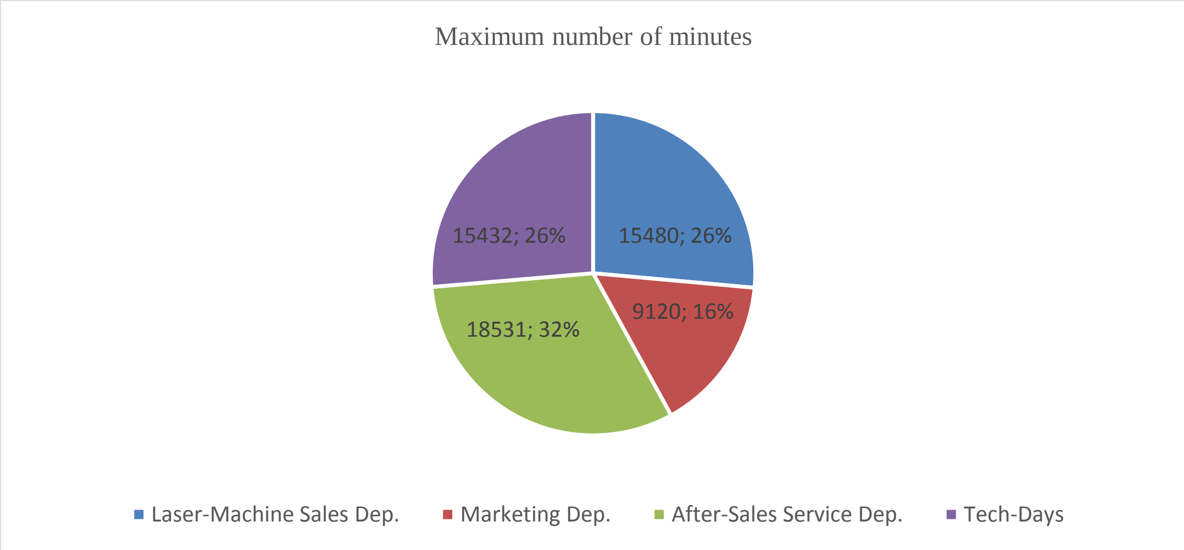


DIAGRAM 15. THE PROPORTION OF TIME PER ACTIVITY COST CENTER BASED ON THE MAXIMUM NUMBER OF MINUTES.

As illustrated by diagrams 13-15 the after-sales service department has the largest proportion of minutes during the NPI process. However, the laser-sales department have the most significantly larger proportion of time consumed than costs which shows that it has relatively in-expensive activities to perform compared to the other cost-centers. Furthermore, the after-sales service department has the most significant decrease in proportion of time relative to proportion of costs. The relatively high cost driver measures illustrated in table 15 explains this phenomenon by showing that the activities in the after-sales service department have the highest average cost drivers (cost measures) of all cost centers.

Generally speaking, those activities and cost centers that have relatively low level of time consumption but high costs can be considered to allow room for lower price negotiations. For example, process cost-efficiency improvement could be achieved by negotiating with suppliers that provide the same services with different pricing options to a lower cost. In contrasts, those activities and cost centers with relatively high level of time consumption can be considered to allow room for process efficiency improvement in terms of reduced time cycles. A summary of the cost centers average costs of activities are illustrated in figure 28.

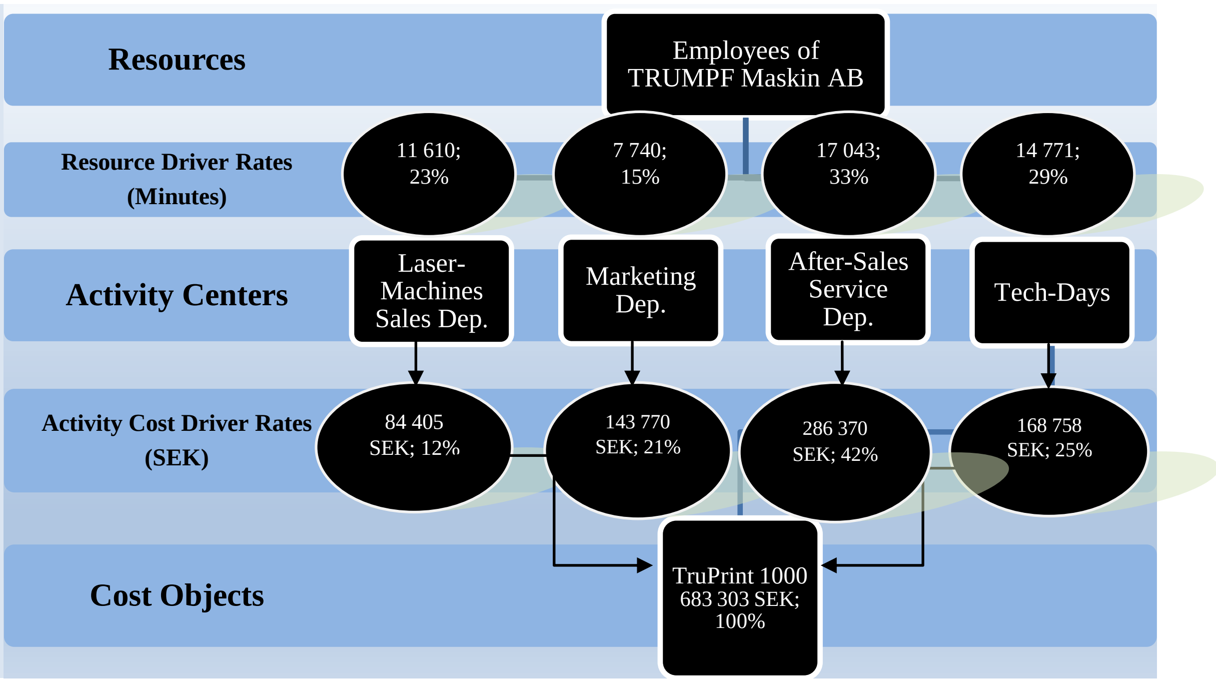


Figure 28. The average cost per cost center based on the TDABC system. Inspired by: Turney (2005, p. 96, figure 5-3). Own developed model.

5.3. Contribution margin analysis with three different scenarios – How to use the data from the cost model?

Cost centers	Minimum Costs	Maximum Costs	Average Costs
The Marketing Department:	116 237 SEK	171 302 SEK	143 774 SEK
The Laser-Machine Sales Department:	56 270 SEK	112 540 SEK	84 405 SEK
The After-Sales Service Department:	266 540 SEK	306 200 SEK	286 400 SEK
The Tech-Days/New Product Show Event:	112 505 SEK	225 011 SEK	168 758 SEK
Total indirect and direct costs:	**551 552 SEK**	**815 053 SEK**	**683 303 SEK**

Table 20. The total cost per cost center in the NPI process of TruPrint 1000.

Assume that the purchase price for TruPrint 1000 is 2 300 000 SEK and the desired contribution margin (CM)/cost-volume-profit (CVP) margin is set at 4 % excluding the NPI process costs. In addition, assume that this purchase price is set to cover the incremental cost (cost per unit of output) of R&D and manufacturing in the earlier stages of the NPD process. Furthermore, suppose that the fictional sales price per unit is 2 800 000 SEK. Then the gross profit margin per unit is sales revenues minus direct (manufacturing) cost per unit. This is 500 000 SEK, i.e. approximately 22%. Finally, assume that the actual cost per activity center is the "average" costs illustrated in table 20. Then the total cost, income and contribution margin (CM), i.e. profit/loss for 1 unit is illustrated in figure 29.

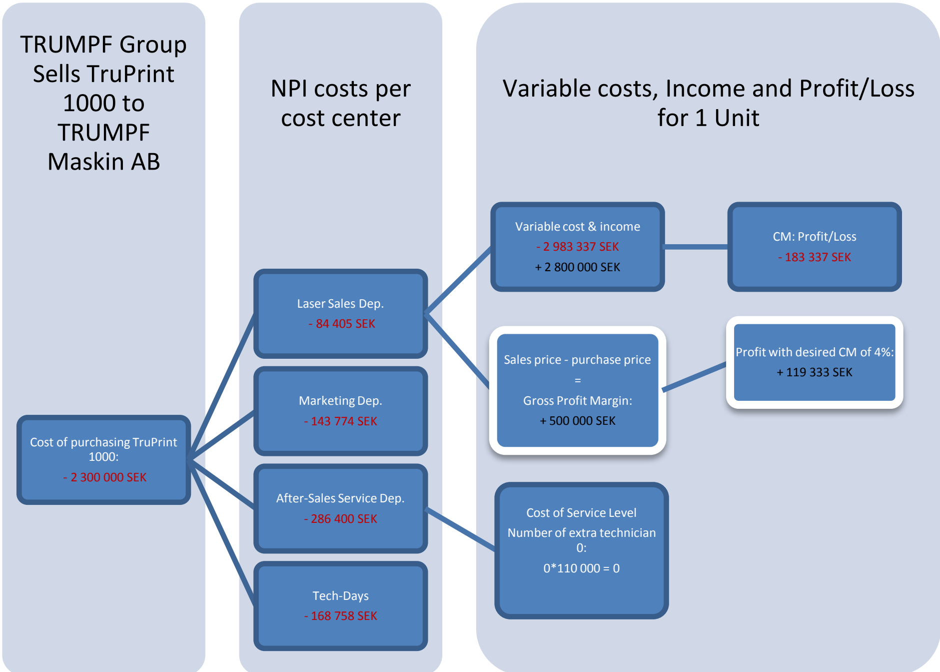


Figure 29. The total cost and income for 1 Unit sold. Own developed model.

As illustrated in figure 28, sales of 1 unit to the price of 2 800 000 SEK results in a loss of 183 337 SEK. In addition, with a total cost of 2983 337 SEK the sales price for the first unit should be 104% of Variable costs to reach desired CM of 4 %: 3 102 670 SEK. This is equal to a CM of 119 333 SEK (3 102 670 – 2 983 337 SEK).

So, let us analyze how many units that is necessary to sell in order to reach the desirable contribution margins of 2 %, 3% and 4%. This should be done while considering the three different gross profit levels estimated by the respondents during the interviews: 11 %, 12% and 13 %. This means that we have three different scenarios. The fictional sale prices given the three different gross profit levels per unit sold are illustrated in table 21 (see page 104).

Gross profit margin rates for TruPrint 1000	Fictional product sales prices	Purchase prices (direct costs)	Gross Profit/marginal sales income
111%	2 553 000,00 SEK	2 300 000,00 SEK	253 000,00 SEK
112%	2 576 000,00 SEK	2 300 000,00 SEK	276 000,00 SEK
113%	2 599 000,00 SEK	2 300 000,00 SEK	299 000,00 SEK

Table 21. The Fictional sales prices, purchase prices and revenue given the estimated gross profit margins.

Given the data outputs in table 21, the contribution margin per gross profit margin level can be calculated. The contribution margin (CM) is the sales revenue minus variable costs (i.e. indirect costs and direct costs from the NPI process, see table 20) and purchase price (incremental cost of manufacturing, see table 21). Table 22 (see appendix for complete version) and diagram 16 illustrates the contribution margin rates from 1 unit sold to 20 units sold. The variable costs used to calculate the CM is based on the average total cost per cost center (see table 20).

Units	Profit/loss per unit sold (with 11 % gross profit margin)	Profit/loss per unit sold (with 12% gross profit margin)	Profit/loss per unit sold (with 13% gross profit margin)
1	- 430 337 SEK	- 407 337 SEK	- 384 337 SEK
2	- 177 337 SEK	- 131 337 SEK	- 85 337 SEK
3	75 663 SEK	144 663 SEK	213 663 SEK
4	328 663 SEK	420 663 SEK	512 663 SEK
5	581 663 SEK	696 663 SEK	811 663 SEK
6	834 663 SEK	972 663 SEK	1 110 663 SEK
7	1 087 663 SEK	1 248 663 SEK	1 409 663 SEK

Table 22. The three contribution margin rates in the range of 1 to 7 units sold excluding cost of service level management. Ownd developed model.

As illustrated in table 22, the NPI process and purchase of TruPrint 1000 becomes profitable per unit sold at three units sold whit a gross profit margin level of 11%, 12 % and 13%. Furthermore, the table illustrates that the goal of selling at minimum four TruPrint 1000 during the fiscal budget year 2017/18 will result in a contribution margin (CM) of 328 663 SEK (11% Gross profit margin), 420 663 SEK (12% Gross profit margin) and 512 663 SEK (13% Gross profit margin). This is marked yellow in table 22. Hence, this is the profit before tax (revenue minus the variable costs) that directly or indirectly relates to the product. However, additional overhead costs such as ERP system maintenance and additional capital assets not included in the cost model are not included in any of the CM calculations.

The CM has been calculated by adding the gross profit margin levels to the purchase price of 2 300 000 SEK to get the sales prices per unit sold. For example, the sales price of TruPrint 1000 with a gross profit margin level of 13% was calculated as follows: 113%*2 300 000 SEK = 2 599 000 SEK. The gross revenue per unit, i.e. sales income per unit, is then 2 599 000 SEK – 2 300 000 SEK = 299 000 SEK. Diagram 16 is a graphical illustration of the data from table 22.

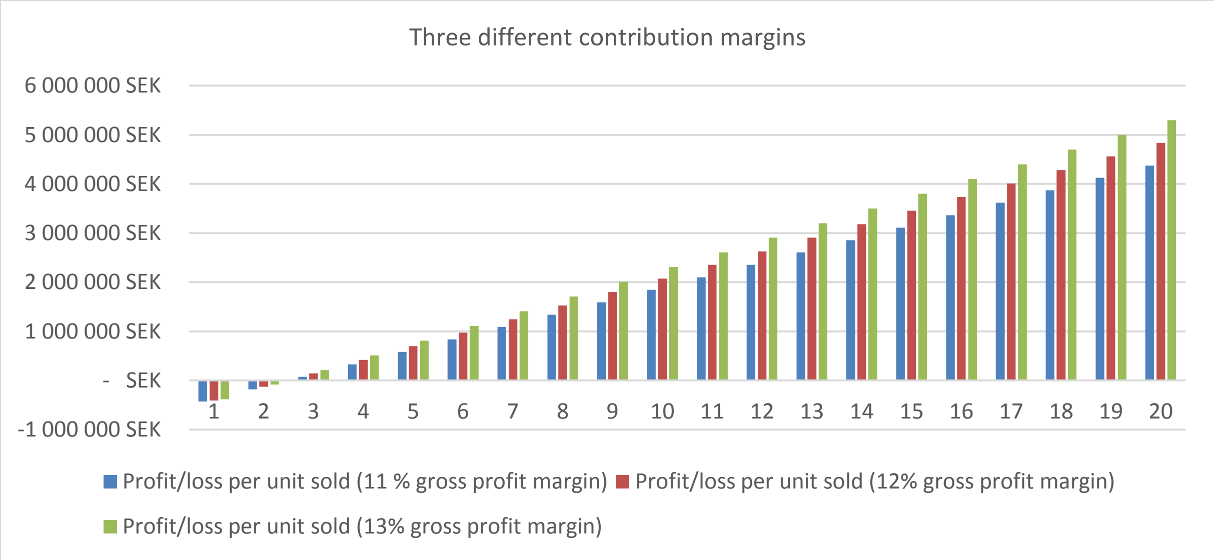


Diagram 16. The three different contribution margin levels given the three-different gross profit margin rates.

Table 23 (see complete table in appendix) illustrates the contribution margin in percent based on the same data from table 22. Hence, notice that the desired contribution margins of 2%, 3% 4% per unit are achieved after four units sold with a gross profit margin of 11 %. The desired contribution margins of 2% and 3% is achieved at 3 units sold with a gross profit margin at 12% and 13% respectively. A gross profit margin of 13 % is of course most desirable. However, a gross profit margin at 12% is also desirable since the highest suggested contribution margin of 4% is achieved after 4 units sold while it takes 5 units to achieve the same CM level with 11%.

Units	**CM in SEK (GPM = 11 %)**	**CM in percentage (GPM = 11 %)**	**CM in SEK (GPM = 12 %)**	**CM in percentage (GPM = 12 %)**	**CM in SEK (GPM = 13 %)**	**CM in percentage (GPM = 13 %)**
1	- 430 337 SEK	-14%	- 407 337 SEK	-14%	- 384 337 SEK	-13%
2	- 177 337 SEK	-3%	- 131 337 SEK	-2%	- 85 337 SEK	-2%
3	75 663 SEK	1%	144 663 SEK	2%	213 663 SEK	3%
4	328 663 SEK	3%	420 663 SEK	4%	512 663 SEK	5%
5	581 663 SEK	5%	696 663 SEK	6%	811 663 SEK	7%
6	834 663 SEK	6%	972 663 SEK	7%	1 110 663 SEK	8%
7	1 087 663 SEK	6%	1 248 663 SEK	7%	1 409 663 SEK	8%

Table 23. The contribution margin in percent within the range of 1 to 7 units sold excluding cost of service level menagement. Own developed model.

The contribution margin in percentage have been calculated by dividing the three-different contribution margin rates in table 22 by the total purchase price per unit (2 300 000 SEK * number of units sold) plus the total average cost of the NPI process (683 337 SEK).

5.4. Contribution margin analysis including cost of service level – How does the business performance change if we include cost of service level in the cost model?

The previous contribution margin (CM) analysis does not take the cost of maintaining a desired service level into account when calculating the CM per unit sold. According to laser group leader from the after-sales service department, one service technician is suitable in order to maintain a desired service level for two machines. Thus, when a third machine has been sold the company needs to educate an additional service technician, and when a fifth machine have been sold a third machine technician needs to be educated and so on. The cost of training a machine technician was estimated to be in total 110 000 SEK (55 000 SEK in Sweden and 55 000 SEK in Germany). Hence, the cost per machine sold increases with 110 000 SEK for each increase to an odd number after 2 machines have been sold. Table 24-26 (see complete tables in appendix) illustrates the revenue per product sold, the Variable costs (including cost of service level) per unit sold, and the contribution margin with a gross profit margin level of 11 %, 12% and 13% respectively. The table also illustrates that the desired CM on 2 % is now achieved after 4 products sold with a gross profit margin level of 11% compared to table 23 that shows a CM of 3% for 4 units sold. Thus, the CM is approximately 1 % lower with the cost for service level management. This is due to the accumulated input of costs from maintaining desired service level. Hence, the accumulate costs for maintaining desired service level is 110 000 SEK at 3-4 units sold, 220 000 SEK at 5 to 6 units sold, 330 000 SEK at 7 to 8 units sold and so on.

Units	**Revenue (with 11% gross profit margin)**	**Variable costs**	**CM (with 11% gross profit margin)**	**CM in percentage (with 11% gross profit margin)**
1	2 553 000 SEK	2 983 337 SEK	-430 337 SEK	-14%
2	5 106 000 SEK	5 283 337 SEK	- 177 337 SEK	-3%
3	7 659 000 SEK	7 693 337 SEK	- 34 337 SEK	0%
4	10 212 000 SEK	9 993 337 SEK	218 663 SEK	2%
5	12 765 000 SEK	12 403 337 SEK	361 663 SEK	3%
6	15 318 000 SEK	14 703 337 SEK	614 663 SEK	4%
7	17 871 000 SEK	17 113 337 SEK	757 663 SEK	4%

Table 24. Illustrates the contribution margin with a gross profit margin level of 11% including cost of service level management. Own developed model.

Units	Revenue (with 12% gross profit margin)	Variable costs	CM (with 12% gross profit margin)	CM in percentage (with 12% gross profit margin)
1	2 576 000 SEK	2 983 337 SEK	- 407 337 SEK	-14%
2	5 152 000 SEK	5 283 337 SEK	- 131 337 SEK	-2%
3	7 728 000 SEK	7 693 337 SEK	34 663 SEK	0%
4	10 304 000 SEK	9 993 337 SEK	310 663 SEK	3%
5	12 880 000 SEK	12 403 337 SEK	476 663 SEK	4%
6	15 456 000 SEK	14 703 337 SEK	752 663 SEK	5%
7	18 032 000 SEK	17 113 337 SEK	918 663 SEK	5%

Table 25. Illustrates the contribution margin with a gross profit margin level of 12% including cost of service level management. Own developed model.

Units	Revenue (with 13% gross profit margin)	Variable costs	CM (with 13% gross profit margin)	CM in percentage (with 13% gross profit margin)
1	2 599 000 SEK	2 983 337 SEK	- 384 337 SEK	-13%
2	5 198 000 SEK	5 283 337 SEK	-85 337 SEK	-2%
3	7 797 000 SEK	7 693 337 SEK	103 663 SEK	1%
4	10 396 000 SEK	9 993 337 SEK	402 663 SEK	4%
5	12 995 000 SEK	12 403 337 SEK	591 663 SEK	5%
6	15 594 000 SEK	14 703 337 SEK	890 663 SEK	6%
7	18 193 000 SEK	17 113 337 SEK	1 079 663 SEK	6%

Table 26. Illustrates the contribution margin with a gross profit margin level of 13% including cost of service level management. Own developed table.

Furthermore, table 23 shows that the goal of selling four *TruPrint 1000* machines during the fiscal budget year 2017/18 gives a positive contribution margin of 116 236 SEK (CM = 1%) when the gross profit margin is 11%. However, it does not meet the desired minimum contribution margin of 2 % since it gives a CM equal to 1%. Compare this with a gross profit margin level of 12 % (table 25) and 13 % (table 26). Both meets the desired CM margins given that four units are being sold during the fiscal budget year 2017/18 with a CM equal to 2% and

3% respectively. Table 27 shows the difference in contribution margin (CM)/cost-volume-profit (CVP) depending on the three-different gross profit margin (GPM) levels including cost of service level.

Units	CM in SEK (GPM = 11 %)	CM in percentage (GPM = 11 %)	CM in SEK (GPM = 12 %)	CM in percentage (GPM = 12 %)	CM in SEK (GPM = 13 %)	CM in percentage (GPM = 13 %)
1	- 430 337 SEK	-14%	- 407 337 SEK	-14%	- 384 337 SEK	-13%
2	-177 337 SEK	-3%	-131 337 SEK	-2%	-85 337 SEK	-2%
3	- 34 337 SEK	0%	34 663 SEK	0%	103 663 SEK	1%
4	218 663 SEK	2%	310 663 SEK	3%	402 663 SEK	4%
5	361 663 SEK	3%	476 663 SEK	4%	591 663 SEK	5%
6	614 663 SEK	4%	752 663 SEK	5%	890 663 SEK	6%
7	757 663 SEK	4%	918 663 SEK	5%	1 079 663 SEK	6%

Table 27. A summary of the contribution margin (CM) levels given the three-different gross profit margin (GPM) levels including cost of service level (installation, maintenance and technical services). Own developed table.

Diagram 17 illustrates the revenues with 11%, 12% and 13% gross profit margins (blue, green and yellow strings) and variable cost (red string) of *TruPrint 1000* based on the data in table 27.

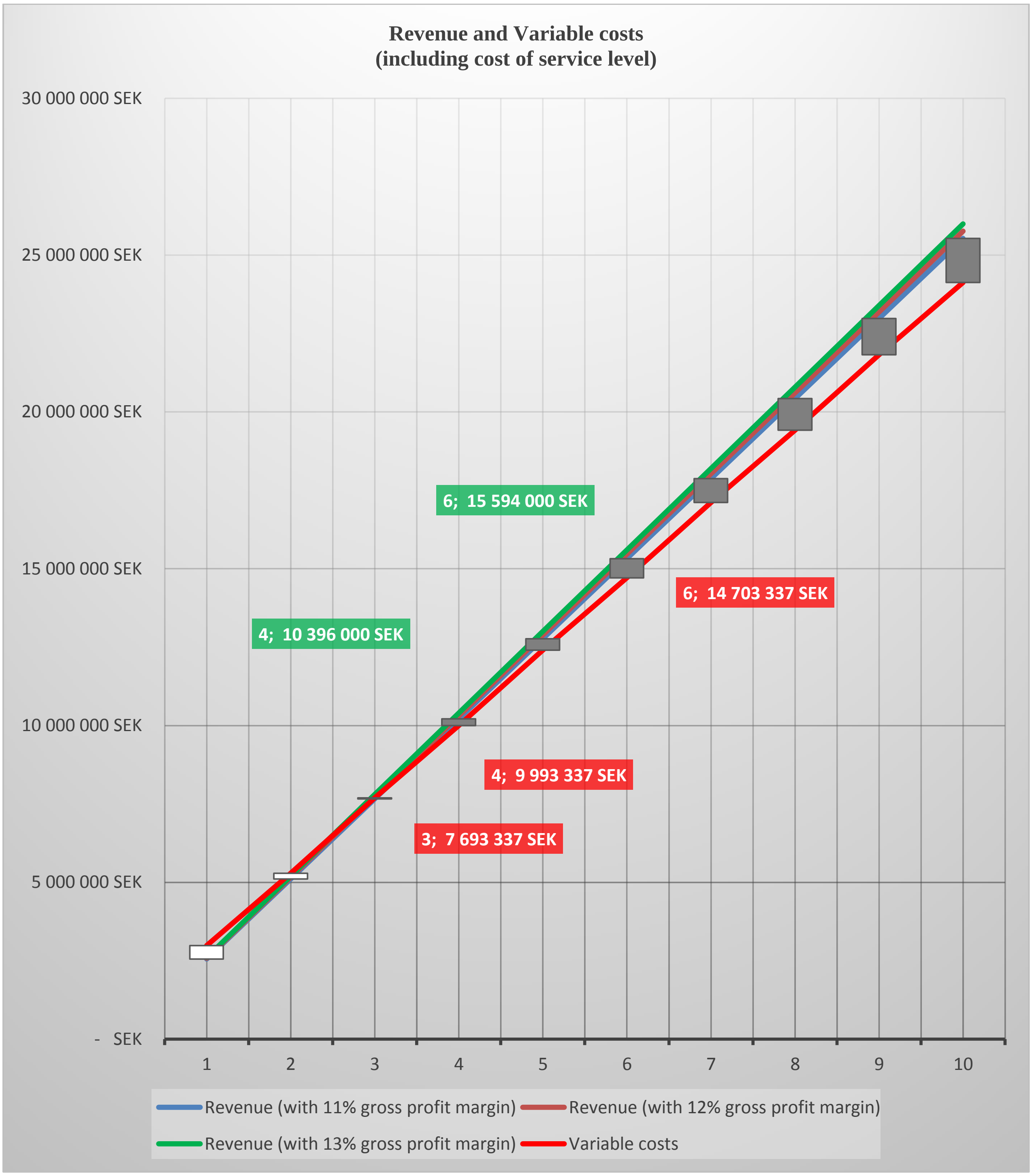


Diagram 17. Illustrates the revenues and sales volume with gross profit margin levels of 11 %, 12% and 13 % including cost of service level in Variable costs. Own developed model.

Diagram 17 and table 24-26 shows that the break-even points are 3 units sold with a gross profit margin level of 11% and 12 %. The break-even point is the point where the Variable costs equal total revenue. The break-even points with a gross profit margin of 11% and 12% are reached when the sales revenue is approximately 7 700 000 SEK. The contribution margin is the marked rectangles in the diagram which equals sales revenue minus variable costs. The white rectangles show a negative contribution margin and the black rectangles shows a positive contribution margin including the break-even point at 3 units sold. A gross profit margin of 13% gives generates a contribution margin of 1 % at 3 units sold and a sales revenue of approximately 7 800 000 SEK. The contribution margin is approximately 900 000 SEK at 6 units sold when the gross-profit margin is 13%.

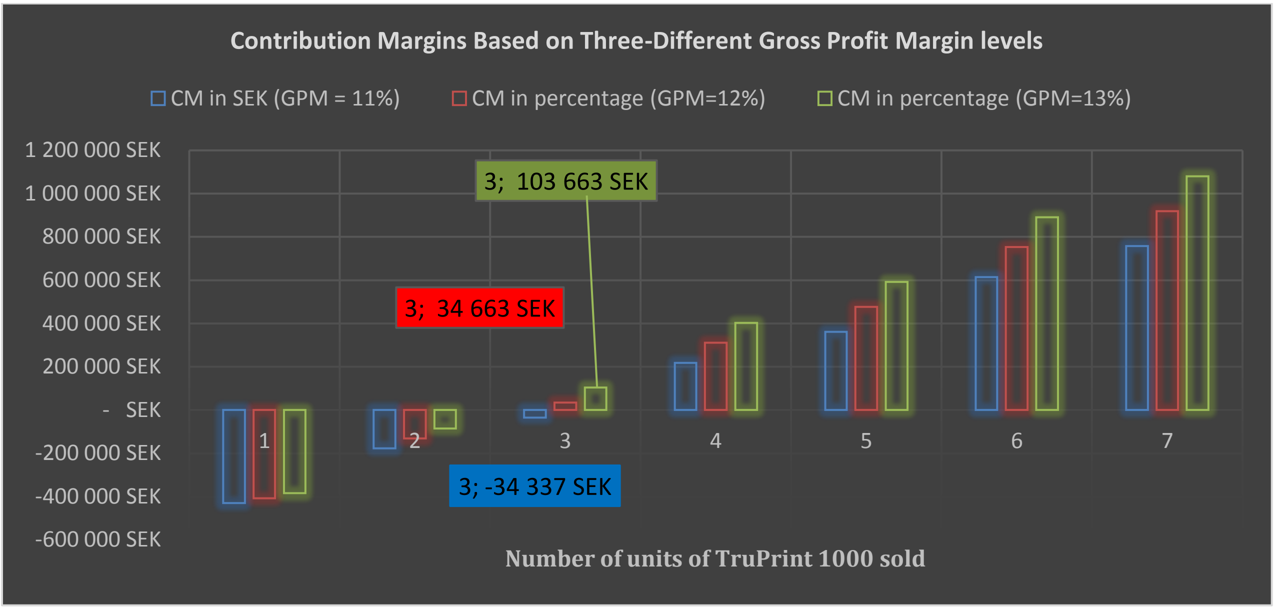


Diagram 18. Three contribution margins based on the three-different gross profit margin levels (11%, 12% and 13%) including variable costs, purchase price and cost of service level management. Own developed diagram,

Diagram 18 illustrates the three-different contribution margin levels (sales revenue minus variable costs) based on the data in table 27 including the cost for service level management. It shows that the break-even points are approximately 3 units sold for the gross profit margin (GPM) of 11 % and 12%. This means that the contribution margin (revenue minus Variable costs) is approximately 0 SEK. A gross profit margin of 13% gives a contribution margin of 103 663 SEK at 3 units sold.

The Chartered Institute of Management Accountants (CIMA) in UK (2001), argues that the data generated from an ABC system such as the TDABC model can be used to negotiate price, product features, quality, delivery and services with customers, also known as Activity Based Management (ABM). The cost model of this thesis has generated variable cost information and how different sales prices and gross profit margin levels affect the contribution margin. Drury (2012, p. 168) argues that this information allows companies to:

- Analyze break-even points, i.e. when the total income of sales equals the cost of sales (as illustrated in diagram 11);
- Determine the effects on profit when the selling price or number of units sold varies (as illustrated in table 23-25);
- Estimate what sales volume is required to meet additional costs arising from an increased input of resources and activities, e.g. increased amount of advertising campaigns;
- Allocate resources to increase net profit etc.

These activities are included in the CM analysis which essentially is the analysis between the cost of input, the revenue volume from outputs (products sold and services) and the volume of profit in the short run (Drury, 2012). Hence, this information can be used as support when negotiating about sales price in order to guide decision-making process towards the budget goal given the estimated number of units sold. Furthermore, cost models that are based on the ABC system enables information of how costs vary as the units of inputs (or units of work) per activity vary. This allows for more cost transparency in business process. As Dickinson and Lere (2002) argues - ABC recognize the variation in costs as a consequence of changes in other than production volumes such as the amount of time for customer training, referred to as product-level activities. Thus, this cost model system permits one to estimate the cost of activities associated with marketing and sales resource consumption (sales training, trade shows, service preparations etc.). This can increase the sales representatives' understanding of the impact of his or her decision on firm cost and profitability. Kaplan and Cooper (1998) refer to this as strategic ABM, i.e. *doing the right things* (effectiveness). This encompasses shifting demand of activities from unprofitable services, deals, products or customers towards more profitable uses by the use of the cost model.

In addition, given the increased cost transparency, the cost model may assist in budgeting processes such as sales-budgeting as more cost information enables more detailed business planning. This is what Turney (2005) refers to as Activity Based Budgeting.

However, as Hauser and Katz (1998) argues, the right metrics do not necessarily have to show a direct causal relationship on eventual outcomes. Instead, the key concept is to choose the metrics that reflects the need of its purpose. For example, in a SBU, the number of sales times margin (revenue) might be a good metric for the sales force, but less directly and less immediate for the technical support team. Instead, customer satisfaction might be a more appropriate metric to improve the value-added activities performed by the technical support- and after sales service teams.

"The key concept is that the metrics are chosen so that actions and decisions which move the metrics in the desired direction also move the firm's desired outcomes in the same direction."

- (Hauser and Katz, 1998, p. 520)

5.5. Cost model analysis: What criteria does it meet? – What does the cost model contribute with?

Rummler and Brache (2013, p. 297) argues that it is important to consider the different levels of an organization when building a measurement system. They suggest three steps: (1) *Organization level, (2) Process level,* and (3) *Job/Performer level.* These steps have been generally summarized in figure 23, 29, and a more detail illustration of the process is illustrated in figure 25. The activities are described in the previous activity cost centers (tables 6 -18).

The cost model and its metrics (activity cost driver rates) have been developed to measure and manage costs in TRUMPF Maskin AB. As argued by Cooper and Edgett (2008), metrics are fundamental for enabling management and the main purpose of this cost model is to enable improved cost management based on a fact-based analysis of resources and capabilities. This has been done by establishing a set of measures and indicators for relevant NPD activities to identify gaps in value-generation, -waste/costs and drive improvement. This is what Kahn et.al (2005) argues that metrics should enable. Furthermore, the cost model aims to fulfill the three fundamental activities: (1) *measuring* (evaluating how things are doing), (2) *educating* (teaching us the value of things), and (3) *directing* (potential problems can be identified and managed by the metrics of the cost model) as suggested by Malnyk et.al (2004). Furthermore, the cost model and metrics has three basic functions as proposed by Cooper and Edgett (2008), Franceschini et.al (2007, pp. 10-11), and Melnyk et.al (2004, p.211). These are to:

- enable people to evaluate and *control* the performance of the resources of which they are responsible;
- *communicate* performance to internal- and external stakeholders for several purposes;
- and to enable *improvement*.

Furthermore, the cost model aims to fulfill all the seven criteria properties developed by Dombrowski et.al (2013):

The first criteria, (1) *relevance for enterprise targets* means that the cost model can support the strategy and targets of TRUMPF Maskin AB and help employees work in the same direction by allowing Activity Based Management (ABM) and activity based budgeting.

The cost model includes the second criteria, (2) *quality of data,* due to the fact that the metrics can be influenced by the users of the metrics. For example, the time consumption per activity or other cost driver measures can be manipulated by performing the activities with a more limited number of resources or with shorter cycle-times.

The criteria (3) *compatibility of the hierarchy* means that the cost model can provide relevant information for the persons monitoring the NPI process. As shown earlier, the data from the cost model can be processed to illustrate contribution margin levels given different product sales prices. This can provide useful information for sales-budgeting, product-mix decision-making, and sales-price negotiations, - providing both strategic and operative support.

The cost model can also fulfill the fourth (4) criteria of *variability* since it is possible to change the weight of metrics importance when goals are changing due to changes in corporate environment. The values of the cost driver measures can be changed as the input into the process changes. For example, if a larger 3D printer is to be introduced, the cost model users can simply take the weight of it and replace the old weight in the cost model. Similarly, if the larger 3D printer demands different type of material, then it can be incorporated into the cost model and replace the old material. Hauser and Katz (1998, pp. 522-527) argues that an effective metric system should provide information about changes in business processes that allow employees to change their efforts in response to the metrics system and improve the outcomes. In addition, Kaplan and Anderson (2004) argue that the TDABC system allows the users to estimate (approximate) the unit time required for each new activity. These estimates replace the old cost driver measures and are included in the cost-rate calculations. Furthermore, when changes in price per resource or shift in the efficiency of activities occur, the ABC analyst recalculates the unit time estimates (and thus the cost of resources) to reflect the process improvements. They argue that the ABC system is easy and flexible in recognizing and responding to changing demands placed on firms and operating systems. This goes in hand with Melnyk et.al's (2004, p.210) suggestion that there is a need of metrics that go beyond simple reporting to create means for identifying improvement opportunities and anticipating potential problems adopted to dynamic environments.

The fifth criteria (5) *the periodicity* of metrics concerns the time it takes to measure processes or collect data which generate metrics with enough information to provide support to decision making. Dombrowski et.al (2013) suggests that the periodicity for short-term goals or current state analysis needs to be shorter than a month. TDACB model can take more than one month to develop depending on how large the implementation is going to be. However, when the model is in place Kaplan and Anderson (2004) argues that the model can be updated fast and efficiently on the basis of events rather than on the basis of the calendar (e.g. once a quarter or annually).

The sixth criteria (6) *visualization* concerns how metrics are illustrated, i.e. how the collected data are communicated so that as much of the data can be understood as fast and as accurate as possible. The cost model of this thesis has been used to provide information of different contribution margin rates depending on the sales prices per unit sold, i.e. gross profit margin level. This has been illustrated in diagrams and tables to provide examples of how the data can be processed and used.

The last and seventh criteria (7) *effort of metrics* concerns the tasks necessary for the usage of measures which includes: the generation of data, collection/measurement of data, processing of measures, and generation of valid feedback and representations of processes' value. The effort of metrics can be used to evaluate how much they generate in value compared to the cost of usage, i.e. the productivity of metrics. According to Kaplan and Anderson (2004) when the TDABC system has been implemented it should demand significantly less effort to monitor and maintain relative to similar costing systems such as the ABC system. However, the amount of effort demanded varies depending on the size of the firm and to what scale the system is being implemented. For example, Jänkälä and Silvola (2012) conducted a study regarding how the ABC model influence small Finnish firms' financial performance based on a survey and archival data. The firms' sizes were around 10 to 49 employees and the results showed that the firms who conducted full-scale implementation performed better than those who did not. However, the highest improvement was achieved by those firms who had poor past profitability and were struggling with increasing marketing costs and constant sales. Thus, this indicates that large-scale implementation and frequent usage TDABC system are profitable to small firms.

Hauser and Katz (1998, pp. 522-527) argues that it is important to understand the interrelationships between internal and external customers so that the metrics guide decisions and actions to generate desired and balanced inputs and outputs within the interlinked and interdependent value chain. This is something that the Franceschini et.al (2007) argues that process models and process maps can provide by mapping the sequential activities in the NPI process. The process model should illustrate the major activities, decision-making practices, interactions, constraints, and resources of organizations while its targets are included. This is illustrated in figure 25-27 and figure 30 (on next page) by showing the major sequential activities and their interlinkage. However, more detailed information of what decision making practices that involves within each stage and activity are described in the activity cost driver rates calculations per activity cost center (tables 6 -18).

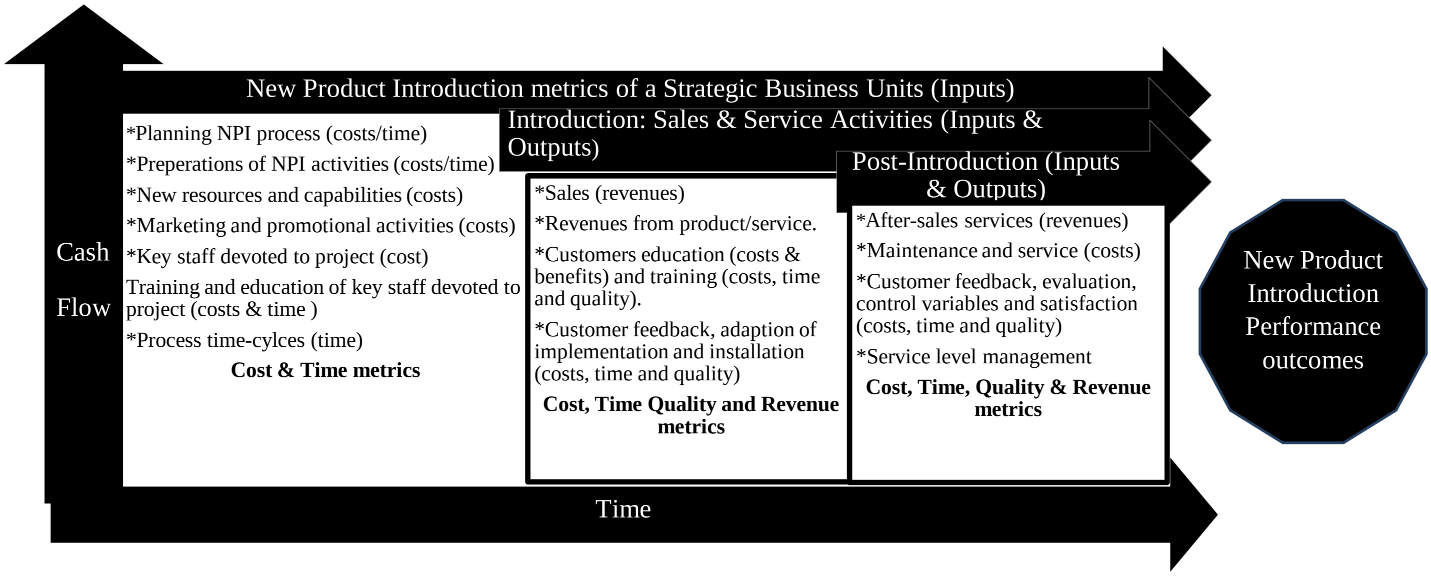


Figure 30. New product introduction metrics of a Strategic Business Unit's process productivity (Outputs (revenue & quality) /Inputs (cost & time). Inspired by: Andrew et.al (2008, pp.13-14), Stump et.al (2002, pp. 443-444), Muller et.al (2005, pp. 39-40) and Atkinson (1999). Own developed model.

A successful TDABC model would support decision making and improve the planning of the NPI processes for each product (Kaplan and Anderson, 2004). In the case of TRUMPF Maskin AB, the company do not use one NPI process since each product are unique and demands different activities that consumes different levels of resources (time and costs per activity varies). This makes it difficult to predict the costs and time efforts in the NPI process. However, the successful TDABC model would solve this problem by providing clear and useful information about the time and costs consumed by similar products. Therefore, this will enable more accurate estimation of how much time and cost the activities of the new NPI process costs. Even the initial use of the developed TDABC model for a product would enhance the planning of the NPI process. This is because qualified estimations are done by experts working with the NPI processes and have experience of previous NPI processes of relatively similar product. Hence, TRUMPF usually develop incrementally improved products within their product categories which lessens differences between product versions. Furthermore, when measurements and metrics, i.e. resource drivers and activity drivers for some products have been developed and incorporated into the model, the estimations for the next similar products (or new product versions) becomes more accurate. This is because the model users become more aware and experienced of what factors affect- and how they affect the cost drivers in the model. Using the TDABC model, its drivers can easily be adjusted by incorporating the approximate time difference of activities in the NPI process (Kaplan and Anderson, 2004). The user estimates the time based on the differences in product characteristics (and thus the differences in service needs).

The successful TDABC would also provide information to estimate the critical sale volume that is needed to be achieved before the next version of the product is to be introduced to the market. The model would then provide the information necessary to more accurately estimate the critical volume of sales and return per new product – in order to balance the cost of purchase (TRUMPF Maskin AB purchase products from its parent company, including material, services, components etc.) and the cost of preparing/executing the NPI process (the cost centers of the cost model). Furthermore, the model can be used to identify what sub-processes/-activities in the NPI process that cost most, i.e. specify cost of activities in detail (to the point it make functionally and economically sense) (Turney, 2005). This allow for prioritization of what activities to conduct (effectiveness/doing the right things) and how to conduct them (efficiency/doing the things right), so that the process can be improved (Franceschini et.al, 2007; Kaplan and Anderson, 2004). The increased understanding of the links between costs and time in the NPI process, activities and products enables more timely execution and effective strategic management. This is due the process-view and horizontal-view provided by the TDABC model that enhances the understanding of what activities that causes what outcomes, enabling better strategic management of what to execute and when (Turney, 2005).

The TDABC model can be used as a mean to improve decision-making so that the NPI becomes more effective and productive in terms of input (resources, cost & time) and output (sales revenues and quality/customer satisfaction) ratios. One way of doing this is to use the deviation of product characteristics that fundamentally affect the activities of the NPI process and how it is performed. This deviation can be used to forecast/predetermine the time to finish the NPI process by changing the variables (cost driver measures) in the cost model and by adding new activities (if necessary) to the cost model. This enables the users to derive the costs for the new NPI process more accurately. The data collected from the actual introduction of new products can then be used to adjust the cost model accordingly. This data can be used in for example sales budgeting and price negotiations during the execution phase of the NPI process. The cost information would also enable quantitative forecasting of costs in the NPI of upcoming product versions (with similar product characteristics). This is because the cost model would provide historical cost information of previous NPIs of similar products which the analyst can use to determine the cost of introducing new products. Hence, the quantitative data generated by the cost model would allow TRUMPF to have better control over the NPI processes in both the preparation and execution phase. In addition, the forecasts enabled by the cost model can be used to guide product-mix and investments decisions (CIMA, 2001). However, the quality and accuracy of the forecast of the NPI process would depend on how well the new product has been documented and how well the product descriptions confirm with actual product characteristics. Hence, TRUMPF Maskin AB plans its NPI processes based on the product documentation received from TRUMPF Group. Thus, the quality of the forecast would mainly depend on two factors; (1) the amount- and quality of the data generated by the cost model, and (2) the quality of the new product documentation that is (possibly) going to be introduced.

5.6. Cost model analysis: The pitfalls of the cost model – What should be avoided when using the cost model?

The cost model is not perfect and free from pitfalls. Kahn et.al (2005) argues that there is a risk that companies are not using metrics to their fullest advantage due to the following reasons:

1. Metrics used are not the right ones.
2. Tracking mechanism is inadequate.
3. Bottom-line implications of performance are not considered.
4. Management process is missing.

Hence, if this cost model is to be implemented, there is a strong need for a clear management process plan, i.e. how to use the cost model, who is responsible for implementation and how to update and maintain the model. Furthermore, too many metrics will be misleading as they tend to become contradictive, and too much focus on metrics will make them overvalued, rather than the real goal of delivering value to the marketplace (Kahn et.al, 2005). It is therefore important to consider the broader business context and long term- strategic objectives when using the TDABC cost model that generates short term NPI cost performance measures. In addition, it is important to acknowledge the risk of measurement systems not being accepted or resisted by performers within the process (Rummler and Brache, 2013, p.268).

The cost model illustrates the costs i.e. quantitative and financial measures of *TruPrint 1000* and not a detailed illustration of the revenue streams derived from *TruPrint 1000* except for the contribution margin. However, besides the contribution margin many additional incomes streams may derive from on sale of TruPrint 1000. These may be new product enhancements, after sales (spare parts) and services (consultation programs etc.). However, as argued by Dombrowski and Malorny (2016) there may be conflicts between internal (customer) objectives and external (customer) objectives in terms of who should pay for services such as maintenance, repair etc. These conflicts create grey zones between the supplier and customers who demand a lot of resources and time to manage which can balance, or in worst case, exceed the revenues from value-added activities such as after sales and customer service. This would decrease the differences between the total profit (direct and indirect revenues) from *TruPrint 1000* and the CM of *TruPrint 1000*.

Despite these conflicts, we see an increasing demand of valued-added services and education in the manufacturing industry. This is especially the case in technology-oriented industries with a rapid pace of technological change which demand extensive educational efforts of buyers' as their knowledge structures become obsolete. Thus, education and openness becomes competitive advantages for the providers as the necessity to educate their customer's increases (Stump et.al, 2002). Similarly, Brettel et.al (2014), argues that value added services provided from manufacturing companies allows them to differentiate themselves in order to ensure a strong competitive position. Stump et.al (2002) argues that the focus of the customer education should be on the innovations impact on costs and benefits/profits, rather than overemphasizing the complex technical attributes of the product. Thus, if the cost model is to be implemented it is suggested that it is extended to include the costs of value-added services and after sales. This would enable contribution margins to be developed for these additional services and thus allow for a more detailed and accurate reflection of total profit margin. Furthermore, the technology providers/sellers should actively attempt to manage buyers' expectations regarding what the product can do for them. This often means that the provider needs to lower the buyers' unrealistic expectations (Stump et.al, 2002). Indeed, if the customers' expectations are not meet then the risk for conflicting objectives increases which in turn leads to lower customer satisfaction.

Furthermore, since the cost model data are financial and quantitative in its nature it does not include other non-financial quantitative measures. However, for some activities, such as customer services, the most appropriate metrics would be non-financial measures such as customer satisfaction. As Hauser and Katz (1998) argues: metrics should be developed to guide actions towards the desired direction of the firm. For this purpose, Kaplan and Norton's (1996) Balanced Score Card can be used as a framework to develop a measurement system in which the cost model and non-financial metrics provide complementary and useful information. For example, customer services could be measured by the cost model and non-financial measures. Then these measures could be compared or weighted against each other to evaluate total profit and benefits derived from a product or customer. Hence, the CM may not reflect all benefits and revenue derived from the units of sales. Hence, *TruPrint 1000* may allow additional revenue streams from after sales activities. TRUMPF Group are already providing various value-added services such as AXOOM and process apps that can be integrated into the programming system of their machines and enable IoT. This would allow for distant process monitoring and real-time updates 24 hours a day which enables higher productivity. For example, process sensors would send alerts whenever the process deviate from the program and the program can be designed to allow quick fix before problems occur.

5.7. Cost model analysis: Cost, Time and Quality – What business performance can be measured with the cost model?

One needs to take into consideration that different performance outcomes need different time-spans in order to be measured. Atkinson (1999) argues that the essential aspects for measuring success of a project of business process can be summarized in the so called "Iron Triangle".

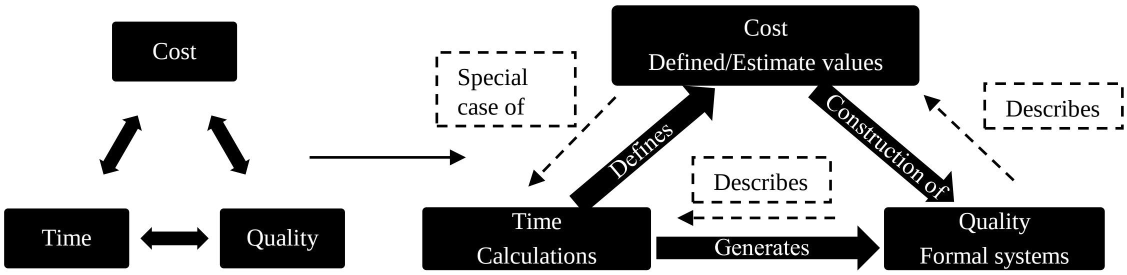


Figure 14. "The Iron Triangle" (left) consisting of three essential performance parameters: Cost, Time and Quality. The modified iron triangle (right) explaining relationships. Sources: Atkinson (1999, p.338) and Tagemark (2014).

As illustrated in modified iron triangle (right), quality can be considered as formal systems, i.e. being accordance to usual requirements, customs, conventional etc. In addition, quality can be considered to be a product of time and costs. Thus, quality gives indications of how much time and resources that have been consumed to generate a specific quality output. As Francschini et.al (2007) argues, quality can be recognized as the ability to fulfil different types of requirements (productive, economic, social, etc.) that is specified and agreed-upon by different people, with concrete and measurable actions. Furthermore, he argues that quality targets are central when analyzing a phenomenon (or process, or result): argue that an indicator is "*the qualitative and/or quantitative information on an examined phenomenon (or a process, or a result), which makes it possible to analyze its evolution and to check whether quality targets are met, driving action and decisions".*

Time can be viewed as calculations that define costs and generate quality (the right modified iron triangle). Time is central for the TDACB system and the cost model of this project since they are based on the same time-equations. The majority of cost driver measures are based on the number of minutes consumed per activity, i.e. cycle-time or activity time durations. Costs can be viewed as estimations of value of resources and special cases of time that construct formal systems/quality. As Drury (2012) argues, costs can be divided into indirect cost (common cost for several cost objects), direct costs (can exclusively and specifically be traced to one cost objects) and variable costs (both indirect and direct costs linked to a cost object). Hence, the cost model of this thesis generates variable costs which allow calculation of contribution margin (sales revenue - variable costs).

The impact received by the customers are quality criteria which can be measured within a couple of weeks after implementation, e.g. after an initial sale and installation of a new 3D printing machine (Atkinson, 1999). In mid - term perspective, business success can be measured after one or two years. This would be for example whether the annual sales-budget and desired contribution margins are achieved. Long-term strategic success is measurable after about four to five years. This can for example be how much the market share has grown for a particular product portfolio/category such as metal 3D-printers for industrial application.

Cooper and Edgett (2008) argues that by measuring the results of a NPI process allows the analyst to determine whether or not it have been successful, if it met its performance targets, what to learn from the process and how to improve it. Despite these benefits, they estimate that only 30% of corporations measure the performance or outcomes of new product projects once the product has been introduced. Hence, companies could increase profitability by implementing a performance measurement system (PMS) for this purpose. The TDABC model could possibly help in generating those benefits and perhaps lead to higher profitability (and a competitive advantage) if implemented on a large scale as suggested by Jänkälä and Silvola (2012).

5.8. Cost model development framework and implementation analysis – How was the cost model developed and how to implement it?

If the cost model is to be implemented it is of prime importance to involve the user of the cost model system. Hence, it is important to engage the internal customers who are the enablers of the activities on all organizational levels from vision and strategy to operational activities. Furthermore, it is to the benefit of the company if the cost model successfully is integrated to its ERP system to allow for efficient and effective cost management (Stout et.al, 2011). Tung et.al (2010), argue that managers and their support towards measurement systems are highly influential in the effectiveness of the PMS in respect to the performance related outcomes. Furthermore, greater commitment towards staff training enables superior achievement of staff-related outcomes. Hence, it is then fundamental that the managers support the implementation of a new performance measurement system to enhance its chances of being successful. In addition, they suggest that managers should put great emphasis on staff-related outcomes by designing the PMS so that employee contributions and employee needs are incorporated into it. This cost model aim to reflect the employees and managers needs as much as possible. However, it is only developed for the NPI process of *TruPrint 1000*. Thus, for larger scale implementation, additional employees would need to get engage into the development and extension of the cost model. The findings of Tung et.al (2010) also suggest that the perspectives of Balanced Scorecard (BSC) when developing measurement systems can enhance their effectiveness. Thus, the solution is to avoid the pitfalls (illustrated in figure 32) behind underperformance that causes difficulties associated with the implementation of the cost model. This includes engaging and motivating managers, developers and users, and providing them with enough time and resources to conduct pre-studies, pilot-tests and implementation.

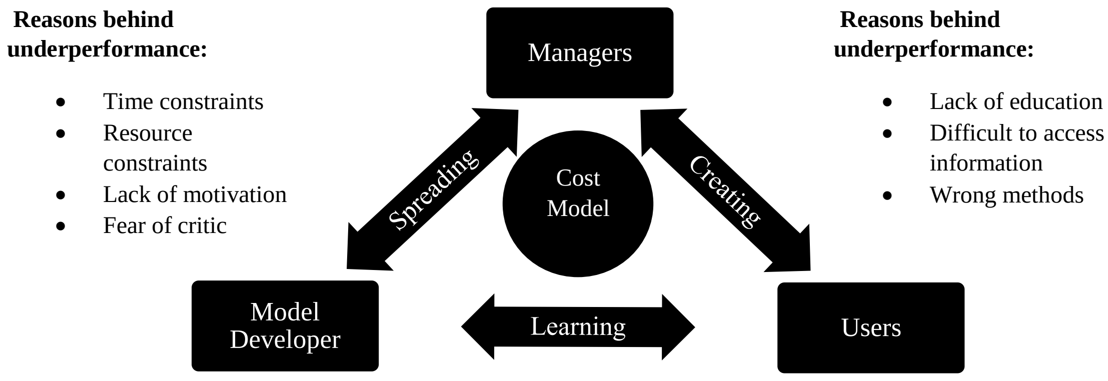


Figure 32. The Challenges with new cost model implementation. Inspired by: Tagemark (2014, p.484). Own developed model.

The cost model and NPI cost analysis of this thesis is based on the BSC model and eight steps developed in the literature review (figure 28, next page). The first step (contextual background) was technology and business opportunities are identified. This can be viewed as the first initiative that determines what products and services to introduce and sell to customers. In other words, it is the value proposal that determines the cost objects of the cost model. The cost object of this study, TruPrint 1000, was suggested by the CEO, Hubert Wilbs, of the company and it was analyzed through observations during product show events and with secondary data. The following seven steps are related to the four processes in the BSC model developed by Kaplan and Norton (1996).

The second step (*Vision & Strategy)* are related to first processes in the BSC model (1) *translating the vision.* It is the articulation of the shared company vision, supply of strategic feedback and facilitation of strategic reviews. This promotes learning, a clear purpose, a consensus of where to go, and business motivation. It is important to incorporate this perspective into the cost model in order to ensure that its function align with strategic business goals (Kaplan and Norton, 1996).

The third step (*people)* underlines the importance of involving managers and users in the development of the cost model so that it becomes useful for them. The people (employees and managers) has the information of the organization and its processes. They know the different aspects of the cost objects subjective to measurement in the NPI process and how activities are performed. The cost model needs to incorporate this information. It is related to the second process in the BSC model *(2) communicating and linking.* Meaning that does who use the cost model and executes strategies needs to be involved in the development phase of the model to understand its purpose, realize its function and ensure that it meets their needs. In addition, it is important to align the model with strategic objectives and operative requirements so that it motivates people to act towards long-term goals like annual sales-budgets (Kaplan and Norton, 1996).

The fourth step (*process approach)* relates to the third process: *(3) business planning,* in which activities are identified and linked in the NPI process and illustrated in a process map. This facilitates the integration of vision and strategy into business processes and financial plans to ensure accurate allocation of resources, correct prioritization of activities, and aligned coordination of initiatives and actions toward long-term strategic objectives (Kaplan and Norton, 1996). In addition, the process map allows the selection of accurate measures to enable the purpose of the cost model (Franceschini et.al, 2007, pp.4-5). The process map makes it easier to see the contribution each function is expected to make to the process and can be extended to reflect the goals of each function that contributes to the NPD and NPI process (Rummler and Brache, 2013, p. 306).

The fifth and sixth step *(Metrics and Measurement system)* is the selection of metrics and instruments to facilitate accurate cost measurement of processes and activities. Thus, it is also related to the third BSC process *(3) business planning* in which measurements that apply to the four perspectives of the BSC model are selected. This means that the metrics should enable: (1) the financial perspective, i.e. financial performance information to shareholders; (2) the customer/stakeholder perspective, i.e. information to both external and internal customers; (3) the learning and growth perspective, i.e. information to key-stakeholders that enables process improvement, strategic alignment and achievement of the company's vision; and (4) the internal business process perspective, i.e. information on the type of business process that the firm must excel at in order to satisfy shareholders, as well as internal- and external customers (Kaplan and Norton, 1996).

The seventh step *(cost of NPI activities-TDABC)* is the use of the metrics and cost model to develop data and information used to communicate the business performance, i.e. efficiency and effectiveness of processes. This step includes the technical details of measurement based on the five main moments when building the TDABC model suggested by Kaplan and Anderson (2004): (1) *Estimate the cost per time unit of capacity;* (2) *Estimating the unit times of activities;* (3) *Driving cost-driver rates,* (4) *Analyzing and reporting costs;* and (5) *Updating the model.*

Finally, the eighth step *(Cost Management & ABM)* is the step in which the information generated by the cost model is processed and analyzed to generate useful insight into the cost of business processes. This means that it should provide information on what activities are being performed, the cost of each activity, why the activities are undertaken, and how well they are performed (Drury, 2012). It is linked to the fourth process of the BSC model: *(4) feedback and learning.* This means that the final step includes management of the results generated by the developed metrics/cost model that is used to reflect the performance and results of business activities. It focuses on whether the company, its departments or its individual employees have met their short-term targets from all four perspectives, i.e. financial targets, customer targets, internal business process targets, and learning and growth targets. The feedback system, i.e. the information generated by the metrics/cost model should be able to test, validate, and modify the cause and effect relationship between business activities and outcomes. This is to steer them towards the business strategy and vision (Kaplan and Norton, 1996). The essential goal of ABM and the management of TDABC model is: (1) to improve the quality and value received by customers, and (2) to improve profits by providing this value (Turney, 2005).

This framework for developing and implementing the cost model has been summarized in figure 31 (see page 116).

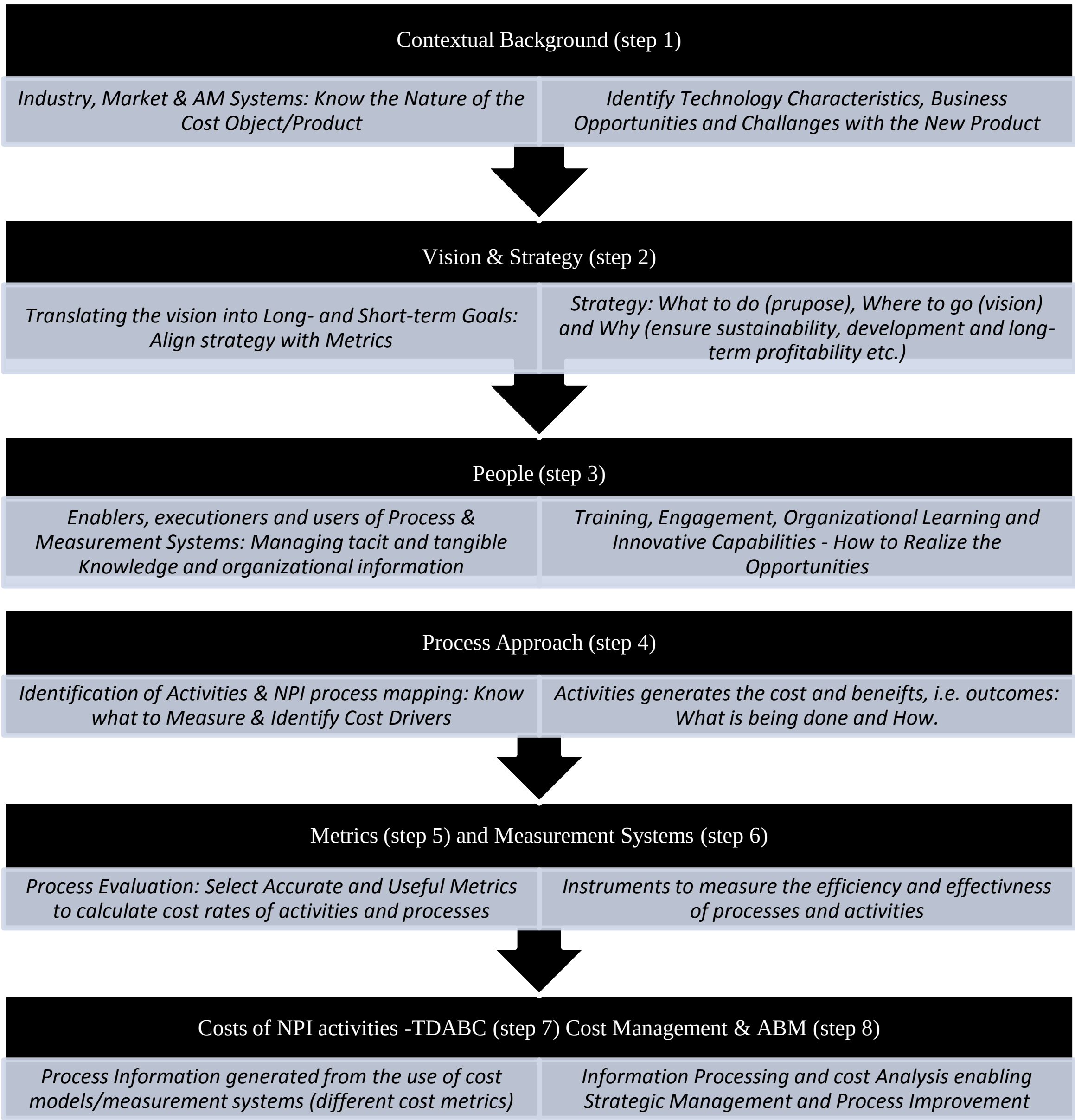


Figure 33. The cost model development framework. Own developed model.

6. Discussion

This chapter compose of conclusions about the impact the cost of the NPI process have on TRUMPF Maskin AB's business performance and how it can be used to improve the NPI process. It also includes a discussion of the limitations of the cost model and improved. Finally, cost model contributions and future implications are discussed. Future implications include how the model can be extended and used in other NPI processes or projects or provide a framework for similar cost models.

6.1. Cost model contributions and future implications

The cost model can provide a framework for more extensive activity costing systems for organizations and projects. The cost model can effectively be used to support management of new products and projects. The data generated provide fact-based information to support decision-making which can guide processes towards desired directions and enable higher profitability of single cost objects. However, as suggested by Jänkälä and Silvola (2012), the activity based cost model is more likely to provide higher profitability to companies that use it more extensively than those that do not. Thus, an extensive implementation and usage of this cost model is suggested in order to take the fullest advantage of it.

The contribution margin analysis is an example of what the cost model data can be used for. The CM can guide decision making towards higher profitability and support sales-budgeting. However, it is important that the cost model users understand how the model works and that the analyst is aware of the different conditions of other users. This is to avoid isolated decision-making and enable more transparency into each other's activities. The analysts will then understand better how his/her decision affects the conditions for the next decision-maker in the chain of interlinked activities. For example, sellers will understand better how conditions to different customers affect cost of after-sales services and overall profitability through the contribution margin analysis. However, the cost model should be implemented and used more extensively for this purpose in order to work effectively.

The cost model can also be used to perform quantitative cost forecast of NPI processes based on previously recorded NPI costs of similar products. The variables in the cost model can be adjusted by the users to fit the NPI process based on the documentation of the new product. This would allow for improved planning and preparation of NPI processes.

6.2. Cost model Limitations and Strengths

The TDABC model developed for the NPI process of *TruPrint 1000* in TRUMPF Maskin AB has several restrictions. First of all, the indirect cost estimates are approximate since they are not based on an exact measure from invoices or similar sources. Since the indirect costs are based on the 'cost of employees' data from the annual report of 2016-06-30, there is a risk that the average indirect cost estimates are outdated. For example, new salaries may have been negotiated since then. Furthermore, the cost model is restricted to estimate the NPI process costs for *TruPrint 1000*. Thus, different products require different activity cost driver measures. As argued by Turney (2005) the cost drivers need to be appropriate for the cost object so that the cost of activities accurately reflect the cost of the cost object. This should be done while guiding decision-making towards strategic objectives (Kaplan and Norton, 1996) and guide actions (operative and strategic) towards the desired direction of the firm (Hauser and Katz, 1998).

Another limitation is that the cost model only includes quantitative and financial measures of business performance. This relates to the financial perspective, i.e. financial performance information to shareholders- In addition, it includes the internal business process perspective includes information on the type of business process that the firm must excel at in order to satisfy shareholders, as well as internal-and external customers (Kaplan and Norton, 1996). It also includes the learning and growth perspective since the cost data can be processed and used as mid-and long-term strategic planning, e.g. budgeting, pricing etc. However, in order to complement the cost model non-financial measures should be included. For example, customer satisfaction measures are an appropriate measure for customer services. This measure relates to the customer/stakeholder perspective which includes information to both external and internal customers (Kaplan and Norton, 1996).

Drury (2012) and Kaplan and Anderson (2004), argues that the cost model can be adapted to several different cost objects. In addition, cost driver measures can efficiently and effectively be updated as conditions changes

(Kaplan and Anderson, 2003, p.11). The cost model allows for better cost transparency as variable costs, including cost of activities can be traced to the specific cost object, in this case *TruPrint 1000.*

6.3. Concluding remarks

The TDABC system has proven to be an applicable costing technique for NPI processes and projects. This case-study has proven this point. Furthermore, if the TDABC system is implemented then effectiveness and efficiency gains can be achieved by replacing older and traditional costing systems. This is especially true if the cost model is integrated with the firm's current ERP-system to allow automated costing and faster updates of its cost driver measures. If the cost model is implemented successfully and used extensively by the firm then it can lead to higher mid-term and long-term profitability. Thus, it is suggested that the cost model is being analyzed further according to the specific requirements of the firm and then decided upon whether to implement it. From a general perspective, the TDABC system has been implemented and proven to be beneficial for companies in terms of strategic control and operative efficiency and profitability. This has especially been the case for small-medium sized enterprises (SMEs). Furthermore, it is important to complement the cost model with non-financial measures such as customer satisfaction in order to provide a better picture of business performance. This can be achieved by combining the four perspectives and processes developed by Kaplan and Norton (1996).

TRUMPF Maskin AB has a need for metrics (Indicators) in order to enable process improvement in their NPI process. The cost model of this thesis has illustrated an example of how these metrics can be developed and used, and what obstacles to overcome. Hopefully this can provide insight for similar future studies, and be used as a framework for development and practical application of cost models.

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8. Appendix

8.1. Definitions A-Z

Accounting: Businessdictionary.com (2017) defines accounting as the practice and body of knowledge concerned primarily with: methods for recording transactions; keeping financial records; performing internal audits; reporting and analyzing financial information to the management; and advising on taxation matters. Thus, accounting provides information on the: resources available to a firm, the means employed to finance those resources; and the results achieved through their use.

Distribution: includes all the activities associated with the movement, storage and delivery of finished goods from the point of sale to the customer. Businessdictionary.com (2017) defines distribution in commerce as the movement of goods and services from the source to the final customer, and the movement of payment in the opposite direction, right up to the original producer or supplier. Important physical distribution functions include customer service, order processing & inventory control, transportation and logistics, packaging and final delivery to the end-user.

Finance: according to Investopedia.com (2017) finance includes the management of credit, investments, assets, liabilities and other financial activities related to running a corporation.

Fixed cost: These costs tend to remain the same regardless of production or process output such as rent, insurances, some advertisement etc. (Investopedia.com (2017).

Incremental cost: Is the cost that varies per production or sales volume and is also referred to as marginal cost (Investopedia.com (2017).

Marginal benefit: The incremental increase in a benefit to a consumer caused by the consumption of an additional unit of good (Investopedia.com, 2017).

Marginal cost: The incremental increase in a company's input costs to produce one additional unit of output (Investopedia.com, 2017).

Process: ISO 9000:2000 clause 3.4.1, defines "process" as "*a set of interrelated or interacting activities that transforms inputs into outputs."*

Variable cost: Can be defined as a corporate expense that varies as production or process output varies in character, volume, price etc.

8.2. Cost Model Development list

1. Identify activities is the step of deciding how many details of an activity that should be measured and how to define and describe each activity. When developing the TDABC model, this step also includes the estimation of practical capacity for as many activities as possible. This step consists of the following rules:

I. Match the level of detail of each activity to the purpose of the model. For example, if the purpose is strategic (e.g. choosing how different markets and customers are to be served), the main task is to include enough details that accurately assign cost from important activities to cost objects. On the other hand, if the objective is to improve a process (e.g. to better meet customer needs and reduce costs of activities per product) the model typically includes more information about activities and their details as well as the cost objects.

II. Use macro activities to balance conflicting objectives. If the model both includes strategic and process improvement objectives - a conflict may occur as the supply of details (for process improvements) may confuse strategic users. The solution is to use aggregations of related activities that consist of activities: of the same level, with the same activity driver and have a common purpose. These aggregated and related activities are called *macro activities*.

III. Combine insignificant items means that activities that are too small to be worth recognizing individually should be combined. This eliminate the time for estimation in the development process of the model and the calculation of cost drivers when using the model. It also helps to reduce the system clutter.

IV. Describe activities clearly and consistently. This step is essential since the description and categorization of each activity determines the effectiveness of the system and the information it provides. *A clear description of each activity enhances the ability to* *communicate the work that each activity represents. A consistent definition of activities makes it easy to find activities of the same type or process* (Turney, 2005, p. 267). A clear description consists of short descriptive and understandable labels, e.g. “staff training for new product” is a short, understandable and fully descriptive of the activity.

2. Reconstruct a general ledger. This step means that the details of financial data and costs from the general ledger are reduced and adjusted to the needs of the TDABC model. This step consists of three rules:

I. Combine related accounts from the general ledger that are connected with the process subject to the model, e.g. the NPI process, and its activities. Very detailed financial information consisting of hundreds of accounts may satisfy accountant’s that needs to pinpoint the type of expenditure. However, this creates a burden to extract each detail and use it in the TDABC model. It creates additional work since each cost needs to be assigned to the activities in the model. Thus, the solution is to combine related costs from the general ledger that share a common purpose, and are assigned to activities in the same way. For example, salaries, health insurance, and pension costs can be combined into one account called “personnel costs”. This reduces system design effort and system clutter.

II. Decompose costs to department level means that the combined costs from the general ledger should be subdivide and assigned to departments since they represent the source for most of the data on activities. For example, the percent of department effort expanded on each activity can be applied to the department’s personnel cost as a resource driver (cost consumed per activity). When developing the TDABC model, the productivity rate for each activity, e.g. the number of minutes that it takes to train staff or prepare material and spare parts for a new product, is used instead of the estimated percent of department effort per activity.

III. Adjust items from the general ledger so that they easily can be assigned to activities. For example, the cost a the NPI process can be collected to a special holding account and assign to the activities of the process over time. This means that costs are assigned to the NPI activities in the general ledger. It is a recommended step in building an ABC-based performance management system that support activity-based budgeting and monthly analysis of activity performance. It enables automated data transfer to the ABC model and can resolve general ledger problems – both of which reduce the cost of the ABC system maintenance.

3. Create activity centers means that activities are grouped and reported in a way that is meaningful for the user. Including departmental and cross-functional reports of activities. The rules for creating activity centers includes:

I. Put activities into departmental activity centers first.

II. Use attributes, i.e. labels describing the type of activity clearly and consistently which allows the users to identify and easily locate activities with identical characteristics based on their need for information. For example, a user may be interested in NPI process quality information that cuts across different departments. The user may use attributes (labeled activities) associated with preventing, detecting and correcting poor NPI process quality. Two labels for preventing this may be staff training and preparing of product material and components according to new product specifications/documents. Labels for detecting may be, product inspection, checking customer satisfaction, service levels, component testing, measuring and evaluating variation in time to finish activities. Labels for correcting may be inspecting repairs, conduct troubleshooting (stepwise technical machine problem solving or systematic process problem solving) and inspecting returns.

III. Use nested activity centers to create hierarchies of activity information. This means that similar activities centers conducted on the same hierarchy in the organization are nested together in one activity center. This allows the user to easily focus on different levels and breadths of information. For example, a process level view of a NPI process allow the identification of main activities such as new product preparation, procurement, marketing planning and staff training, administration and customer services. Each of these main activities can be viewed as activity centers consisting of other related sub-categories of activities. The new product material preparation may consist of product inspection; product documentation; component inspection and material selection. Marketing planning may include planning of events, adds, in-house and various ways to catch the interest of customers. Staff training may be categorized into training of technicians, sellers, product managers etc. regarding the new product release.

4. Define resource drivers. This step links the cost to the activities which means that the resource drivers represents the measures used to calculate the cost of activities. The goal is to select resource drivers that accurately measures the cost of the activities without requiring an excessive amount of time and effort to use in the model. This step includes the following rules:

I. Use common sense to determine how to assign cost.
II. Separate effort and non-effort costs. This means that costs associated with people doing work (effort costs) should be separated from non-effort costs (vacation, breaks etc.) and costs that cannot be traced.

5. Determine attributes means that labels that enhance the meaning of activity-based information are attached to the data system which follows two rules:

I. Let the objectives of the model govern the choice of attributes since different objectives require different reports. The attributes facilitate the preparation of these reports and can be adopted to strategic and process improvement objectives. Process improvement use attributes as cost drivers and performance measures that facilitates judgment about what work is carried out and how it may be improved. Strategic models benefit from attributes by allowing the user to identify the specific source (a customer or product) to the cost in a process (NPI process). Furthermore, the ABC model can be linked to balanced scorecards using the attributes as each activity can be tagged with an attribute for the scorecard perspective it supports.
II. Let the user assign sensitive or judgmental attributes. This is good when some attributes are too user-sensitive to be defined by the designer or when the attribute cannot be specified in advance when the system is designed. For example, value adding or non-value adding defined for process improvement may be a sensitive issue. The designer may be an outsider and should be cautious in making judgments about the work done by someone else. Furthermore, make as insightful decisions as the user can.

6. Selecting activity drivers is the step where metrics that represents the cost of activities is assigned to cost objects so that products, customers and other cost objects are costed accurately. In the TDABC model, activity drivers are defined as quantities of outputs, e.g. the number of sessions of staff training per product or customer education per customer/product. It is also defined as the processing time per unit of each cost object, such as the time it takes to finish material preparation, product documentation, NPI process documentation, prepare ads, plan an in-house etc. The assigning of activity costs to cost objects has six rules:

I. Pick activity drivers that match the type of activity. For example, a unit activity driver such as direct labor hours are not acceptable to use for the measure of number of batches produced, since the direct labor hours per unit/product, and number of units varies with little regard to the number of batches produced.
II. Pick activity drivers that correlate well with the actual cost of the activity. This regards the measure that should be used to calculate the cost of the activity assigned to the cost object. It usually lay between choice of choosing the number of times an output from an activity is generated, or the time (in hours, minutes etc.) it takes to finish the activity/ to generate the output has the strongest correlation with the performance of the activity. The choice depends on the circumstance. If the time and effort required to perform an activity varies from time to time, e.g. product information preparation, customer segmentation and marketing varies from product to product, then it is best to measure it by the number of hours it takes to finish each task. However, if the effort per activity does not vary, then it makes more sense to use the number of times each activity is repeated.
III. Minimize the number of different drivers means that the number of number of metrics representing the cost of activities assigned to cost objects should be at a minimum to minimize the cost of measurement. Hence, just enough activity drivers should assign cost to the cost objects accurately.
IV. Pick activity drivers that encourage improved performance. This means that the metrics linking activity costs to products and other cost objects should be used as performance metrics. Most often, this means that the more detailed metrics used – the more likely they are to encourage improved performance. For example, a driver used to measure "the time for new product or first-part inspection" focus attention on the time and cost required by inspection activity. In contrast, the number of ads may yield accurate cost of new product advertisement, but it doesn't focus attention on the time consumed for preparing the ads etc. The TDABC model estimate diversity in time equations which reduces the number of activities needed to report accurate costs.
V. Pick activity drivers for low cost of measurement. For example, the number of minutes spend on preparing each marketing activity may be too costly and require too much time. However,

picking activity drivers that generalize the time spend on each major activity and then estimate the cost spend on sub-activities by the number of outputs produced from each activity may be less costly and time-consuming. Hence, measuring the number of times an activity is conducted instead of the time it takes to finish it are usually less difficult and costly, especially when the number of "ads" already is counted in the information system.

VI. Don't pick activity drivers that require new measurements. It usually already exists useful drivers in the company's information system and using these saves time and costs of making new measurements.

8.3. Contribution Margin Data

The following five tables (22-26) illustrate the complete contribution margin data.

Units	Profit/loss per unit sold (with 11 % gross profit margin)	Profit/loss per unit sold (with 12% gross profit margin)	Profit/loss per unit sold (with 13% gross profit margin)
1	- 430 337 SEK	- 407 337 SEK	- 384 337 SEK
2	- 177 337 SEK	- 131 337 SEK	- 85 337 SEK
3	75 663 SEK	144 663 SEK	213 663 SEK
4	328 663 SEK	420 663 SEK	512 663 SEK
5	581 663 SEK	696 663 SEK	811 663 SEK
6	834 663 SEK	972 663 SEK	1 110 663 SEK
7	1 087 663 SEK	1 248 663 SEK	1 409 663 SEK
8	1 340 663 SEK	1 524 663 SEK	1 708 663 SEK
9	1 593 663 SEK	1 800 663 SEK	2 007 663 SEK
10	1 846 663 SEK	2 076 663 SEK	2 306 663 SEK
11	2 099 663 SEK	2 352 663 SEK	2 605 663 SEK
12	2 352 663 SEK	2 628 663 SEK	2 904 663 SEK
13	2 605 663 SEK	2 904 663 SEK	3 203 663 SEK
14	2 858 663 SEK	3 180 663 SEK	3 502 663 SEK
15	3 111 663 SEK	3 456 663 SEK	3 801 663 SEK
16	3 364 663 SEK	3 732 663 SEK	4 100 663 SEK
17	3 617 663 SEK	4 008 663 SEK	4 399 663 SEK
18	3 870 663 SEK	4 284 663 SEK	4 698 663 SEK
19	4 123 663 SEK	4 560 663 SEK	4 997 663 SEK
20	4 376 663 SEK	4 836 663 SEK	5 296 663 SEK

Table 22. The three contribution margin rates in the range of 1 to 20 units sold.

Units	Contribution Margin (with 11% gross profit margin)	Contribution Margin (with 12 % gross profit margin)	Contribution Margin (with 13% gross profit margin)
1	-14%	-14%	-13%
2	-3%	-2%	-2%
3	1%	2%	3%
4	3%	4%	5%
5	5%	6%	7%
6	6%	7%	8%
7	6%	7%	8%
8	7%	8%	9%
9	7%	8%	9%
10	8%	9%	10%
11	8%	9%	10%
12	8%	9%	10%
13	9%	9%	10%
14	9%	10%	11%
15	9%	10%	11%
16	9%	10%	11%
17	9%	10%	11%
18	9%	10%	11%
19	9%	10%	11%
20	9%	10%	11%

Table 23. The contribution margin in percent within the range of 1 to 20 units sold. Own developed model.

Units	**Revenue (with 11% gross profit margin)**	**Variable costs**	**CM (with 11% gross profit margin)**	**CM in percentage (with 11% gross profit margin)**
1	2 553 000 SEK	2 983 337 SEK	- 430 337 SEK	-14%
2	5 106 000 SEK	5 283 337 SEK	- 177 337 SEK	-3%
3	7 659 000 SEK	7 693 337 SEK	- 34 337 SEK	0%
4	10 212 000 SEK	9 993 337 SEK	218 663 SEK	2%

5	12 765 000 SEK	12 403 337 SEK	361 663 SEK	3%
6	15 318 000 SEK	14 703 337 SEK	614 663 SEK	4%
7	17 871 000 SEK	17 113 337 SEK	757 663 SEK	4%
8	20 424 000 SEK	19 413 337 SEK	1 010 663 SEK	5%
9	22 977 000 SEK	21 823 337 SEK	1 153 663 SEK	5%
10	25 530 000 SEK	24 123 337 SEK	1 406 663 SEK	6%
11	28 083 000 SEK	26 533 337 SEK	1 549 663 SEK	6%
12	30 636 000 SEK	28 833 337 SEK	1 802 663 SEK	6%
13	33 189 000 SEK	31 243 337 SEK	1 945 663 SEK	6%
14	35 742 000 SEK	33 543 337 SEK	2 198 663 SEK	7%
15	38 295 000 SEK	35 953 337 SEK	2 341 663 SEK	7%
16	40 848 000 SEK	38 253 337 SEK	2 594 663 SEK	7%
17	43 401 000 SEK	40 663 337 SEK	2 737 663 SEK	7%
18	45 954 000 SEK	42 963 337 SEK	2 990 663 SEK	7%
19	48 507 000 SEK	45 373 337 SEK	3 133 663 SEK	7%
20	51 060 000 SEK	47 673 337 SEK	3 386 663 SEK	7%

Table 24. Illustrates the contribution margin with a gross profit margin level of 11%. Own developed model.

Units	**Revenue (with 12% gross profit margin)**	**Variable costs**	**CM (with 12% gross profit margin)**	**CM in percentage (with 12% gross profit margin)**
1	2 576 000 SEK	2 983 337 SEK	- 407 337 SEK	-14%
2	5 152 000 SEK	5 283 337 SEK	- 131 337 SEK	-2%
3	7 728 000 SEK	7 693 337 SEK	34 663 SEK	0%

4	10 304 000 SEK	9 993 337 SEK	310 663 SEK	3%
5	12 880 000 SEK	12 403 337 SEK	476 663 SEK	4%
6	15 456 000 SEK	14 703 337 SEK	752 663 SEK	5%
7	18 032 000 SEK	17 113 337 SEK	918 663 SEK	5%
8	20 608 000 SEK	19 413 337 SEK	1 194 663 SEK	6%
9	23 184 000 SEK	21 823 337 SEK	1 360 663 SEK	6%
10	25 760 000 SEK	24 123 337 SEK	1 636 663 SEK	7%
11	28 336 000 SEK	26 533 337 SEK	1 802 663 SEK	7%
12	30 912 000 SEK	28 833 337 SEK	2 078 663 SEK	7%
13	33 488 000 SEK	31 243 337 SEK	2 244 663 SEK	7%
14	36 064 000 SEK	33 543 337 SEK	2 520 663 SEK	8%
15	38 640 000 SEK	35 953 337 SEK	2 686 663 SEK	7%
16	41 216 000 SEK	38 253 337 SEK	2 962 663 SEK	8%
17	43 792 000 SEK	40 663 337 SEK	3 128 663 SEK	8%
18	46 368 000 SEK	42 963 337 SEK	3 404 663 SEK	8%
19	48 944 000 SEK	45 373 337 SEK	3 570 663 SEK	8%
20	51 520 000 SEK	47 673 337 SEK	3 846 663 SEK	8%

Table 25. Illustrates the contribution margin with a gross profit margin level of 12%. Own developed model.

Units	**Revenue (with 13% gross profit margin)**	**Variable costs**	**CM (with 13% gross profit margin)**	**CM in percentage (with 13% gross profit margin)**
1	2 599 000 SEK	2 983 337 SEK	- 384 337 SEK	-13%
2	5 198 000 SEK	5 283 337 SEK	- 85 337 SEK	-2%

3	7 797 000 SEK	7 693 337 SEK	103 663 SEK	1%
4	10 396 000 SEK	9 993 337 SEK	402 663 SEK	4%
5	12 995 000 SEK	12 403 337 SEK	591 663 SEK	5%
6	15 594 000 SEK	14 703 337 SEK	890 663 SEK	6%
7	18 193 000 SEK	17 113 337 SEK	1 079 663 SEK	6%
8	20 792 000 SEK	19 413 337 SEK	1 378 663 SEK	7%
9	23 391 000 SEK	21 823 337 SEK	1 567 663 SEK	7%
10	25 990 000 SEK	24 123 337 SEK	1 866 663 SEK	8%
11	28 589 000 SEK	26 533 337 SEK	2 055 663 SEK	8%
12	31 188 000 SEK	28 833 337 SEK	2 354 663 SEK	8%
13	33 787 000 SEK	31 243 337 SEK	2 543 663 SEK	8%
14	36 386 000 SEK	33 543 337 SEK	2 842 663 SEK	8%
15	38 985 000 SEK	35 953 337 SEK	3 031 663 SEK	8%
16	41 584 000 SEK	38 253 337 SEK	3 330 663 SEK	9%
17	44 183 000 SEK	40 663 337 SEK	3 519 663 SEK	9%
18	46 782 000 SEK	42 963 337 SEK	3 818 663 SEK	9%
19	49 381 000 SEK	45 373 337 SEK	4 007 663 SEK	9%
20	51 980 000 SEK	47 673 337 SEK	4 306 663 SEK	9%

Table 26. Illustrates the contribution margin with a gross profit margin level of 13%. Own developed table.

8.4. TRUMPF Group Background

Milestones	TRUMPF
1923-1949	***The Beginning**:* The company is founded by Christian Trumpf in Stuttgart, Germany (1923). It produced *flexible cables for attachnments*, *electric shears* and *flexible shafts*. The production buildings remain undamaged (1939). In 1947 it increases its product range by manufacturing the stationary nibbler: TRUMPF nibbler TAS.s
1950-1967	***The Economic Miracle Years:*** In 1950, stationary machines, especially for sheet metal processing, make the company gradually increase in size and go global. TRUMPF has 145 employees and its sales exceeded the one-million mark. 1957 TRUMPF patents the first coordinate guidance system for metla sheets: the starting point for the numerical constrol that all machine tools will be operated with later. In 1961, the company had 325 employees and achived 11 million in sales. Its first foreign company is founded in Zug, Switzerland (1963). The firm has 440 employees and sales of DM 20 million in 1967.
1968-1984	***World Market***: In 1968, TRUMPF presents the first sheet metal fabrication machine with a numerical control system: TRUMATIC 20. It enabled fully automatic work at the machine, right down to tool changes, for the very first time. All the information required to prcess sheet metal was stored on perforated computer tape. One year later, the compny founds a U.S. subsidiary in Farminton, Connecticut. Today, Farmingotn is the second-largest TRUMPF location worldwide, and the headquarters for the U.S. market. In 1972, TRUMPF moves to Ditzingen from Stuttgart which has more suitable production and traffic conditions for its size. The firm had 800 employees in 1975 and its salse was DM 73 milion. Berthold Leibinger becomes the new chairman of the Managing Board at TRUMPF in 1978. He has returned from an information-gathering trip in the USA with a CO2 laser and founded a subsidiary in Japan in the same year. In 1979, TRUMPF enter the laser processing market with its first combination punching-llaser machine: TRUMATIC 180 LAERPRESS. The company has 1500 employees and sales of DM 300 million as of 1984 and recieved its new and curretn logo symbolyzing the company's solidity and its orientation towards the future.
1985-2004	***Laser:*** In 1985, TRUMPF presented its own C02 laser: LASER TLF 1000. It had 1 kW of beam performance and is the first compact laser resonator with RF-excitation. TRUMPF's activites in the solid-state laser sector began with its participation in the firm of Haas Laser GmbH in Schramberg which is 100-percent owned by the TRUMPF Group since 1992. The company opens its laser factory at its headquarters in Ditzingen in 1998. The company adapts to the requirements of globalization and internationalization in 2000. The same year it enters the Additive Manufacturing market The firm had by then 4800 employees worldwide and achieved sales of 1 billion euros. In 2003, the company opens the Sales and Service Center in Ditzingen, Germany. During the same year it presents a new 2kW disk laser prototype with a high laser beam quality which enabled new applications like scanner welding. The company continues to develop solutions for the machien tools, laser and electronic sectors.
2005-Future	***Change of Generation:*** In 2005, shortly before his 75th birthday, Berthold Leibinger retired from the Managing Board after 40 years. His daughter Nicola Leibinger-Kammüller was appointed as the new President of the Group and Chairwoman in the Managing Board. In 2008, the TruLaser 3030 NEW was presented as an upgraded laser machine with higher productivty than its predecessor but with the same robustness and reliability. In 2010, the TruLaser 5030 fiber is presented at the international technology trade show for sheet metal processing "EuroBLECH 2010" in Hannover. In 2010/11 it had approximately 8456 employees and achieved sales of 2.02 billion euros. In 2016, the company re-enters the market with its two new metal 3D-printers for industrial applications: TruPrint 1000 and TruPrint 3000. Today, TRUMPF Group's industries include: the steel processing industry, the automotive industry, the aerospace industry, the transportation and vehicle industry, electronics and micro-technology industry, welding of tubes and profiles, the photoelecrtic industry, the semiconductor manufacturing industry, marking of cheramic industry, and the plastic processing industry etc. The firm engage in Industry 4.0 through several development projects such as the working team Smart Serivces Welt. TRUMPF is a member of the Allianz Industrie 4.0 BW, and the Industry 4.0 working group Bundesministerium für Bildung und Forschung (BMBF) (since 2011). It is a partner of the global innovation platform CODE_n and the CyProS Project (cyber-physical production systems). It founded the digital business platform AXOOM GmbH, offering IT service solutions for manufacturing firms. Its combined offerings of expertise and knowledge, TRUMPF machines and IT solutions provides a solid platform for customers to build their own Smart Factories, step by step.