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School of Engineering

Development of an Evaluation Framework for assessing Automated Solutions

PAPER WITHIN *Production Systems*
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This final thesis has been carried out at School of Engineering at Jönköping University within the main area production systems. The work is a part of the Master of Science program Production Development and Management. The authors are responsible for the opinions, conclusions and results herein presented.

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Abstract

Purpose	The purpose for conducting this research is to develop a framework, for evaluating implementations of advanced manufacturing technologies. By identification KPIs that are suited for evaluations and functions that applicable in frameworks.
Method	Design research method (DRM) was carried out to finalize the evaluation framework. The method encourages for conducting literature review and case study to analyze and gather data.
Findings & analysis	DRM assisted in identifying answer for the developed research questions. The answers for the first two research questions presented as lists while the third are presented as a framework. Logic behind included KPI and framework function is presented as well.
Conclusion	Industrial contribution is an evaluation framework that manufacturers use to assess a newly implemented automated solutions and determine whether it is beneficial. The process for evaluating the performance of particular manufacturing activities by using the defined framework is part of the academic contribution.
Delimitation	One of the thesis' delimitations is that it exclusively focuses on manufacturing activities. Furthermore, only material handling activity was used to verify the evaluation framework's functionality. In addition, the developed EF was not fully tested at the case company in order to demonstrate it is full applicability.
Keywords	Advanced manufacturing technology, Evaluation framework, Key performance indicators, Performance measurement system, Performance objectives

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- **Rabi Josefsson & Thomaslee Jojy**

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1 Introduction

This chapter presents the background that has led up to the problem description and the purpose for conducting the following thesis, presented in the same outline as well. Lastly, this chapter presents the research questions, delimitation, and outline of this thesis.

1.1 Background

Manufacturing companies are constantly facing challenges from different direction, both external (market demand) and internal (e.g., manufacturing obstacles) (Sahoo & Yadav, 2018). In all countries, small and medium enterprises are considered the backbone of economic progress. The majority of manufacturing SMEs have simple systems and procedures, which allows for greater flexibility, immediate feedback, a shorter decision-making chain, and a better awareness of customers. Due to global competition, technological advancements, and changing customer expectations, SMEs are under immense pressure to maintain their competitiveness in both domestic and worldwide markets. As a result, SMEs seek for constant improvement and change (Singh et al., 2008). Customers are expecting high-quality products at lower costs with a growing number of product variants in order to gain and maintain a competitive advantage. Therefore, manufacturing companies aim at implementing various solutions in order to decrease the pressure from the market and gain more market shares (Esturilho & Estorilio, 2010). Strategies are developed and available for manufacturers to implement in order to being a better competitor on the market. These strategies are ranging from high performance equipment to manufacturing strategies (Rodrigues et al., 2021). In order to handle the aforementioned growing requirements, manufacturing companies are recommended to implement new equipment's, designed to handle manufacturing challenges (Klein & Thomas 2006). However, implementing new technologies implies that the development in other areas needs to be initiated. Otherwise, it could result in suboptimization while the issues remain (Hagström et al., 2006). I.e., that manufacturing managers needs to make strategic decision on whether the intended solution to implement can create suboptimization obstacles or if it fits one's own manufacturing cell, individually, without affecting other areas negatively (Majchrzak & Paris, 1995). Other scholars raise the concern of implementing automated solutions by emphasizing for instance increasing production capacity (Ratnasingam et al., 2019). Automation is part of advanced manufacturing technology (AMT) which is something that has increased in the manufacturing industry. The concept of AMT is associated with improving the capabilities of manufacturing and is recognized as having a positive impact on e.g., labour productivity, plant performance, and company competitiveness. AMT also adds another important factor, which is to reduce the need of having skilled worker at every working station (Yu et al., 2011). With an extensive pace of implementing AMTs, there exist an urge to monitor the performance of different activities so that companies have a chance on improving criteria's that affect e.g., their production or manufacturing capabilities. Organizations must monitor their performance in order to receive proof that their objectives and goals are being met (Ghalayini, 1997). In order to attain these goals, companies must utilize their performance management system and should understand performance indicators in order to measure, manage, and compare performance (Ishaq Bhatti et al., 2013). Inadequate control over a company's processes and activities has an impact on its operating results and process performance, prompting the company to iden-

tify which areas are most affected and in need of improvement. The assessment of process performance, as well as the use of instruments that allow visualization and monitoring of their status, has been one of the tactics taken by businesses over the last few decades (Petrillo et al., 2019). Hence, the development of performance measurement systems (PMS) that allows companies to visualize the performance of measured activity. To that, a PMS, of any type of process/activity, need tools to indicate whether a company is on the right track to enhance their activity or if changes is needed. That is why companies utilize different key performance indicators (KPIs) and place a great effort on choosing right KPIs that reflect the company's competitive strategy (Rodrigues et al., 2021). If the source of measuring an activity performance comes from the idea of replacing current way of performing the activity by implementing a solution, as AMT, it should provide competitive advantage to the company (Kayakutlu & Büyüközkan, 2010). Another reason for why this is of a great importance to measure the performance, of any activity, it is to provide some feedback on whether a change in the system is successful or not (Bhagwat & Sharma, 2007).

1.2 Problem Statement

Strategic alignment with the company's manufacturing capabilities and strategic goals is of great importance. Studies have shown that fostering developed manufacturing strategies show good results on manufacturing performance. To be able to implement a strategy fit for the company's capability is as strategically advantageous. However, in order to know if a manufacturing plant/facility has the capabilities of implementing manufacturing strategies, performance measures need to be executed (Thun, 2008). The measures are realized in terms of performance objectives, including cost, flexibility, quality, dependability, and speed, which derives from the company's strategic goals (Bellgran & Säfsten, 2010).

In today's market many SMEs faces challenges with the increase of competition and market demands. SMEs sees the volatile changes due to factors such as e.g., globalisation or advancement in technology from competition. SMEs tends to respond to these challenges by seeking AMT practices that are aligned with their strategies (Fultion & Hon, 2010). In order for AMT adoption to be seen as successful, manufacturing companies must choose appropriate technology which fit is their strategy. Hence, stressing the need for finding an alignment between manufacturing capabilities and strategic goal in order to evaluate how AMT adoption affects performance objective (Fulton & Hon, 2010).

Due to the complexity of AMTs, companies face many challenges in evaluating the success on how different situations have been handled. This has led to the development of a multi-dimensional domain regarding how and what to measure. KPIs are considered the most important instruments for measuring and controlling an organization's processes. These indicators can be used to determine if operations are carried out effectively, as well as to optimize all of the resources involved (Meier et al., 2013). Some might argue that the problem is frequently linked to the identification of relevant KPIs, the setting of targets, the availability of data, and the involvement of people who will use those (Braz et al., 2011). However, in general, there is minimal guidance for manufacturing companies on how to choose and apply performance measurements (Digalwar & Sangwan, 2011). The frameworks available are frequently stated in general terms, leaving it up to manufacturing companies to tackle their specific difficulties (Tangen, 2004). A major challenge manufacturer has to manage are questions regarding

performance objectives and how to evaluate certain choices that has been made to increase performance (Khalili & Alinezhad, 2018). Due to these challenges, a need to develop a framework that can both evaluate and monitor the performance within the context of manufacturing strategy is significant. However, the difficulty involves allocating and organizing acquired data so that it becomes effective when inserting it in the framework to evaluate the activity. To summarize, manufacturing companies have to tackle challenges erupted by the process of justifying intended solutions that seeks to enhance manufacturing performance (Small, 2007). Since it does not exist a PMS with right KPIs to measures how AMT implementation is affecting manufacturing strategic goals a need to develop an EF exists (Amrina et al., 2020).

1.3 Purpose and Research Questions

Many manufacturing companies have initiated their journey toward automation, which has necessitated strategic changes. Thus, when these strategic changes occur, companies need to identify and measure whether it is in the right path or not. Normally, SMEs already use various kinds of KPIs to measure their performance within the company. However, limited research has been conducted focusing on measuring the right performance of a certain activity. The established framework aims to have a high level of applicability so that it can be adapted by SMEs that currently has a low level of LoA (Level of Automation) and compete at novice level regarding AMT practices. The establishment of intended evaluation- and monitoring framework aims to steer production managers in the right track. So that they can take decisions based on accuracy and precision in order to enhance the manufacturing strategy by implementing new AMT practices.

The purpose of this thesis is to develop an evaluation framework for the usage of evaluating implementation of AMT practice compared with current manufacturing activity performance.

In order to fulfil the purpose, three research questions (RQs) have been established. The first RQ has been formulated in order to identify and summarize the existing performance measurement systems, which serves as a foundation for creating the evaluation framework:

- Which are the PMSs, presented in literature, that are currently used in SMEs in order to measure the performance?

The second RQ has been formulated in order to identify the relevant KPIs that exist in the literature.

- Which KPIs are needed to be consider in order to ensure that companies at SME level fully evaluate the successfulness of newly implemented automated solution at novice level?

The third RQ covers the developments of this research, which is to examine how emphasized evaluation framework can be developed based on the results of the RQ1 and RQ2.

- How can an evaluation framework for measuring the successfulness of adopting automated solution be formulated?

1.4 Scope and Delimitations

The answers for the RQs are only applicable for manufacturing practices where intentional enhancement of manufacturing activity is in focus. The answers of the RQs are

limited to AMT practices of the following: automated handling, automated- inspection, packing-, and assembly, and robotics. However, the evaluation frameworks (EFs) functions will only be verified on material handling activity. The method of choice for developing the answer for the third RQ has four stages, where this thesis delimits itself to the third stage. I.e., the development of intended EF will not be tested with e.g., a focus group to verify its applicability in a SME. However, the EFs functions and method for gathering variables needed to measure KPIs will be verified in a case company. Additionally, the answer for third RQ will only display whether a strategic objective is affected positively or negatively. I.e., an exact value on e.g., how much a particular performance objective have decrease due to AMT solution will not be displayed. KPIs from case company will not be considered since this thesis focus on findings from other researchers regarding the applicability and relevance of KPIs for manufacturing activities within SMEs.

1.5 Outline

Chapter 2 presents the theoretical background of the thesis. The reader will be introduced to fundamental theories and concepts linked to the study in this section. The chapter outlines with a focus on automation theory and frameworks, followed by performance objectives, measures, and system.
The method and its implementation are presented in detail in Chapter 3 and are organized in the same order as respective method was utilized. In this chapter, the various methods that will be used to conduct this study will be presented in depth. This played an important role in answering the research questions that were developed.
The theoretical findings are presented in depth in Chapter 4. The following chapter will describe the findings of from literature review, with a focus on creating summary tables of results for effective presentation. This means that the answers to the first two RQs will be presented in this chapter.
The researchers employed a strategy to construct a framework, which will be detailed in Chapter 5, i.e., the Framework Development. The aim of this section is to show how DRM stages were used to develop the EF by describing what was acquired at each level. The connection between the RQs, the reasons for their designs, how the EF works, and how the EF is presented are all covered in this chapter.
In Chapter 6, Discussion and analysis, the findings from the literature review (RQ1- and 2) are discussed in this chapter, which eventually leads to the developed EF (RQ3). The analysis is drawn along the discussions about how the answers to all of the RQ are connected. Eventually, the methods for research will be discussed.
Lastly, in chapter 7, the thesis is summarized in the conclusions. The chapter ends with a summary of the study's implications and future research.

2 Theoretical Background

This chapter describes the theory of the key topics of this thesis, i.e., automation and performance evaluation. The chapter is outlined with first elaborating on the theory of automation and frameworks, and lastly, performance objectives- measures- and system.

2.1 Automation

Automation is seen as mechanical systems that execute activities after given command. From a productivity perspective, automated technology or equipment are increasingly incorporated to exclude various manual activities. The factor that has given rise to the interest of automating manufacturing activities is the increase in market demand for products with higher quality manufactured in shorter leadtime. The market also sees those manufacturers are enhancing their flexibility in order to adapt to market changes as well being able to compete provide products with low costs. Nevertheless, automation is a strategic technology to be incorporated to stay advantageous against competition. Automation plays an important part in manufacturing when aiming at reducing production cost- and cycle times-, increase quality-, dependability-, and flexibility, and improve manufacturing floor space utilization (Dey & Sen, 2020). Manufacturing systems that are automated performs activities such as processing, assembly, inspection, and material handling. Automation is a technology that contributes or aims to integrate various systems or manufacturing cells, where the goal is to increase the level of automation. Meaning that more that one of the aforementioned manufacturing activities could be executed in the same manufacturing system. These systems could be e.g., machine tools that process parts automatically, automated inspection technology to control the quality of products, etc. There are three overall automation types in manufacturing. *Fixed automation* has high production volume and the automated operation(s) equipment(s) are fixed at particular position in the manufacturing system. *Flexible automation* produces products in medium volume where changeover time is the focus to be kept as low as possible and processing parts with various equipment. Lastly, *programable automation,* wherein the focus is to change the sequence of operations based on the product configuration. When utilizing programable automaton the production volume is usually low (Groover & Jayaprakash, 2016).

2.2 Levels of automation

Manufacturing industries compete in different level pending on size and technology, the same goes for automation, see figure 1. The level of automation that a company implements indicates the level they compete in. Within the context of manufacturing, *Levels of automation* (LoA), is defined as interactional tasks with different division (levels) between machines and workers. From the same contextual perspective, finding the proper LoA for a manufacturing company could be a decisive strategy to maintain, if not incrementally, a systems effectiveness (Granell et al., 2006). LoA regard both mechanized and cognitive tasks between workers and the equipment. The level of automation a company has often depends on the product and the process complexity The importance in implementing or adapting to LoA is that the level should be aligned with the manufacturing strategy. Since the companies' LoA has an ad hoc nature, the level is increasable and can thus adapt to changing manufacturing strategy (Lindström & Winroth, 2010). The right choice of LoA has also an economic perspective, i.e., too

high level of LoA places companies in a vulnerable position with less chance of other investments. Additionally, leading to the situation that companies do not fully utilize the LoA and forcing them to add more cost to decrease the LoA (Lalic et al., 2020). Automation could also be seen as existing on five different levels, illustrated in following figure, from a device to an enterprise level which defines the levels certain company compete in (Groover & Jayaprakash, 2016).

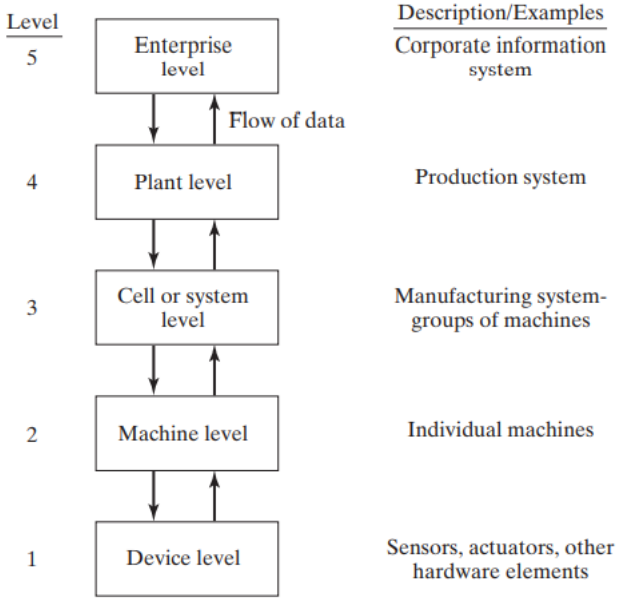

Figure 1: The levels of automation from a hierarchy perspective, (Groover & Jayaprakash, 2016).

2.3 Automation migration strategy

The need for automation migration derives from identifying activities that are repetitive and goes through 3 phases before reaching full migration. Phase 1 includes implementing tools for new product development at a single station. Phase 2 involves automating repetitive tasks at cell, i.e., increase automated manufacturing activities in single manufacturing cells, while work unit is moved in between cells. Lastly, phase 3 involves integration of automated single cells so that it forms multi-stations that are executing automated manufacturing activities (Groover & Jayaprakash, 2016). To go from manual labour to automation is a strategic decision where manufacturers develop their activities to produce desired products efficiently (Ker et al., 2013). However, automation migration does not necessarily need to be considered for new product developments, it could also be considered when manual production lines move to automated due to strategic advantages (Susanti et al., 2021). I.e., the migration from manual to automation is a strategy to aid new product development but could also find its foundation from an activity within a process that has been automated.

2.4 Performance objective

Performance objectives (POs) are statements that help a company define an overall vision, set goals, and measurable steps to attain a desired outcome (Alogan & Yetiş N, 2006). Successful production improvements result in producing items that may be manufactured and sold financially from the standpoint of investors in a for-profit business, although profitability is sometimes difficult to gauge quickly and directly (Katzenbach & Smith, 1992). When companies try to implement new methods to their production, there are certain key points that they look into. Five POs are listed as following:

- ***Quality:*** this objective involves how closely the activities that make up the product can meet the demands specified by the design (Greasley, 2008). Every organization's success is determined on it is level of quality. Customers nowadays want high-quality items, and companies that can provide high-quality products at a cheaper cost win the game. Input, output, and throughput (process quality) are the three key areas where quality is verified. Because in the output and how often it can be delivered (throughput) is what the customer receives and assess quality (Heckl & Moormann 2010; Badri et al. 1995).
- ***Cost***: the finances that are required to obtain the inputs and activities to manage the transformation process to products are considered as cost. Organizations that compete in cost strive to keep it low as possible. The reasons are because it provides higher levels of profit and gains more market shares (Greasley, 2008). External stakeholders are more concerned with cost-based performance measurements, which is why businesses utilize cost accounting systems that contain efficiency and effectiveness measures as part of an effort to link internal and external performance measures (White, 1996). Manufacturing cost, value added cost, selling price, operation cost, and services cost are the cost performance measures established (Neely et al., 1995; Ishaq Bhatti et al., 2013).
- ***Dependability:*** concerns itself with meeting the planned delivery times of products and services to both internal- and external customers. This PO can be measured in percentage where customers receive their product or service on planned time (Greasley, 2008). The reason for that is because time is a critical driver of an organization's manufacturing performance. Manufacturing organizations around the world are concerned about time-based manufacturing in order to get a competitive advantage over their competitors (Koufteros et al.,1998). Which means that the deliveries are not explicitly the only focus when it comes to *dependability*.
- ***Flexibility:*** adapting to market changes or customer demands are important factors when it comes to manufacturing competition. The main concern of *flexibility* is to adapt quickly to changes. Time is an important variable when measuring ***flexibility*** because it considers how fast the manufacturing system can change e.g., it is tools to provide other products to the market (Greasley, 2008). Capability is related to this objective meaning that manufacturers studying this objective to see if company is capable enough to satisfy the quick changes in market (Nicholas, 2018).
- ***Speed:*** in comparison with *dependability*, this objective is more concerned about how fast companies are able to deliver products and services to customers. This objective has internal- and external effects on performance where the internal provides fast throughput and the latter short delivery times (Grunberg, 2004). The delay time between the request from a customer and the delivery is also the concern of *speed* objective. Here, this objective is related to cost because being able to provide products fast usually means that products are made-to-stock, which increases the company's operation cost. But if company is able to shorten the aforementioned delay and provide products fast without less volume of, or none at all, make-to-stock, then *cost* can also be kept low (Greasley, 2008).

2.5 Performance Improvement

Businesses seek to increase performance for being a better competitor as it results in acquiring more market shares, thus increasing revenue. However, depending on focused objective there are several strategies to improve performance (Grünberg, 2004). Explo-

ration and retention of knowledge are critical components of increasing inventive performance. Previous research has showcased that in many of the companies, the management is still confused in understanding the ways of improving the performance. Many of which are referred to as key performance indicators (KPIs) inaccurately (Badawy, 2016). There are four different types of performance indicators:

1. Key result indicators (KRIs): KRIs describe the progress in a certain area or essential success aspect.
2. RIs (result indicators): inform that what one has accomplished.
3. Performance indicators (PIs) indicate what is needed to be done.
4. Key performance indicators (KPIs): inform what has to be done in order to drastically improve performance (Badawy 2016).

It is critical for businesses to keep their operations efficient in order to be profitable over time. If manufacturing is kept in good working order, performance improvement will not be extremely expensive, as it should yield a return on investment. A poorly maintained manufacturing facility, on the other hand, can bring a company to collapse. The impact of both efficient and inefficient manufacturing is significant, as it affects all other aspects of the business in terms of customer responsiveness and competitive advantages (Grünberg, 2004).

2.5.1 Key Performance Indicators (KPI)

Manufacturing organizations undergo transformations as a result of automation, particularly inside their production systems. Companies expect cost and time reductions as a result of shorter manufacturing times, but they face obstacles such as budget constraints, lacking standards (Flaeschner et al., 2020), and a lack of technological transfer from research to industry (Gausemeier, 2016). Companies can overcome these obstacles by selecting and evaluating individually acceptable digital technologies and solutions for their specific difficulties, as well as considering the appropriate key performance indicators (KPIs) in manufacturing. The KPIs focus on the performance of the most important organizational factors for an organization's current and future success. They provide management with information on how the organization's core processes are doing and how they relate to the overarching strategic goals. Key performance indicators are a set of performance indicators that have been picked or established upfront by management that strongly reflects the essential variables that are of particular significance for the operation of an organizational unit (Samsonowa, 2011). Because the KPIs are developed from the organization's strategy and are continually presented to the board to indicate the organization's overall success, the CEO's concentration is critical. A KPI must be understood by all employees and clearly explain what action has to be taken in order to be effective. Late deliveries, for example, is a KPI that directly shows that time has to be saved, and employees do everything they can to reduce the delays. As a result, a KPI (Kibira et al., 2017) is a quantitative and strategic measurement that can be produced directly from or through an aggregation function of e.g., physical measures, data, and other KPIs (Siedler, 2020). KPIs highlight a company's key success factors and aid in understanding and improving manufacturing performance (Kibira et al., 2017). Because there are so many KPIs in manufacturing, several ways try to organize them using different systems, or so-called performance measuring systems (PMS).

The PMS employs the KPIs established (Kibira et al., 2017) and organizes them hierarchically into supporting elements, Basic KPIs, and Comprehensive KPIs, with the goal of providing a useful tool for industrial operations management and continuous improvement (Fig. 2). By distinguishing between quality, productivity, maintenance,

as well as time and quantity, structured KPIs describe the operations performance of a manufacturing system. The KPIs should be attached to a team so that they may be readily maintained and influenced by minor modifications if necessary. In order to provide positive results, they must also have a major impact and affect the essential success criteria, preferably more than one part of the organization's strategy (Rydberg & Östh, 2016).

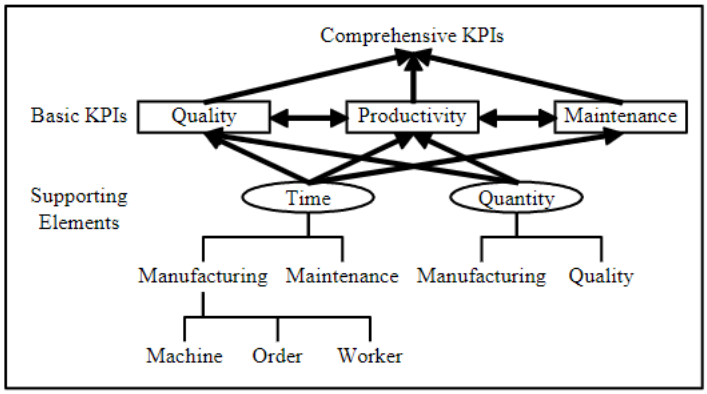

Figure 2: KPI categorization according to Siedler (2020)

2.6 Performance Measurement

In order to guarantee the applicability and value of measurements, they must be analyzed or established with relation to the organization's overall strategy, in addition to recognizing and distinguishing between KPIs, KRIs, RIs, and PIs (Parmenter, 2015). The development and evaluation of possible performance indicators is the most crucial phase in determining performance measures (Kueng, 2002). To ensure that the indicators are useful and applicable, organizations should first work on selecting and defining appropriate measurements for their focus area (Parmenter, 2015).
Performance measurement and management strategies are now widely used in all sectors of industry and trade, including public service (Bititci et al, 2012). Productivity management, budgetary control, integrated performance measurement, and integrated performance management appear to be the stages in the development of the performance measurement sector. Performance measurement (PM) is considered as one of the most important steps when a manufacturing company is trying to optimize its operations performance (Csanády et al., 2019). PMs are usually a measure of output parameters since the company’s results after input shows how well a company performs. Measuring the manufacturing systems performance provides capability figures and give rise to strategic decision making (Granell et al., 2006). In summary, PM is the act of evaluation the effectiveness and efficiency a company’s activities (Khan et al., 2021).

2.7 Performance measurement system

A performance measurement system (PMS) is seen as the bridge that unify strategic planning and operational control who consider both cost- and non-cost factors. Over the years PMS has gone from purely considering financial perspectives to include and establish indicators that aspire to create value. The concept of PMS foundation is strictly based on neglecting the idea of trade-offs and instead integrating performance metrics that could provide results in several areas by compatibility. As example, instead on focusing on return of investment, financial perspective, PMS seeks to measure long-term goals with indicators of customer- satisfaction and loyalty. PMS has different type of levels where the top level is called strategic level and it is where the managerial

indicators come to play where use of balanced scorecard is frequent while lowest level (operational level) has indicators such as work reports (Quagini & Tonchia, 2010). The overall agenda of a PMS is to translate corporate goals, compare performance (benchmarking), monitor operations, evaluate resources, coordinate activities, motive resources, and provide organizational education by studying results provided by the measures during PMS development and process monitoring (Quagini & Tonchia, 2010). Performance measurements are tools for analysing, managing, and improving the activities of an organization. Effective performance measures enable to comprehend the following:

- how well the organization is doing, i.e., an accurate description of the process.
- if the organization is on track to reach its objectives (definition of objectives and reference standards).
- if the consumers are satisfied (process development control).
- if the firm have control over their processes (controlling organizational effectiveness and efficiency factors).
- if and where process improvements are required (identification and implementing solution to a problem) (Franceschini et al, 2007).

2.7.1 PMS characteristics

According to Quagini & Tonchia, (2010), characteristics of PMS are divided into three categories: *elements*, *architecture*, and *interfaces*.

- The elements simply tell what is to be measured by presenting indicators who are one part of the PMS. The elements are both objectives established by forecast and results establish by measures of categorial performance. When setting the elements of the PMS it is important to consider what measures are presented and in which does it give the reader most information.
- Architecture is a very broad term that emphasize the relationship between different indicators and has three different forms: Vertical, Horizontal and Process. Vertical defines the level of indicator and horizontal identifies how adequate the indicators are with the organizational unit. While process explains which indicator can be utilized in order to measure and monitor.
- The last category which characterizes a PMS is called interface since one of the goals of PMS is to make sure that systems interact with each other. According to Quagini & Tonchia (2008), the PMS should interact with at least one of three systems: management control system, which could be e.g., an organizations budget sheet, or the system to draw accounts for production cost, etc. Production management system, which are systems that e.g., concerns itself with production planning such as an MRP systems (material requirement planning system). The last system that a PMS needs to be able to interact with is a strategic planning system of an organization and aims to compare performance targets based on forecast and results, and exemplified illustration of a strategic planning system.

PMS strategy deals with both *content* and *process* and could be summarized accordingly: *content*; deals with both *competitive priorities* such as establishing key success factors and *choice of interventions*; could be for instance, developing the technological level (reaching ha higher level of LoA) that reflects the *competitive priorities*. The strategical *process* of PMS is concerned with implementation processes (Quagini & Tonchia, 2010).

2.7.2 Designing & implementing PMS

The first to be considered when designing a PMS is to decide in what type of environment it is intended to be implemented in, e.g., production departments (internal environment), customers (external environment), as well what kind of characteristics (elements, architecture, and interface) the PMS should have. The next step is to make sure that intended characteristics fits existing PMS. Eventually developers should list subjects in form of KPIs that are to be included in the PMS when choosing dimensions. That is usually between two category groups which are cost (cost and productivity) and non-cost (quality, time, and flexibility). Other considerations need also to be established such as, what unit of measure each indicator should have, e.g., pieces, particular currency, etc. A PMS has to have its principles and should act as pillars to the system based on the environment that the PMS is to be executed in (Quagini & Tonchia, 2010). As e.g., if the PMS is to be utilized on production level, then a principle could be to have zero-inventory if the enterprise operates with Lean influences. Franceschini et al. (2007) justifies the reasons to use a performance measuring system:

- focus attention on what needs to be done and within organizations argues for how time, resources, and energy could be used to achieve objective goals. Measurements give an organized strategy for focusing on a program's strategic plan, goals, and performance.
- Performance measurement enhances internal communications among employees as well as outward communications between the firm and it is consumers and stakeholders. The emphasis on measuring and improving performance (results-oriented management) produces a new climate that affects all elements of the organization.
- Performance assessment aids in the justification of initiatives and their expenses. Measurements help to support the decision-making process by demonstrating a program's strong performance and long-term impacts with favorable outcomes.

2.8 Performance evaluation

Organization’s evaluate performance based on efficiency and effectiveness by weighing the two terms against each other. I.e., when organizations have an agenda with steps to reach it is goal, by analyzing e.g., time required to reach the goal and the successfulness of each step. Performance evaluation (PE) is composed of data, taken from performance measures, and considers the quality of the data from effectiveness and efficiency perspective. The uniqueness of PE is that it considers secondary results. As an example, if the goal is to produce a variety of products and to measure strategic manufacturing schedules. The first result would be, intentionally, identifying a strategic manufacturing schedule. Then secondary result would be various manufacturing schedules to produces different products based on different circumstances. The reason for why PE emphasizes secondary results is because it provides unintentional benefits. Which in accordance with the aforementioned example would be the organization will have data for comparing futuristic manufacturing schedules with different circumstances, additionally providing a multi-criteria-decision analysis (Dyckhoff & Souren, 2020).

2.8.1 Multi criteria decision making

Automation has been viewed as a critical aid for modern manufacturing organizations in order to improve product quality and production. The problem of choosing the correct automated tool for a certain industrial application and production environment

among the enormous number of various robots on the market has become increasingly difficult (Sen et al, 2015). Improper automated solution selection may have a negative impact on a company's competitiveness in terms of plant productivity and product quality (Rao et al., 2011). As a result, while choosing an automated machine for a specific industrial application, the decision maker must consider all of its characteristics. Researchers have proposed several methodologies for automaton selection, including the use of multi-criteria decision-making (MCDM) methods, production system performance optimization models, computer-assisted models, and statistical models (Chatterjee et al., 2010). The former, i.e., MCDM, has due to its ability to analyze numerous conflicting alternatives on a set of criteria, attracted substantial attention from managers for solving various real-life challenges. The technique enables managers to choose the most appropriate option while maintaining their subjective and intuitive insights. MCDM analysis has several distinct qualities, including: 1) the ability to accommodate several non-commensurable and competing criteria, 2) the ability to handle different units of measurement among the criteria, and 3) the ability to evaluate various options. It has a significant advantage in evaluating intangible aspects such as brand, image, risk, difficulty level, and so on, all of which can have a significant impact on the final decision. This is perhaps one of the most important reasons behind choosing MCDM's approaches by industry practitioners. Many companies use MCDM methodologies to model issues including facility placement, supplier selection, inventory management, risk management, outsourcing, and knowledge management (Thakkar, 2021).

3 Method and implementation

The different methods that have been used in order to conduct this study will be presented in detail in this chapter. This serves as major part in answering to the research questions developed. The chapter is outlined after the order that each method has been used.

3.1 Research design

The nature of this thesis is qualitative, meaning that the data is expressed in form of words and figures for providing deeper understandings of what is tried to be developed. Qualitative research help capture the context of current problem description (Säfsten et al., 2020). Qualitative data analysis will be conducted, which will be expressed more thoroughly in coming chapter. Qualitative research aids in studying phenomenon and the relationship between studied variables. In this case to study critical KPIs for assessing the successfulness of implemented automated manufacturing solutions (Gough et al., 2017). Another reason that argues for pursuing qualitative research is because it aids in developing the theoretical framework. The philosophical approach is based on critical realism, meaning that what is seen can be obtained. Critical realism focuses on explaining what is experienced within the context of observation. The fundamental reason for conducting qualitative research is due to its inductive- and explorative characteristics (Säfsten et al., 2020). This is highly related to the attempt for answer the third RQ which is to take acquired data and create novel theory, i.e., a framework. The findings of the first two RQs acts as theoretical pillars for the developments of the third RQ. In order to answer to first and second RQs, knowledge needed to be gained by studying the works of other researchers. In particular their approach on structuring the process of implementing automated solutions in a manufacturing environment. In order to identify adequate models and KPIs, data from literature review will be collected. The observations that will be performed has its respective attribution to validify the framework. In order to establish findings needed for this EF, relevant literature need to be allocated, categorized, and relationship between findings needed to be drawn (Säfsten et al., 2020). To create assurance and prove applicability of the developed EF, this thesis has selected a case where the aim is to evaluate an activity where the goal is to eliminate manual labour. Additionally, to increase the validity, credibility, and authenticity triangulation is considered by conducting case study, literature review, within design research methodology (DRM) (Saunders et al., 2016), see figure 3.

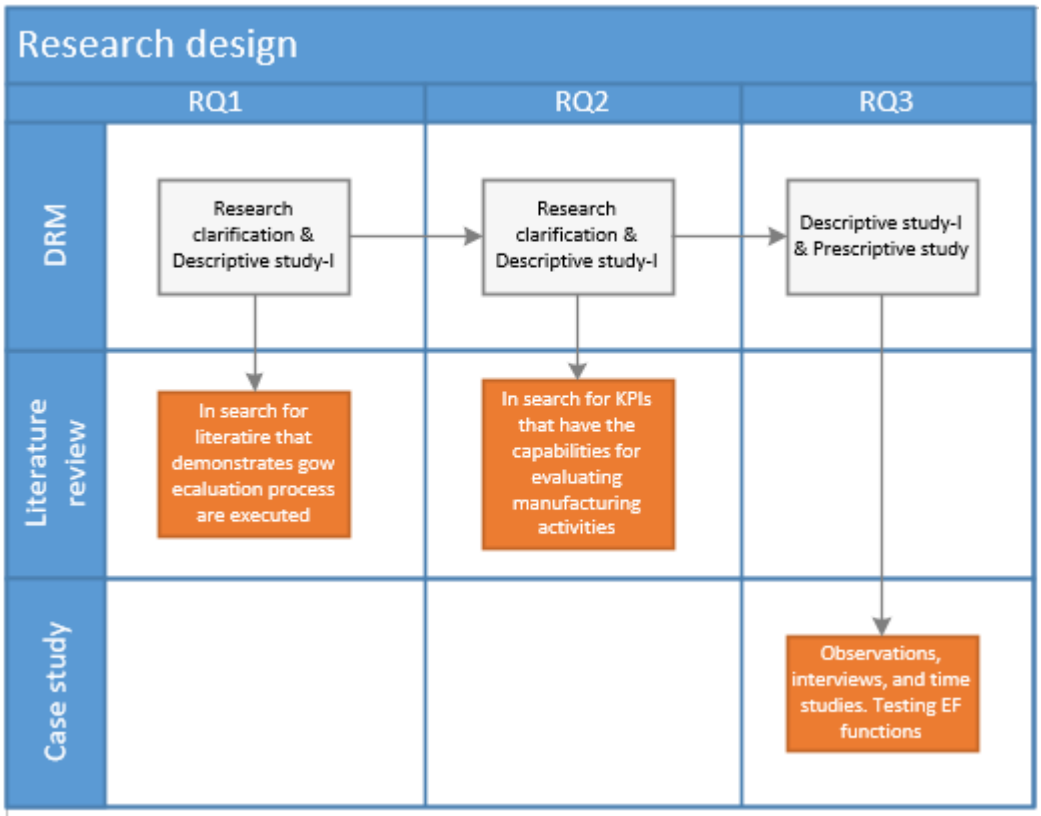

Figure 3: Illustration of research design, where orange boxes explain the activity within each stage of DRM that are to be explained in coming sub-chapter.

3.2 Design research methodology

This method acts as an umbrella, where methods such as case study and literature review have been conducted as a support for this method within its stages, which are to be explained.

Efficiency and effectiveness have been found as one of the primary reasons for developing an artefact for industrial application due to dynamic complexity that industrial challenges show characteristics of (Blessing & Chakrabarti, 2009). The following methodology has been applied to aid the developments of an EF. The definition of design in the DRM's context is referred to the activities executed to create an EF for developing production systems (Säfsten et al., 2020). The answers for the first two RQ's are combined to develop an answer for the third RQ. Followingly, DRM has been identified as a proper method since it has an underlying agenda: (1) develop understandings; and (2) develop support for activities. For the DRM to be initiated it needs theory of existing case, a vision (in this case an EF), and a vision to change to situation to the better. The DRM has four stages and will be explained further in coming sections. The following figure 4 is taken from the works of Blessing & Chakrabarti (2009), an illustration of the DRM overview.

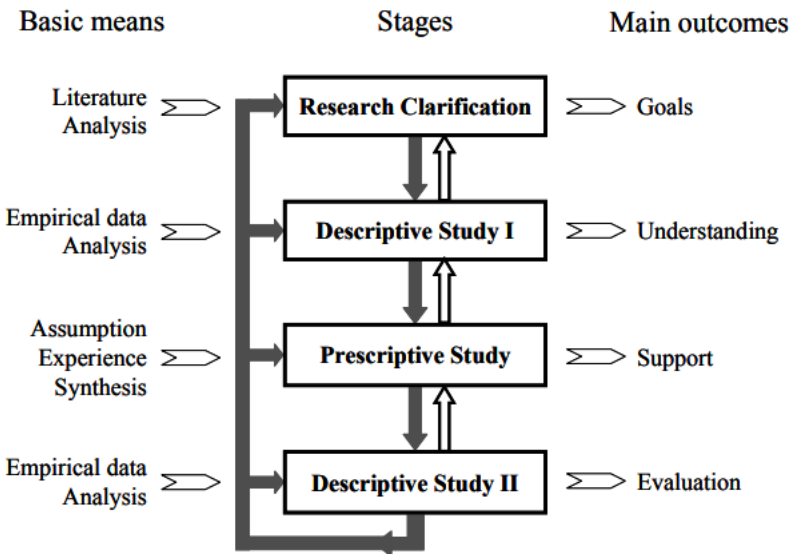

Figure 4: DRM overview (Blessing & Chakrabarti, 2009).

3.2.1 Clarifying the current situation

This stage is seen as a research clarification (RC) and starts of by first identifying topics of interest, which could also come from external interest such as institute, company, etc. Within conducted research clarification has been done in parallel with both a situation that a company experienced with academic interest. RC was used to determine whether the literature had an EF that are similar to the vision that this thesis aims to develop. Additionally, literature review, which is the main tool within this stage was used to identify answers for the RQs, as well connecting theory that supports the design of the EF. Finally, this stage emphasizes the choosing of type of study, which are based on the seven types detailed by Blessing & Chakrabarti (2009), see figure 5. Type 3 was conducted in this research, *development of support*. The arguments for why choosing the third type were because of the following:

- Existing literature is not sufficient enough to aid current circumstances of situation.
- Existing support only aids particular situations meaning that they show less applicability.
- Existing literature does not draw links between factors of both interest and success.

Research Clarification	Descriptive Study I	Prescriptive Study	Descriptive Study II
1. Review-based →	Comprehensive		
2. Review-based →	Comprehensive →	Initial	
3. Review-based →	Review-based →	Comprehensive →	Initial
4. Review-based →	Review-based →	Review-based → Initial/ Comprehensive	Comprehensive
5. Review-based →	Comprehensive →	Comprehensive →	Initial
6. Review-based →	Review-based →	Comprehensive →	Comprehensive
7. Review-based →	Comprehensive →	Comprehensive →	Comprehensive

Figure 5: The illustration showcases the different types of researchers emphasized by Blessing & Chakrabarti (2009).

3.2.2 Identifying EF functions

The purpose here is to gain a better knowledge of the current situation by identifying and clarifying, in detail, the elements (Blessing & Chakrabarti 2009). In this case KPIs and company desires for increase performance objectives within specific manufacturing activity.
Both the focus area and goal are clearly stated here, and literature review are carried out to emphasize the situation and aid functions developments. During this stage, the researchers focused on detailing similar situations for examining what was lacking in other PMS(s) within identified literature. As well considerations for making the evaluation task an easy one. Which is where case study comes in to play, since it provided inspiration to include functions that made the EF convenient. In order to identify gain inspirations from the case situation methodological instruments was used during case study, such as observations and interviews. As e.g., KPIs identified in the literature give rise to developing interview questions for acquiring variables to conduct measures. This provided ideas on how to apply functions in the develop EF as well how to design the functions. This process sees that empirical data from literature review and the data from both observations and interviews should support each other (Blessing & Chakrabarti, 2009). I.e., data such as KPIs and PMSs support each other by being connected and that connection being verified through observation and interviews.
Blessing & Chakrabarti (2009), encourages to provide a rough sketch of the concept. Based on the findings of the literature and case study, the data gathered was used to assist the researchers in developing the initial stage of the EF.

3.2.3 Constructing the EF

Blessing & Chakrabarit (2009), identify this stage as prescriptive study (PS), where conclusion from previous stage is extended to finalize the construction of the vision (EF). In this stage the researcher aims to connect findings from case study and literature review with the theoretical purpose, i.e., connecting POs with KPI's. It is in this stage that the EF starts to take its form. I.e., logic behind design such as having a variable list inspired by list of interview questions or connection between KPIs and POs (Blessing & Chakrabarti, 2009). During this stage it is advised to utilize a software to develop the EF. Excel seemed like a fitting software since it provides functions to program mathematical formulas that could be connected to boxes, which is the main design of the EF and will be presented coming chapters. Blessing & Chakrabarti (2009) argues that during the PS searches for literature should focus on findings from works with obstacle in resemblance to current. I.e., in this case to find studies where researcher aims to evaluate processes. With a goal to identify criteria's necessarily to determine if problem solving approach is successful (Blessing & Chakrabarti, 2009).

3.2.4 Testing EF functions

In descriptive study II researchers are advised to draw the impact of support, e.g., knowledge, guidelines, checklists, methods, and tools, and how well it can relate to the situation. I.e., control how well have the KPIs (that acts as support) been formalized in the study so that the EF can be applied in all situations. The first step of this stage is to identify criteria for evaluating the model's (EF) applicability and secondly, to try the EF (Blessing & Chakrabarti, 2009). The method is followed by activities such as: to evaluate if the development fulfils it is purpose in various situations; identify necessary improvements for futuristic situations; and perform research clarification once again to verify all needed supports are identified.

3.3 Literature review

In order to contribute to a certain area, existing knowledge needs to be revealed (Säfsten et al., 2020). The goal of a literature review (LR) is to give a summary, classification, comparison, and mapping of prior information. The information gathered from the LR will be applied in order to answer research questions (Boell & Cecez-Kecmanovic, 2015).
Studies have shown that SMEs sees adoption of AMT as a key condition to stay competitive but fails to identify key success factors (Koc & Bozdag, 2009). These key success factors are not allocated in literature, hence the arguments for conducting LR within this topic (Jaidka et al., 2013). The purpose of LR, in regard to RQ1 and RQ2, is to determine what research has already been done and extract fragments of findings and apply in developing EF.
Since the term KPI is very broad and defining a KPI depends on studied factor, phenomenon, or company interpretation. It is due to its unspecified interpretation of determining what is considered as a KPI that makes LR a prerequisite for this research. The same goes for PMSs, i.e., LR provides clarification on how to execute them. Since the first stage of LR was to analyze theory and extended it is applicability. Thus, initiating stage is by starting a process of deductive nature – analyze existing theory, formulates RQ(s), acquire data from literature, draw conclusion – but aims to use finding as data for inductive conclusion (Karlsson, 2016).

3.3.1 Structure of literature review

This thesis applied descriptive mapping based on the process from Booth et al (2016) by using comprehensive terms, in this case terms related to AMT, KPIs, and PMS. The reason for applying descriptive mapping is to examine previous research and identifying the gaps between theory and research. Within the works of Booth et al (2016), elucidations are brought up regarding the stages of literature search. This thesis only applied the stages that are seen as relevant for finding answers for RQ's: (1) *scoping search*, where it is advised to utilize databases that are agreed upon, in this case it is ScienceDirect and Emerald; (2) *conduct the search*, in this stage strings are established based on relevant terms and Boolean constraints, such as AND and OR are applied. Number of hits is based on strings and what databases that were used are presented in table 1. Simultaneously as this thesis applies its search string it needs to consider screening criteria in order to assess whether literature has any relevance to the research. This thesis focused on two key aspects when considering whether literature is relevant or not which is: does the literature, both demonstrate and emphasize, structured approach of presented models for evaluating studied process; secondly, are there any KPI explained for monitoring/measuring process that concerns the interest of this thesis? See figure 6 for screening processes that guided in picking relevant literature to answer the first two RQ's. The horizontal arrows indicate the next step to be conducted if the answer is **YES** based on the question presented in the boxes below the vertical arrows. If the answer, anywhere, is **NO** in the screening process then article is considered as not relevant. Before the last box, if relevant terms are found in article, then a snowballing approach is advised to be performed.

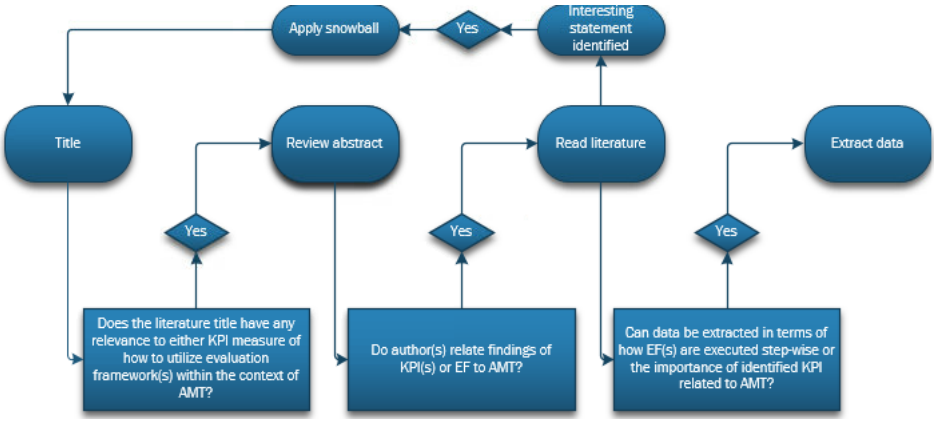

Figure 6: An illustration of the screening process, executed from left to right and starts with title.

During this process it was recognized that different terms were frequently emerging that are related to the area of study. This argued for applying snowball approach during the reading of the literature, in order to gain more knowledge regarding important terms. Snowballing is a method where researchers usually go through reference list of studied works in order to gain more knowledge e.g., factors that have weak explanation in the studied literature (Vissak, 2020), hence it was deemed relevant to carry out in this LR.

Table 1: This table presents number of hits is based on string and which database (ScienceDirect and Emerald), how many articles were considered as relevant based on screening process, and for what RQ data is tried to be retrieved based on string.

RQ	Database	Search string	Number of hits
RQ1	ScienceDirect	“Performance evaluation” AND "framework"	110
		("KPI" OR "Key performance indicator") AND "Evaluation framework	284
		"Performance measurement" AND "evaluation techniques" AND "automation"	41
		("Performance measurement system") AND ("Production performance" OR "Manufacturing performance") AND ("SME")	30
	Emerald	"Automation implementation" AND "evaluation"	36
		("Performance measurement system*" OR "evaluation framework*") AND ("AMT implementation" OR "advanced manufacturing technology implementation")	9
		"Performance measurement" AND "evaluation techniques" AND "automation"	42
		("Performance measurement system*" OR "Performance measurement framework*" OR "Performance measurement model*") AND ("AMT implementation" OR "advanced manufacturing technology implementation")	33
		"Performance measurement system" AND "Production performance" AND ("SME*")	60

RQ2	ScienceDirect	("KPI" OR "Key performance indicator") AND "Evaluation framework	284
		KPI AND "AMT" AND "implementation"	41
		“Implementation management” AND "AMT"	26
	Emerald	“Implementation management” AND "AMT"	24
		AMT AND "implementation" AND "(critical success factor)"	127
		("Performance measurement system*" OR "evaluation framework*") AND ("AMT implementation" OR "advanced manufacturing technology implementation")	9

3.4 Case study

The nature of the case study is exploratory, which suites this thesis research approach. Thus conducted a single case study. The data collection techniques that have been applied in this method are observations of the case situation, unstructured and semi-structured interviews with employees that are performing the activity of interest, as well as managers. It is during the execution of the case study that the EF is first applied. This is to try the functions of the EF and to assess if filled out variable(s) calculate the value of the KPI that the company says it performing at. The observation, and interviews were for collecting data to compare manual labour with automated activity and assess the implementations successfulness. All data collection techniques demonstrate how to acquire values for respective KPI variable, presented in the coming chapter.

3.4.1 Interviews

Interviews were conducted with the case company in order to acquire qualitative data that is the variables to measure the KPIs. According to Williamson (2002), three types of interviews exist: structured, unstructured, and semi-structured. Unstructured and semi-structured interviews were carried out in order gather data about the case company and manufacturing activity of interest.
Semi-structured interviews use a standardized list of essential questions that are more open and allow respondents to elaborate on their responses. This interview method is distinguished by an explanatory approach in which the interviewer is given the opportunity to directly ask follow-up questions (Yin, 2018). In case studies, unstructured interviews were found as a common interview type. It is distinguished by a lack of standardization and a concentration on exploratory and in-depth features of the subject (Williamson, 2002). The interviewees are free to discuss any part of the topic they like, and there are no constraints on the format of the interviews (Yin, 2018).
The first interviews were fully unstructured in the early stages of the study. Allowing the researchers to obtain a better insight and in-depth knowledge of the purpose regarding case situation. Literature studies were undertaken after the data acquired through the unstructured interviews and was analyzed in order to better comprehend and gain knowledge in the focus area. Semi structured interviews were carried out after ensuring that knowledge was being developed on the area of focus, namely the components to measure and identify that aid in the development of the EF. Standardized questions were created, see **appendix 9.3**, to ensure that all information gaps were filled out.

3.4.2 Observations

Observations were employed as a supplement to gather data to improve the validity factor. Observations have proven to be a significant element of comprehending assembly processes (Patel & Davidson, 2019). This is a frequent data collection strategy used in exploratory studies (Saunders et al., 2016). According to the study, there are two sorts of observations: structured and unstructured observations (Patel & Davidson, 2019). Observation provided quantitative data and knowledge regarding manufacturing activity that is planned to be automated. In order to acquire a better understanding of the activity, it was decided to conduct observations with both employees and supervisors. Observations were also utilized to check whether the identified KPIs from literature study suited the SMEs in order to compare the performance as well.

3.4.3 Case company and context

The company of interest is a furniture manufacturer in Sweden, where the end station of its manufacturing activities is to pack their products. The case situation is that the company wishes to automate their packaging station and to increase the effectiveness of order filling activities by implementing AMT solution. Manufacturers today sees the need to implement activities and equipment that improves their manufacturing operations, which is a part of the performance objective concern. Swedish furniture industry is not excluded from factors that stresses the reasons for implementing technological solutions that aids manufacturing (Hagström et al., 2006). The company of interest is a SME bed manufacturing company with 45 employees. The primary objective for implementing AMT is to gain more resource time by emancipate resource from manual activity and increasing manufacturing performance. Implementations like these provides an experience of high risk of exposure to investments. Meaning that implementation needs to be evaluated to make sure that it is in accordance with company performance objective.

3.5 Reliability & validity

According to Williamson (2002), considerations must be made when doing a qualitative study to ensure validity and reliability. The reliability considers how well can the research be produced again and imitated, i.e., increase the level of transparency, and consistency. In order to monitor KPIs the first step is to define what is considered as relevant KPI and to measure the phenomenon. The monitoring of KPIs is executed by firstly apply relevant variables that have been identified. While validity concern itself with the appropriateness of conducted measures, accuracy of result analysis, and applicability of findings (Saunders et al., 2016). The purpose of using interviews and observations for triangulation was to validate how the case company uses the developing EF. Both production engineers and employees are interviewed to obtain insights from various stakeholders in the manufacturing process.

3.5.1 Reliability

Researchers tried to improve the EF's applicability by testing the functions of the EF within the case company to increase the reliability. In order to achieve it, precautions were taken when recording the interviews to avoid any possible reliability issues. Observations were also utilized to collect quantitative data in order to understand what was going on in the various production processes. The interview structure and findings from

the case company will be presented in order to demonstrate the thesis' reliability. Measurements were carried out using calibrated equipment, such as a timer for measuring the time it takes to conduct a task manually; this improves the reliability of the study.

3.5.2 Internal validity

Internal validity is defined as the research measures what is meant to be measured (Saunders et al., 2016). Several methods and procedures were taken to strengthen the internal validity of this study. Numerous sources of evidence were utilized; thus, the internal validity of the study was increased (Johnson et al., 1987). Which were conducting interviews and observation as a part of the data collection process to improve internal validity and were employed in method triangulation. This is in line with Johnson et al., (1987) assertion that combining various sources of evidence improves internal reliability. Throughout the research, LRs were conducted, allowing the researchers to compare the findings from the case studies to current theory and determine where they should be based, thus improving the internal validity.

3.5.3 External Validity

External validity, according to Yin (2009), is the extent to which study findings can be generalized or research can be generalized. However, Yin (2009) also criticized case studies for not being able to generalize their findings. Case study designs that are adequately detailed, on the other hand, allow readers to draw conclusions about the findings' external generalization, according to Johnson et al., (1987). As a result, the case company and context has clearly been described in chapter 3.3.2, likewise has the data collection method, data analysis, and study process has been clearly outlined. This is in terms of clearly outlining the data collection method, data analysis, and the entire study process.

4 Theoretical findings

The following chapter aims to present the findings from literature review where the focus will be to establish summary tables of findings for effective presentation.

4.1 Findings for RQ1

Performance measurement systems that are, according to literature, applicable in manufacturing environment will be presented in this sub-chapter. This thesis has followed an inclusion criterion where the models have to be applicable in manufacturing environment, evaluate performance of manufacturing activities, and are applicable to SMEs. The following sub-sections will present findings that are considered as an answer for the first research question.

4.1.1 Analytic hierarchy process (AHP)

The analytic hierarchy process (AHP), established by Saaty & Zoffer (2012), is one of the most used methods for converting qualitative data into ranked information or pairwise comparison data. The hierarchy process is used in this strategy to make difficult problems much more understandable (De Felice et al., 2015).
The AHP model allows for the detection of interactions between a variety of high-level decision elements, some of which are difficult to quantify. AHP balances the interactions among decision criteria and synthesizes the information into a vector of preferences among the alternatives as a multi-criteria decision-making approach (MCDM). AHP has been applied in a variety of situations where hard-to-quantify decision elements are present, e.g., risk assessment. The selection criteria for AHP are appropriateness, convenience of use, and validity. AHP also meets the following criteria: (1) structuring the decision-making process, (2) expressing and modeling preferences, (3) aggregating alternative assessments (preferences), and (4) making recommendations (Barker & Zabinsky, 2011).
The AHP divides a decision-making problem into multiple levels, which form a hierarchy with unidirectional hierarchical linkages between them. Hierarchies or feedback networks can be built using the AHP, and then evaluations of performance measurements can be conducted on pairs of elements in relation to a controlling element to create ratio scales, which are then synthesized across the structure to select the optimal option. The major goal of the problem identified during the process is to reach the highest level of the hierarchy. The physical and/or intangible criteria and sub-criteria that contribute to the aim are found at the lower level's hierarchy. In order to reach highest level of hierarchy the bottom level activities needs to be assessed (De Felice et al., 2015).

4.1.2 Analytic network process (ANP)

The Analytic Network Process (ANP) is a MCDM-making process used in the social, economic, and management domains. The ANP represents the problem as a network, with nodes divided into clusters and directed arcs corresponding to node interactions. The method's goal is to rank all of the nodes in a cluster in order of importance. In most cases, one cluster corresponds to the options for a decision problem, and the procedure gives priorities (importance) to these alternatives in order to aid decision-making. The problem is modeled as a hierarchy in ANP, which is an extension of the AHP. Clusters are hierarchical levels in AHP, linkages are one-directional, and there are no cycles or feedbacks, see figure 7 (Quezada et al, 2021).

There is a network of influences among the elements and clusters in the ANP. With respect to an underlying control criterion, the ANP permit interaction and feedback both within and across clusters of elements (inner dependence) and between clusters (outer dependence). Within and between clusters of items, inner-, and outer dependencies can capture and reflect the concepts of influencing or being impacted relationships. Then, in a methodical manner, pairwise comparisons are done, considering all possible combinations of element/cluster correlations. Each cluster's elements are compared pairwise in terms of their relative relevance in relation to their control criterion (Percin, 2008).

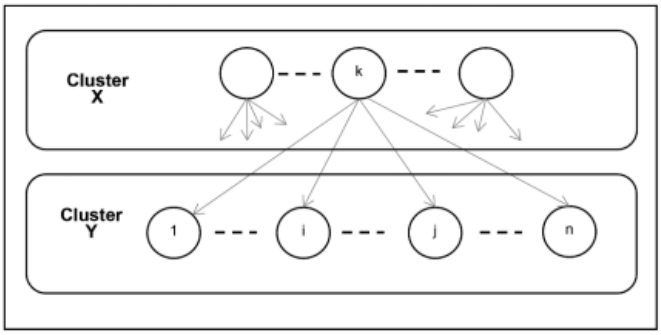

Figure 7: Representation of clusters and nodes in ANP model (Quezada et al, 2021).

4.1.3 Balanced scorecard (BSC)

Kaplan & Norton (1997) proposed the balanced scorecard (BSC) as a strategic management tool that can be used to: (1) clarify and translate vision and strategy; (2) communicate and link performance objectives and measures; (3) plan, set targets, and align strategic initiatives; and (4) improve strategic feedback and learning. It is designed to be a tool for regularly describing an organization's overall performance across a variety of metrics. The tool is focused on businesses or organizational units such as strategic business and not on business processes, which is an important feature of BSC (Kueng, 2000).

The BSC is a conceptual framework for turning a company's vision into a set of PIs that are divided into four categories: financial, customer, internal business processes, and learning and growth, and is evaluated based on those categories, see figure 8. Other indicators are kept for tracking organization's progress toward it is vision, while others are kept for tracking the long-term determinants of success. An organization's ability to learn and improve is measured by the BSC's perspectives. That tracks both present performance (finances, customer satisfaction, business process results, and learning and growth) and initiatives to improve processes (Lee, 2010).

Each of the aforementioned perspective should have their own goals and measures. According to the developer, Kaplan & Norton (1992), the model should contain 15-20 indicators dispersed among the four perspectives (Quagini & Tonchia, 2010). The origin of the BSC lies, both with the desire to become more competitive and the idea of being able to convert organizational assets to value adding activities. Which was traditionally an accounting practice from a financial perspective but has in recent developments been integrated with additional perspectives (Kaplan & Norton, 199). The concept uses a systematic approach to evaluate internal results while also examining the external environment. The Balanced Scorecard allows managers to assess their organization's health from each of the four perspectives outlined Customer satisfaction drives

financial success, effective and efficient business processes ensure high levels of customer satisfaction, and persistent, continuous improvement improves the organization's operational performance, according to this framework (Franceschini et al, 2007).

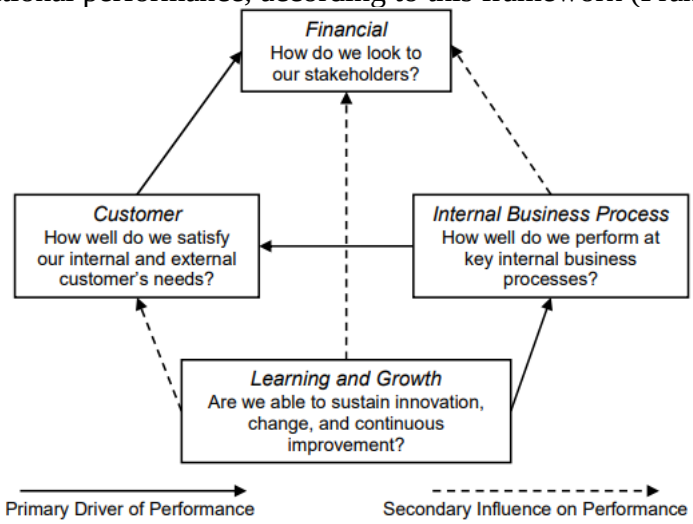

Figure 8: The four perspectives of the Balanced Scorecard model (Kaplan and Norton 1992).

4.1.4 Best-worst method (BWM)

The Best-worst-method (BWM) is used for evaluating the performance of manufacturing processes. The performance measurement system of interest aims to evaluate manufacturing performance in overall. Where it provides the possibility to monitor, control, and take instant actions to improve manufacturing (Khan et al., 2021). The BWM also provides utilizers a weighing function, where a decision could be made based on main- and sub-criteria. The main criteria can be e.g., different capabilities such as technical capabilities while the sub-criteria involve e.g., industrial knowledge (Rezaei et al., 2015). The goal is to ease manufacturers from the difficulty to choose the right decisions to establish a competitive manufacturing strategy with having the potential of analyzing performance as well (Khan et al, 2021). BWM method is used to solve MCDM problems and is executed according to figure 9. The MCDM handles problems where decision makers are exposed to several options where each option needs to be evaluated in order to choose the most effective approach that suit is the target of a project. The BWM can be seen as an approach to rank the different alternatives from worst to best based on criterions (Rezaei, 2015). BWM is a five-stage process and is as following:

1. *Define RQ*, decide the decision criterions (both main- and sub criteria's).
2. *Instrument development*, decide which criteria are the best respectively the worst, where the best is the most desirable aspect while the worst the least desirable.
3. *Data gathering*, conduct pairwise comparison between the criterions and apply a scale from 1 to 9 where 9 is the most important value compared to the criteria.
4. *Analyse data*, compare all the valued criteria.
5. *Disseminate*, calculate the important weights, establish the most optimal solution for respective problem (Rezaei et al., 2015).

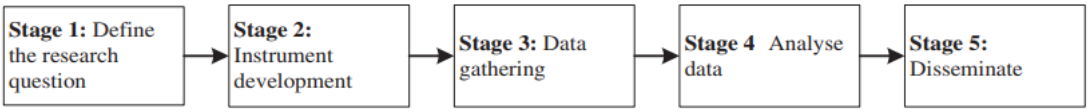

Figure 9: The following illustrates the straight approach for the BWM when going through each stage (Rezaei et al., 2015).

4.1.5 Benchmarking tool to improve production performance (BETTI)

Sustainable growth is highly linked to performance measures, where in places great importance to compare the performance against competition. For SMEs, it is an essential aspect in developing a strategy that almost dictates competitor market position (Singh et al., 2008). The Benchmark tool to improve production performance (BETTI) is a development foundation to assist SMEs in becoming more compatible in the market. The overall function of the BETTI model is to apply PIs in order to first assist the organization in production strategical approaches. Facts and coherences are summarized and then expressed in a form weight factors where they act as evaluation enablers. The method has been developed for SMEs that produce smaller number of batches compare to larger companies. During the developments of BETTI industrial sectors concerned mechanical-, electrical-, and machine building industries. Where e.g., the furniture industry is within the scope. When it comes to the terms benchmarking, manufacturers in general follows the five following phases: (1) what to benchmark needs to be determined (2) establish benchmarking team, (3) identify benchmarking partner, (4) collect and analyze information for benchmarking, and (5) execute benchmarking. Benchmarking has four different types: (1) *internal*, comparing unit is or departments within company, (2) *competitive*, comparing with product competitor(s), (3) *functional*, compare functions with what is considered as best practice within the organization, and (4) *generic benchmarking*, where searches are made for the best practices. The BETTI method focus mostly on generic- and functional benchmarking to evaluate best performances that makes a SME a better competitor (Denkena et al., 2006).

4.1.6 Data Envelopment Analysis (DEA)

Data envelopment analysis (DEA) is described as a powerful tool that is better suited for performance measuring activities than standard econometric methods like regression analysis and simple ratio analysis. DEA is a mathematical approach for converting inputs to outputs using linear programming techniques, with the goal of comparing the performance of similar organizations or goods. Each DMU (decision making unit is) in DEA has the freedom to choose any combination of inputs and outputs to maximize it is relative efficiency. To calculate relative efficiency, DEA use linear programming. This relative efficiency is a non-negative number determined using linear relationships between the DMUs inputs and outputs. In other words, it compares similar DMUs to see how efficient they are at creating a specific level of output based on the quantity of input they utilize (Mardani et al., 2017).

The basic concept behind DEA was to develop a system for identifying best practices among a group of comparable DMUs and forming an efficient frontier. Furthermore, the methodology allows for the measurement of non-frontier unit efficiency as well as the identification of benchmarks against which such inefficient unit is can be compared (Cook & Seiford, 2009).

DEA is a relatively new data-oriented method for evaluating the activity of various peer objects known as DMUs, which convert multiple inputs into multiple yields (Gregoriou et al., 2015). DMUs of various types were used in these DEA applications to evaluate

the activity of objects such as hospitals, colleges, energy matters, metropolises, commercial companies, and related portions counting the activity of nations, areas, and so on. Due to the complex nature of the relationships between the numerous inputs and multiple outputs over the DMUs, DEA might be applied in circumstances that were challenging to related methods (Mardani et al.,2017).

4.1.7 Integrated dynamic performance measurement system

The integrated dynamic performance measurement system (IDPMS) is built on merging three key functional areas: management, process improvement teams, and the factory shop floor (see fig 10). The performance measurement questionnaire, the half-life concept, and a modified value-focused cycle time (MVFCT) diagram are three instruments that enable the functional areas measure and enhance performance in an integrated manner (Ghalayini et al., 1997).
Within the IDPMS, there are three links between the three functional areas. Management uses the *management-factory shop floor linkage* to establish the areas of success and appropriate performance measurements for the factory shop floor. As a result of corporate strategic planning and the results of the performance measurement questionnaire, these categories and measurements have been determined.
Management uses the *management-process improvement team linkage* to define the areas of success and the performance measurements that go with them. This serves as a framework for the process improvement team's efforts as well as a foundation for management reporting. The *process-improvement-team-factory-shopfloor linkage* enables dynamic performance standards consideration. The process improvement teams create acceptable performance standards for each process and planning horizon and eventually pass them on to the shop floor operators/supervisors. Improvements in performance measures come as a result of process improvement efforts (Ghalayini et al., 1997).
The IDPMS enables for dynamic updating of it is main areas of success, as well as the PMs and standards that go with them. Finally, the IDPMS introduces and shows the concept of leveraging the benefit is of process innovations, as well as facilitating the process of justifying operational performance measures (Ghalayini et al., 1997).

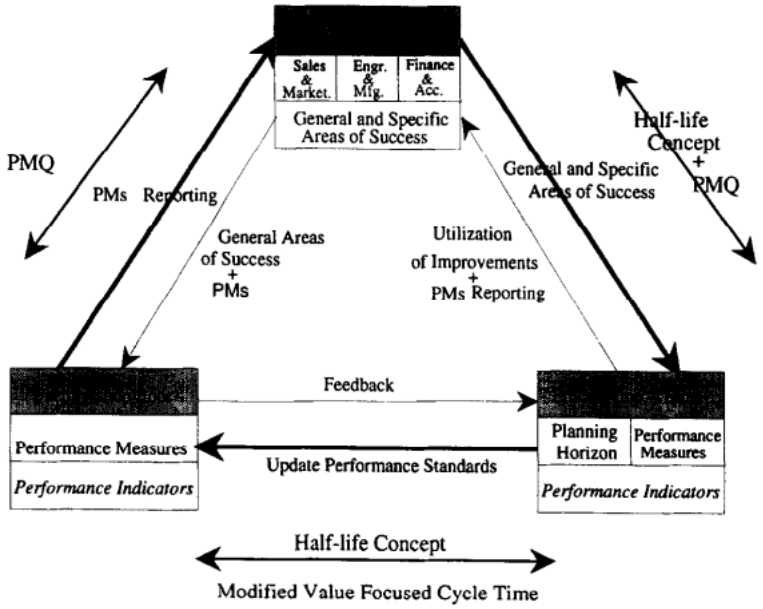

Figure 10: Integrated Dynamic Performance Measurement System (Ghalayini et al., 1997).

4.1.8 Holistic process performance measurement system

Assessing process performance is critical because it allows individuals and organizations to see how they line up against their competitors. Furthermore, evaluating process performance allows for the early detection of problems and the implementation of corrective actions before they become more serious. A process performance measurement system (PPMS) can be defined as an information system that collects performance-relevant data of one or more manufacturing processes using a set of indicators. Then compares current data to previous and desired values, disseminates the findings (current value, target value, gap, and trend for each specified variable, and indication) to the process actors, see figure 11, (Kueng, 2000).
In order to communicate to employees, the overall direction in which a company wishes to move, top management has to write out its vision and mission statements and post them in prominent places. PPMS may be of great assistance in articulating business process goals and objectives. As the relationships between various goals and indicators become increasingly obvious, such knowledge can improve inter-process and intra-process collaboration and learning. A PMS should not only serve as a warning system for performance issues, but also communicate the causes of the issues. Though this conclusion appears to be correct, putting it into practice would be difficult (Kueng, 2000).

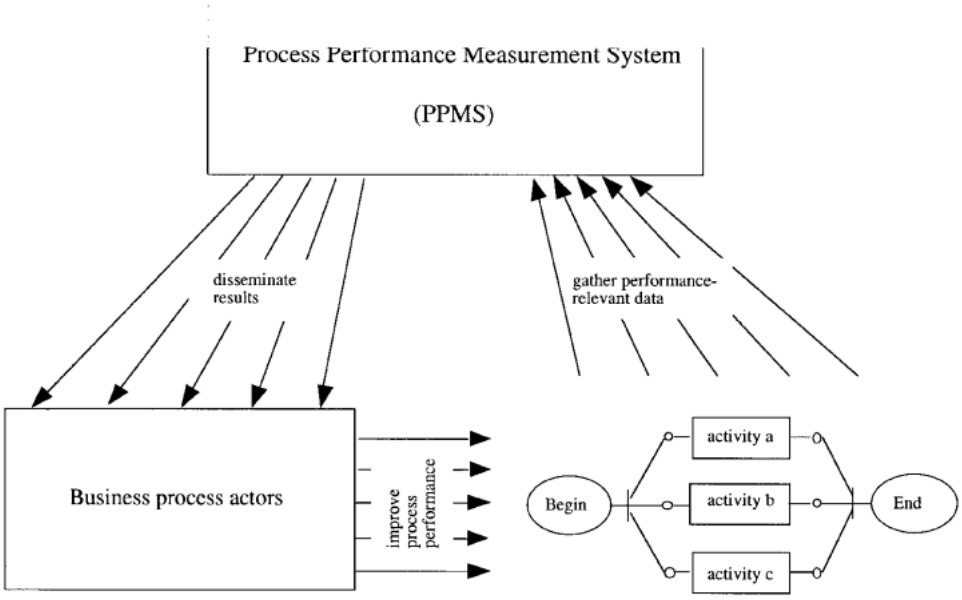

Figure 11: A PPMS from a conceptual point of view (Kueng, 2000).

4.1.9 Performance measurement and management system for SMEs

This PMS includes managerial aspects and has been developed for SME(s). The performance measurement and management system (PMMS) were developed as a response to existing EFs that are found in the literature and shows less adaptability to SME(s). This is because that the majority of the EFs that exists demand great human research and senior management involvement, among few factors, that SME(s) usually cannot afford. Instead, researchers sees that a PMS that consider SME(s) situation better with both managerial and human resources involvement, hence PMMS. Researchers sees that a PMS should have the following considerations:

- Base decisions on information that are currently available within the company
- The measurement should not be expensive to execute

- Able to evaluate past performance and guide managers to take strategical choice for being a better competitor.

The focus of the PMMS is to exploit the richness and try to extend the information that are available in the SME and creatively develop strategic approaches for both evaluation and monitoring processes. The aim of PMMS is divided into two sections, *performance measurement systems* and *performance management systems*. The *performance measurement system* focuses on effectiveness and efficiency of past results from executed actions. While the *performance management system* evaluates and identify current- and anticipated performance, establish critical factors that needs to be considered. It also revises the company's current strategies so that they are in accord with what the PMMS tries to achieve. The *performance measurement system* includes financial practices, which could be considered as business practices (BP) while the *performance management systems* consider non-financial information in order to study drivers and indicators that affect company performance (Bahir et al., 2017). In shortness the PMMS overlooks to aspects of BP's which is the balanced sheet and the income statements and how they are related to overall company departments and functions, see figure 12 below.

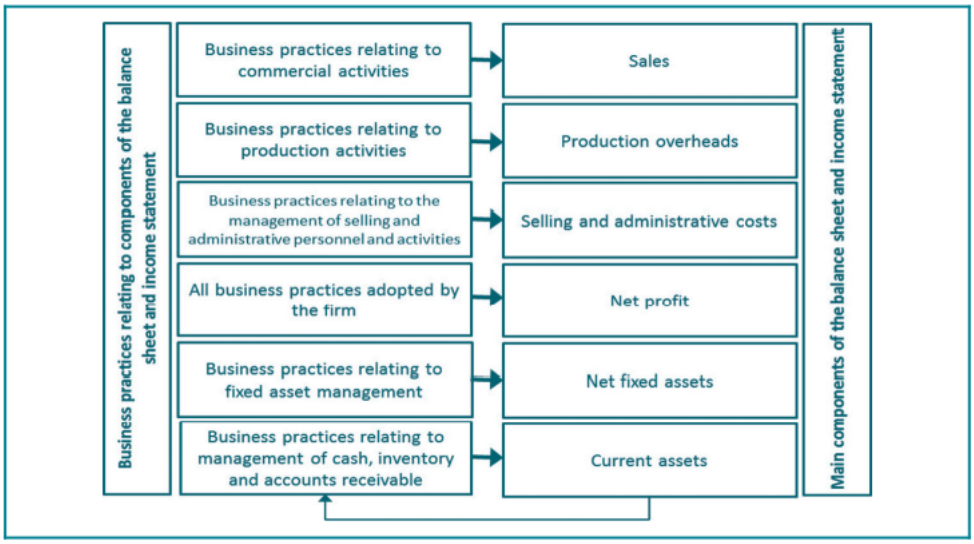

Figure 12: Demonstrates how different BPs are related to different department, functions, and business statements within a company (Bahir et al., 2017).

4.1.10 Compilation of performance measurement systems

The table 2 below complies the findings that are related to the first RQ where it shed light on the different model's characteristics and in what situations they are deemed to be most applicable.

Table 2: Compilations of findings for the first RQ based on literature review.

Method	Reference	Characteristics	Situation Applicability
AHP	(Saaty, & Zoffer,2012), (De Felice et al, 2015), (Barker & Zabinsky, 2011).	(1) structuring the decision-making process. (2) expressing and modeling preferences. (3) aggregating alternative assessments (preferences). (4) making recommendations.	- Applied in situations where hard-to-quantify decision elements are present. - Risk assessment, watershed management etc.

ANP	(Quezada et al, 2021), (Percin, 2008).	(1) Solves MCDM problems (2) Social, economic and management domains (3) Presented in clusters and nodes (4) Ranking nodes in terms of importance.	-Extension of AHP model. -Applied to a large variety of decisions such as marketing, medical, political, military, social, and forecasting and prediction.
BSC	(Kaplan & Norton, 1997), (Kueng, 2000), (Lee, 2010).	(1) Clarify and translate vision and strategy. (2) Communicate and link performance objectives and measures. (3) Plan, set targets, and align strategic initiatives. (4) Improve strategic feedback and learning	- Strategic management tool - Focused on businesses or organizational unit is such as strategic business unit is, not on business processes.
BWM	(Khan et al., 2021), (Rezaei et al., 2015).	(1) Main-, & sub-criteria (2) Provide alternatives to take strategic decision (3) Analyse performance (4) Solves MCDM problems (5) Ranks decisions from worst to best	-Evaluating performance of manufacturing processes. -Supplier assessment and feedback. -Transfer knowledge.
BETTI	(Denkena et al., 2006).	(1) Internal benchmarking capabilities (2) Provide strategical approaches. (3) Weight factors. (4) Focus on generic and functional benchmarking.	- Developed for SMEs - To benchmark internal activities. - Mechanical, industrial and machine building industries.
DEA	(Mardani et al., 2017), (Cook & Seiford, 2009), (Gregoriou, 2015).	(1) Suited for performance measuring activities. (2) DEA is a mathematical approach. (3) Comparing the performance of similar organizations or goods.	- Developed for identifying best practices among a group. - Used to calculate relative efficiency. - Used in evaluating the activity of objects such as hospitals, colleges, energy matters etc.
IDPMS	(Ghalayini et al, 1997).	(1) Built on merging three key functional areas. (2) Management, process improvement teams, and the factory shop floor. (3) Use an overall system analysis tool.	- Areas of success are determined based on the organization's strategy. - Helps to improve the performance of individual department as well as for the whole manufacturing system.
PPMS	(Kueng, 2000).	(1) Allows for the early detection of problems. (2) The implementation of corrective actions. (3) Collects performance-relevant data. (4) Communicate the causes of the issues.	- Great assistance in articulating business process goals and objectives. - Inter-process and intra-process collaboration and learning.

PMMS	(Bahir et al., 2017)	(1) Helps in evaluating past performance. (2) Handles MCDM problems (3) Monitoring function.	-Developed for SMEs - To integrate managerial and human resource involvement. - To integrate department functions.

4.2 Findings for RQ2

The findings for the second research question of this thesis are presented in a table 3 where data has been extracted from literature review emphasized in chapter 3.3. The findings of the LR were utilized to establish the most important KPIs to examine in order to ensure that SMEs can effectively assess the success of a newly adopted automated solution. In addition, the table focuses on how each of KPIs are calculated using various methods. The brief explanation aims to provide help for the reader to understand what the author intended by each KPI in this context.

Table 3: The table represents a summary of findings that answers RQ2, all the equations are inspired by Krause & Aurora (2019).

KPI	No.,	Source	Method of Measure	Description
Machine setup time	**1**	Koc & Bozdag (2009)	Time studies, evaluate human resource time needed for setup	The time to setup the machine before and in between each product change
Quality inspection time	**2**	Koc & Bozdag (2009)	Questions/time studies	Inspect activity output based on criteria and human resource time
Material handling	**3**	Koc & Bozdag (2009)	Time studies	The time it takes to handle the output of activity
Payback time	**4**	Small (2006)	$\frac{Acquistion\ cost}{cash\ inflow\ /\ period}$	Ratio is presented in time, and it provides a measure for when company can expect the

				invest-ment to be payoff
Return on invest-ment (ROI)	**5**	Small (2006)	$\frac{(Net\ income + intreset\ expense) \times 100}{average\ total\ capital}$	Measures effective-ness of return of invest-ment and provides a meas-ure on how com-pany uti-lizes in-vestment
Net pre-sent value (NPV)	**6**	Small (2006)	$A_0 = \sum_{t=1}^{w} (e_t - a_t) \times (1+i)^{-t}$ A_0 = Net Present Value t = Time Period w = Total number of periods under consider-ation et = Receipts in period t at = Pay-ments in period t i = Interest Rate	This KPI expresses the mone-tary value-added ac-tivity in terms of currency generated by the in-vestment
Produc-tion cost	**7**	Boyer & Lewis (2002)	Summary of costs	Calculate the cost of assets & utilities to run produc-tion facil-ity (daily cost of running the pro-duction)
Labour produc-tivity	**8**	Boyer & Lewis (2002)	$\frac{Output\ quantity}{Number\ of\ employess}$	Calculate the total number of labours compared with out-put rate
Internal delivery	**9**	Diaz et al., (2005)	$\frac{\text{received goods}}{Planned\ \text{delivered}\ goods}$	Needed deliveries to and from ac-tivity
Lead time	**10**	Lewis & Boyer, (2002)	Times studies	The time between the begin-ning of a process and the

				appear-ance of it is results.
Inventory turnover ratio	**11**	Diaz et al., (2005)	$\frac{Cost\ of\ goods\ sold}{average\ value\ of\ inventory}$	Measure the inven-tory man-agement, where the equation (eq.,) con-siders profitabil-ity
Work in progress (WIP)	**12**	Sohal (1994)	$Throughput\ rate \times TPT$	Number of unfin-ished products within the system
Through-put time (TPT)	**13**	Sohal (1994)	Process occupancy time + transition time + idle time	Elapsed time to produce one prod-uct
Produc-tivity	**14**	Singh & Gurtu (2021)	$\frac{output}{input}$	Output and input factors are de-fined based on the type of com-pany.
Unit la-bour cost	**15**	Singh & Gurtu (2021)	$\frac{average\ goss\ wage}{totalt\ unit(s)}$	This KPI measure the aver-age sal-ary of pro-duction co-worker and di-vides it over measured period
Profitabil-ity	**16**	Singh & Gurtu (2021)	$\frac{Profit}{Captial}$	Surplus divided over capi-tal cost's
Inventory cost	**17**	Udo & Ehie (1996)	Unit summary	Summa-rize all the cost of unit is in FGI and present in monetary
Floor space uti-lization	**18**	Udo & Ehie (1996)	Area measures	Measure how much space is needed

				for investment compared to without investment to perform activity
Activity availability	**19**	Small & Yasin (1997)	$\frac{Production\ time}{Total\ operation\ time}$	Measures the activity availability
Capacity utilization	**20**	Sambasivarao, & Deshmukh (1995)	$\frac{output\ quantity}{planned\ output\ quantity}$	Measures how much of available capacity is utilized

5 Framework development

This chapter aims to present how the DRM stages have been utilized to develop the EF. Included in this chapter is the connection between the RQ's, reasons for the designs, and how the EF works.

5.1 Theoretical support for design

In order to develop an EF, the theoretical pillars that it stands on needed to be clear, hence a research clarification of PMS's, POs and KPIs. Because the developed EF is a PMS where criteria based on strategic goal can be set in order to compare current- respective desired future state of a manufacturing activity. Current and future state refers to general situations where manufacturers seek to assess whether an AMT implementation of machinery is advantageous by excluding manual labour. Brainstorming session(s) were done in this stage to allocate thoughts and ideas in order to develop the EF. The illustration of the brainstorming session is presented in **appendix 9.1.** The illustration presents four important topics to consider in order to develop the framework which are as following: why to adopt AMT, performance evaluation, limit the EF, and case study to increase validity of the EF. This made it clear on which theoretical fields needs to be clarified in order to aid the RQ answering process. After brainstorming session and important terms have been identified, LR was conducted with a focus to extract valuable characteristics of PMSs, descriptions of POs, and measuring methods for KPIs. Next activity was to identify arguments on how respective KPI are connected to the POs and review which PMS showed most characteristics with the intended developed EF. In the coming sub-sections connections are drawn between POs and KPIs as well advantages and disadvantages of PMSs presented in previous chapter.

5.1.1 Analysis of performance measurement system

In this section it elaborates on how the researchers have analyzed the data that is being considered as the finding for first RQ. Among the various PMSs that exists in the literature, 9 evaluations methods were identified as the best suit for this case. During the identification of those PMSs, following factors were considered: if it is suitable for an automated solution; how can it help in comparing with company's performance objectives; and is it applicable to SME? Analysis on each PMS that has been identified will be explained below. Where it will be stating about its advantages and disadvantages in choosing as an inspiration for the development of the EF.

- ***AHP and ANP method*** - The reason behind why both the methods are analyzed together was because ANP model is considered as an extension to the AHP model (see sub section 4.1.2). One main advantage that both methods had and was advantageous for the thesis was it is property of MCDM (Quezada et al, 2021) and could also be used for SMEs. At the same time the negative side of this methods was, when comparing it with the areas of focus of this study. Here it focused on manufacturing-based activity but these methods focus was on to evaluating social and economic aspects (De Felice et al., 2015).
- ***Balanced scorecard (BSC)-*** Balanced scorecard method served as one of the most important methods in getting inspiration for the developing of the EF. BSC is a widely used PMS system where it helps in turning a company's vision into a set of performance indicators (Lee, 2010). Another advantageous factor was that this method helped aligning the strategic initiatives, in this case the POs based on company goals and to improve the strategic feedback and learning

(Kueng, 2000). One disadvantage found for this method when comparing to what this study intended to do was regarding the framework design. BSC focused on organizational issues in general instead of assessing automated solutions in particular (see sub section 4.1.3).

- ***Best-worst method (BWM)-*** The BWM method was an important PMS identified for this thesis. The main advantage of BWM method is to evaluate the performance of manufacturing processes (Khan et al., 2021) and an approach to rank the different alternatives from worst to best based on criterions (Rezaei, 2015). Focusing on evaluating the performance of manufacturing activity, the weighing function (i.e., the comparison of the current and future state in developed framework) is clearly an inspiration from this method. Which helps in ranking the KPIs from best to worst based on the values obtained and see whether the intended automated solutions suit the company. Disadvantage found for this model was that it evaluates manufacturing performance in overall instead of activity based.
- ***Benchmarking method (BETTI)***- The Benchmark tool to improve production performance (BETTI) is a development foundation that would help assist a SMEs in becoming more competitive in the market (Denkena et al., 2006). This was one sole reason in considering this method as an important one to consider for the study. The disadvantage being considered for this method was that benchmarking of a similar automated implementation with other company or industry would require more time.
- ***Data envelopment analysis (DEA)***- This method was also found for measuring the performance of activities. This model was considered to be relevant as a part of first RQ was due to it is evaluating property on the manufacturing activities (Gregoriou, 2015). And was found to be used for SMEs and accessing the new activities. Since the developing EF tried to ease the work of the user, where there is not so much of mathematical expressions and usage of software is involved. One factor that was considered as negative for this method was the mathematical approach it used for converting inputs to outputs using linear programming techniques.
- ***Integrated dynamic performance measurement system (IDPMS)***- This method was considered important because the IDPMS method was found used across both SMEs and large industries in performance measurement. And it helps in focusing onto the processes for letting know the organization if integration is required on to that field based on the company POs. The negative part of this method in not providing an inspiration was that this method have not highlighted on how to evaluate an automated implementation. Also, for this method the performance measurement involves merging of three key functional areas, which was found hard in this case (see subsection 4.1.7).
- ***Holistic process performance measurement system (PPMS)***- In the urge of developing an EF mainly for assessing the performance of an AMT implementation, this method helps in providing an idea for the framework design. The comparison between the current and future desired state present in the framework design was an inspiration obtained from the PPMS method. But the reason behind not considering this method as an optimal was because, as the theory explains (see sub section 4.1.8) this method was hard to put into practice (Kueng, 2000).
- ***Performance measurement and management system (PMMS)***- The PMMS method focuses on both the measurement and management side of an organization. One of the benefits in considering this method as important was, the applicability in SMEs and its ability to measure the past performance (Bahri et al.,

2017). As transformation to AMT includes assessing the past performance during the manual production time, PMMS helped in providing understanding regarding how to analyze those. But the reason found for improving the existing performance measurement system was due to its too much focus on the cash flow and profitability factor. This EF was planned to be developed based on the POs in which monetary factors were just only one among them and also focused more on towards the activity-based performance evaluation.

5.1.2 Connection between POs and KPIs

This sub-section clarifies the arguments for each respective KPI and how each are connected to the presented PO's. Additionally, table 4 showcase each KPIs connection to respective PO's. which is presented at the bottom of this section.

- ***Machine setup time:*** since this EF is developed for activity-based purposes where evaluation of manufacturing activity performance is done, the machine setup time is a common measure in manufacturing companies and is seen a strategic KPI to measure within the SME community. The reason for this is an important measure is because it affects machine efficiency which is important if considering automated migration as a solution, Sahoo & Yadav (2018). The KPI is mainly measured by conducing time studies, which is cleared in the findings table, see sub-section 4.2. This KPI affects two POs, namely *dependability* and *flexibility*, mostly because they are seen as connected within the context of ***machine setup time***. Because a productions flexibility can increase by having machines that are more dependable. Having machines with lower ***machine setup time*** decreases operation time (Kim et al., 2013)
- ***Quality inspection time:*** this KPI, according to (Koz & Bozdag, 2009), considers product inspection and is an important factor to measure. Since it affects the consumer trust and should be included when measuring manufacturing performance factors (Mustaniroh et al., 2021). This thesis looks into the five POs as companies, overall, tend to compete in and *quality* is one of them.
- ***Payback time:*** automated migration from manual labor usually demands investments which is a sensitive topic of SMEs due to limited space for investment failures and is also considered as barrier for AMT implementation (Stornelli et al., 2021). For that reason, the ***payback time*** is a sensitive KPI for SME in order to approximate when the AMT solution starts to contribute to net profit. The KPI also provide strategic foresight and helps justifying the investment based on how exposed a company can be to an investment (Small, 2006). This KPI is connected to *cost* because it has been proven that business that needs investments for enhance production needs to consider the fact that cost can increase and then manufacturers need to know for how long (Górska & Daron, 2021).
- ***Material handling:*** According to Koz & Bozdag (2009), material handling before and after an activity has been executed is highly relative and could change, e.g., operation time, depending on the AMT solution. It is also argued that implementation of a means that has a goal to ease manufacturing activities can affect the material handling time, thus making it an important KPI to measure (Pattanaik & Sharma, 2008). ***Material handling*** is connected to speed since the KPI affect the efficiency of movement, thus *speed* (Greasley, 2008). *Dependability* is considered because they way material is handled affects the dependability of the supplement system which is a competitive factor (Koufteros et al., 1998).

- ***Return on investment:*** In today's market, managers are almost forced to take intuitively decisions to adopt AMT practices in order to become a better competitor on the market. But at the same time needs to have reluctant sense for protecting themselves from doing impulsive investments. The problem when having a to strong reluctant sense, manufacturers miss out on the chance of seeing the promising ***return on investment*** based on the strategic and technological advantages, thus, to need of respective KPI (MacDougall & Pike, 2004). ROI is one KPI that justifies equipment investments, thus becomes a concern of *cost* (Chan et al., 2001).
- ***Net present value:*** this KPI provides the difference between present value of future cash inflow, making sure that the investment is sustainable in the future based on what in generates now (Krause & Aurora, 2019). The same goes for this KPI as for ROI, meaning that it aids in the justification of equipment investment, thus being a concern of *cost* (Chan et al., 2001).
- ***Production cost:*** due to needed change in production based on the AMT solution, *cost* can change. Thus, the consideration of following KPI in order to compare current- against future state which is, again, based on PO *cost* (Narkhede, 2017). Another argument for why this KPI is critical to follow up is due to be a successful on the market and to compete in the different POs reduction in production cost tends to lead to market leadership (Krause & Aurora, 2019).
- ***Labour productivity:*** this thesis examined a case where a company searched for finding a solution that excludes manual labor. Before doing it, scholars have pointed the need to evaluate the yield of ***labour productivity*** (Krause & Aurora, 2019). In order to compare how much a manual work generates the company in compare to an AMT solution. Thus, making ***labour productivity*** and critical KPI for AMT implementation (Altuntas et al., 2018). Improved ***labour productivity*** speeds up the workflow, creating more time to handle workflow obstacles due to e.g., variation, thus increasing manufacturing *flexibility* (Ojha et al., 2013).
- ***Internal delivery:*** the argument that this KPI has is that change in production could add unwanted load to the internal delivery performance, this affects the delivery duration (Pakdil & Leonard, 2014). This KPI is connected d*ependability* since customer satisfaction is concerned with receiving request goods when desired, in this case customers are the internal customers (Ketokivi & Heikkkil, 2003). Also, that by having a reliable delivery system makes production scheduling more accurate (Jajja et al., 2018).
- ***Leadtime:*** a KPI that is related to how long it takes for a certain operation, in this case an activity, to be completed. This KPI is related to the PO *speed*, see sub-section 2.5.1, and it is critical to increase one's competitiveness. ***Leadtime*** is considered to measure when implementing AMT to assess whether solution is seen as strategically advantageous (Lewis & Boyer, 2002). It has been argued that implementation of AMT practices reduced ***leadtime*** which is a goal of manufacturers. Meaning that operations are done faster, thus being a concern of the PO *speed* (Small, 1998).
- ***Inventory turnover ratio/inventory cost:*** this KPI measures managerial activities for the function of the inventory and explicitly how well inventory content is turned over into revenue. However, this KPI is difficult to be measured by external researchers since information maybe company sensitive (Krause & Aurora, 2019). This KPI needs to be monitored because AMT solutions can result in inventory changes and managers needs to control those *cost*s so that the solution and inventory system are synergized (Sarkis, 1991). The KPI is affected by change in production since it could add unwanted load to the inventory adjustment which usually adds to *cost* (Pakdil & Leonard, 2014).

- ***Work in progress:*** according to Fulton & Hon, (2010) implementation of AMT practices aids in reducing WIP, for that reason the following KPI have been considered as findings. Studies have shown that AMT implementation affects the on-time delivers of parts and products within a manufacturing company. As long a part or product haven't reached the finished goods inventory, it is considered as a product under ***work in progress*** (WIP). The WIP then becomes as an affection on the PO *speed* (Majchrzak & Paris, 1995).
- ***Throughput time:*** according to research, the desire to decrease ***throughput time*** (TPT) is one of the main benefits is of adopting AMT practices (Sohal, 1994). That is why TPT is considered as a KPI when evaluating AMT implementation (Bai & Sarkis, 2017). The KPI affects a company's *speed* objective since it provides a measure on how many parts can be produced by the system over a certain time (De Toni & Tonchia, 1996).
- ***Productivity:*** this KPI has an overall perspective, and an AMT implementation affects this KPI comprehensive variables (output and input). This is since AMT practices, has a direct affection on both *flexibility* and ***productivity***. Meaning that when increasing/decreasing either the PO or the KPI the other one is directly affected (Singh & Gurtu, 2021).
- ***Unit labour cost:*** AMT solution affects the number of labour(s) either it decreases it due to solution have the capability to perform manual labour task or increase it do to maintenance (Krause & Aurora, 2019). Since this is the usual outcome of implementing and automated solution this KPI needs to be measured. The KPI reflects the PO *cost* and needs to be measured when implementing AMT practices (Small & Yasin, 2000).
- ***Profitability:*** the surplus of sold product divided over the cost of selling the product, product development costs included. The KPI is critical since AMT implementation desires investments and investment costs needs to be considered when accounting for product manufacturing, thus affecting the PO *cost* (Fulton & Hon, 2010).
- ***Floor space utilization:*** AMT implementation, especially when it comes the installment of equipment(s)/machine(s), can force layout changes, meaning that shopfloor space could either increase or decrease in free area, depending on the area that the automated solution takes up. Nevertheless, AMT benefit is split between tangible and intangible, in this study it delimits itself from explaining intangible. Tangible benefit is quantifiable benefit is which respective KPI is considered and have shown that it affects *speed* and *cost* POs (Udo & Ehie, 1996).
- ***Activity availability:*** the equation of this KPI is inspirated by plant availability. Since this EF mainly focus on comparing current state of an activity against future state, hence the change in name. The KPI measures the effectiveness of an activity in direct production (Krause & Aurora, 2019). How well a company's activity is available is related to the KPI ***capacity utilization***. Since it has been shown that manufacturing managers aims to increase the ***activity availability*** in order to maximize production capacity (Ferrer et al., 2018).
- ***Capacity utilization:*** according to the works of Sambasivarao, & Deshmukh (1995), AMT implementations should reduce the idle time and aid the production processes, hance the need to follow up respective KPI. To utilize one's capacity strategically is considered as a key for increasing the *flexibility* (Verhaelen et al., 2021).

Table 4: showcase the connection between respective KPIs and POs.

KPI↓ PO→	Quality	Speed	Dependability	Cost	Flexibility
Machine setup time			X		X
Quality inspection	X				
Payback time				X	
Material Handling		X	X		
ROI				X	
NPV				X	
Production cost				X	
Labour productivity					X
Internal delivery			X		
Leadtime		X			
Inventory cost				X	
WIP		X			
TPT		X			
Productivity					X
Unit labor cost				X	
Profitability				X	
Floor space utilization		X		X	
Activity availability					X
Capacity Utilization					X

5.2 Verifying the functions through case study

A comprehensive study was conducted in this stage, where a thorough LR was carried out in previous stage for the ease of developing the EF.
Empirical study was carried out at the case company as a part of the EF development. To verify the functions of the EF interviews and observations were conducted for gathering values for variables to calculate each respective KPI. These data collection techniques were performed as a result of improving the validity for developing the EF. Interviews were conducted where the company employees and the management participated in providing the most important data. The interview question is presented in **appendix 9.3**. The questions were separated into three categories: 1) *KPI-based questions*, where data is extracted from company balanced sheet and income statements, 2) *company-based questions*, in order to get an understanding on how company interpret different variables – some company interpret the output variable in time while others in quantity, 3) *observation-based questions*, in order to get a better understanding of the activity of interest. Interview method helped in indicating if interview questions were sufficient enough to measure all the KPIs, thus, aids in proofing the variable list function. The data collected from the interviews and observations were utilized to check whether the identified KPIs from literature study suited the SMEs in order to compare the performance. By conducting the interviews and observations it was realized that what variables need to be visible in the EF. Hence the inspiration to include a variable list in the design.
During the case study, it was also realized what PMS's characteristics needed to be included in the developed EF. The extracted characteristics from RQ1 findings was as following: (1) category for performance objective, meaning to have KPIs categorized;

(2) Current- against desired future state for comparing and decision-making capabilities; (3) In-plotting capabilities for monitoring features; and (4) Inclusion of comprehensive accounting capabilities for risk assessment situation(s). The latter included, for instance, payback time in order to assess whether an investment for an automated solution is affordable within certain time limit. The KPIs that have been identified as a part of RQ2 were applicable regardless of the activity a manufacturing company is trying to automate only that the variables, within respective KPI equation, are company dependent.
A rough sketch of the framework was developed based on connecting the findings from RQ1 and RQ2, which is presented in **appendix 9.2**.

5.3 Developing the evaluation framework

The structural support for developing the EF is derived from applying the findings from the first two RQs. The first RQ provided inspiration, especially the BSC-, BWM-, and PPMS methods, for which functions to be included in the EF. The BSC method inspired to add a scoring function (performance data of both states), while the BWM has MCDM characteristics which provides several decisions based on established criteria (Rezaei, 2015). Those findings demonstrated how the PMSs were executed and provided inspirational features that the methods had. Scoring tools and weighing functions to assess everything from departments to activities are examples of inspirational features. The developed EF provides decision making feature based on criteria and taken the inspiration from BWM. While the BSC inspired to include an option in the developed EF to set criteria needed to achieve strategic goal based on POs (Kaplan & Norton, 1996). For instance, the KPI *production cost* is connected to the performance objective *cost*, see sub-section 5.1.2, for that reason the KPIs of the EF are categorized based on POs. Lastly, the PPMS inspired to include KPIs that are measurable for SMEs.
The findings from RQ2 are included in the EF as the visible content of the framework, i.e., all the relevant KPIs that should be measured in SMEs for evaluating an intentional automated solution. The KPIs were identified using structured LR, see sub-section 3.3.1, and concluded that these are the most relevant ones. In order to investigate if the identified KPIs are relevant for the case company where the study is conducted, interviews and observations were carried out. This led to collect important data and serve as an input for the variables of KPI equations. Additionally, the case company was an SME which argues more for its applicability. The quantitative data obtained were used to compare the current- and desired future state of the KPIs and see whether every KPI identified were suitable in this case.
The idea behind designing the EF in current way is due to highlight identified functions that was seen less in PMSs used today. Which was the existence of a function that displayed how indicators affects POs. For that reason, KPIs in the framework are categorized and elaborated on more in detail in coming sub-section (Verhaele et al., 2021).
To finalize the design of the EF Microsoft Excel was utilized for programing equations that are connected to a variable list, see **appendix 9.4**.

5.4 Execution of developed evaluation framework

The framework is divided into five categories, based on the five POs presented in subchapter 2.4, which are shown more clearly in **appendix 9.4**. Activity is emphasized since the framework is built to evaluate and compare an activity's current state against

desired future state based on automated migration and/or moving from one level to another. The term automated migration in considers aspects of machinery/equipment investments to emancipated resources or to aid manual labor.
To execute the framework, user's needs to first set goals or a desired state of an activity performance, and/or company strategy goal to perform better in certain objective. The reason for this is to know what to compare against in order to know what to search for that satisfy desired state performance figures. Additionally, users need to measure current manufacturing performance(s) that are activity-based, and thereafter use the framework to evaluate whether intended solution satisfy company's desired manufacturing performance.
The KPIs used in the framework have been proven to be applicable in SME(s) by conducting the interviews and observations at the case company. Variables used to calculate them are founded in a functioning company's income statement and balance sheet. The KPIs and variables that are not usually presented in the income statement and balance sheet can be acquired through observations and interviews. The KPIs are divided into five categories to ease the usage of the framework and to compare KPI in different areas as well for user's interest. I.e., if manufacturer is mainly interested in how the automated solution will affect the *company's* cost objective, that could be achieved with minimal effort, since the framework provides a weighing summary at the end of the EF. Where manufacturers can see those changes in particular category, since each KPI is connected to respective PO.
Based on figure 13, the EF is utilized accordingly: first the company needs to set strategic goal(s) based on POs, meaning that company agree on where they wish to place themselves on the market. Secondly, the company should measure manufacturing activities, in order to acquire performance data to compare against desired state. This will provide an assessing opportunity, to see if current state operates better than desired future state or vice versa. Lastly, the five boxes in the bottom of the EF, see **appendix 9.4**¸provides a summary result to see if, e.g., intended AMT solution, actually exceeds current state from respective PO standpoint. Hence, evaluation is executed to assess whether intended AMT solution is considered as advantageous from strategic goal perspective.
When a KPI box have both values of current/future states then that KPI can be fully compared and connected to it is respective PO box(s). E.g., capacity utilization is a KPI that companies want to increase, when they plot in variables in the variables table for both states automatically this box compare each state. If the future state has better performance than current state, then a +1 will be added to the PO box flexibility (since it is connected to that one). If machine setup time and labour productivity, which also affects flexibility, has a better performance on current state compared with future state then the PO box will add the value -2. In summary the PO will have a -1 value which indicates that the automated solution will have a negative effect on flexibility which usually is a KPI that companies want to increase.

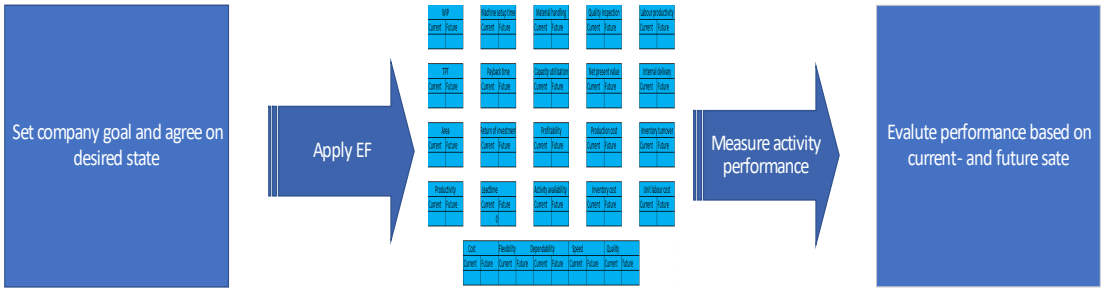

Figure 13: Illustration on how to use the framework from a manufacturing company perspective, (1) set goals and agree on desired state, (2) measure activity, and (3) execute EF.

6 Discussion

This chapter first discusses the findings for the RQs answers and eventually leading up to the discission of research methodology

6.1 Which are the PMSs, presented in literature, that are currently used in SMEs in order to measure the performance?

A LR was used to answer the first RQ where existing PMSs were identified and characterized. The outcome of the LR method helped in understanding about the existing PMS and their applicability in SMEs. Many techniques have been developed over the years, all of which differ in how they calculate different PMs. This could explain why the field of PM is so diverse and new techniques are constantly being created.
Many methods have been developed for identifying and evaluating the various POs that occur in a company. Each PMS was represented in terms of it is characteristics and situation applicability in SMEs to evaluate performance metrics, see table 2. This clearly aids in demonstrating the relevance of the research conducted. The AHP model, for example, aids in assessing and structuring the decision-making process, whereas the ANP model aids in evaluating in the social, economic, and management domains. It seeks to analyze and improve strategic feedback and learning using the BSC model. What's remarkable about the DEA model is that it is ideal for performance measurement activities but has a more complex mathematical approach. Following the various methods demonstrated in the table, a clear picture of what metrics or elements each model aids in analyzing is provided.
During the initial searches using different keywords yielded no interesting papers or conclusions. By using the snowball approach later helped in finding some of the relevant literatures which was useful in collecting the data required. To fill this research gap, the above-mentioned method was undertaken as a technique of answering the first RQ by demonstrating that, despite the abundance of assessment methods available, no method exists to evaluate a newly implemented automated solution in a SME. The existing PMSs identified aided in gaining a better grasp of the various methods for evaluating performance measures. Many of the methods discovered were only focusing on a company's particular PO. Since the goal was to create a framework where different KPIs could be categorized according to the five key POs, combining these identified methods aided in selecting the correct characteristics or properties from the existing methods, which were then used to create the EF.
One thing found as challenging was to relate the identified models within the terms of assessing an AMT implementation. None of the approaches explicitly mentioned how to evaluate an AMT solution because most of the methods focused about identifying and increasing performance measurements across various manufacturing activities. So, conducting a thorough literature search assisted in integrating the many characteristics that each technique possessed and combining them depending on how they would aid in the development of the EF that would support in the evaluation of the AMT implementation. As a result, answering the first RQ establishes a link that can be used in the designing and development phase of the EF as a part of answering to RQ3.

6.2 Which KPIs are needed to be consider in order to ensure that companies at SME level fully evaluate the successfulness of newly implemented automated solution at novice level?

KPIs are seen as critical success factors for manufacturers to reflect their strategic performance. Since investments needs justification for executives, a tool that allocates KPIs and displays real-time view of performance is needed (Lõun et al., 2013). KPIs that were identified in the literature had less arguments for its criticalness. As well, what was seen as more of an issue was the less demonstration on how to measure KPIs. Some literature emphasized various KPIs that were measured or at least considered for conducting respective research. However, the logic behind measuring emphasized KPI was shown less of, i.e., in this context, why it is needed to be monitored for evaluating automated solutions. The reason for this could be that most KPIs in the literature were used to evaluate performance and less for when to implement automated solutions.

Table 3 in the findings chapter, shows the KPIs that should be considered in order for SMEs to adequately evaluate the performance of newly introduced automated solutions at the novice level. All the KPIs were identified during LR, i.e., none of them were established based on e.g., workshop or brainstorming sessions. The KPIs had to be connected to the POs, for emphasizing the affection of intended solution and company strategy, see table 4. The reason for this is to visualize how manufacturing activities today compared to if changes were to be made, are intact with company strategy. Which has been stated that the POs are objectives that helps companies set goals and establish vision.

The identified indicators varied from customer satisfaction, working environment indicators e.g., safety, level of employee fatigue, etc., (Sambasivarao & Deshmukh, 1995). However, the KPIs that are considered as findings had stated argument from researchers with accounting demonstrations. As well why to measure KPI in order to enhance dimensions that are in direct connection with manufacturing capabilities for being a better market competitor (Asakari et al., 2016).

AMTs can assist SMEs in changing their traditional manufacturing approach, improving performance, and increasing market share in both local and worldwide markets (Gunasekaran et al., 2000). This has also been proven, only those situations have been presented where SMEs invest in AMT and ends up with an unsuccessful result from a strategic perspective. Thus, stressing the need for manufacturing SMEs to have proper KPIs that justifies the implementation of AMT (Small, 2007). Additionally, most SMEs have received insufficient attention from researchers and practitioners in order to improve their productivity through AMTs and proper performance measurement evaluation (Mechlinget et al., 1995). Which also stresses the needs to emphasize the competitive situation that SMEs faces. Now the EF allows SMEs to monitor changes in PO's as well as their competitiveness. As a result, SMEs should be aided in using AMTs in order to improve their ability to compete on a worldwide scale (Marrie et al., 2007).

The KPIs concentrate on the performance of the most significant organizational aspects for the current and future success of an organization. They inform management on the organization's fundamental processes and how they relate to the organization's overarching strategic goals (Samsonowa, 2011). By responding to the second RQ, an attempt was made to determine the most relevant KPIs that should be considered when evaluating performance using a LR and case study. Interviews were conducted at the company in order to improve the study's credibility by gathering data for specific KPIs. By comparing the existing and future states of the values, the company's expectations and the importance of performance measurements could be realized.

6.3 How can an evaluation framework for measuring the successfulness of adopting automated solution be formulated?

One of the strongest arguments for building this EF is that SMEs do not have a proper PMS(s) for evaluating AMT investments (Singh et al., 2008). What this research has done is to consider serval PMSs such as the BWM, PPMS, BSC, etc., and not developing them further but combining their functions into one, hence the developed EF. Another aspect that is worth highlighting is the fact that identified PMSs in the literature considered the company or whole departments. Instead, this EF can consider each activity to assess whether its performance is sufficient to achieve company's strategic goal. Even though the EF incorporates a variety of variables, each variable was connected to a KPI that eventually was connected to a PO. This argues for the theoretical connection that the EF design has. Numerical figures were acquired by applying interviews and observations at the case company this was to verify the accounting functions of the EF. I.e., each variable has a connection to the KPIs boxes, when a box has all the numerical figures it needs to be calculated based on programmed formula, then a KPI box will showcase its value.

Research clarification provided ideas and understandings on how a PMS is functioned. This stage initiated brainstorming sessions in parallel for clarifying the characteristics of important topics such as PMS, AMT, validity, and performance evaluation. By including a theoretical support and verifying functions of EF through method, a bridge was established between the findings from the first two RQs and the EF. During the developing phase of the EF, all inspirations acquired through triangulation and findings were connected, which is also something Blessing & Chakrabarti, (2009) encourages. I.e., having a variable list, connection between KPIs and POs, and the difficulty SMEs face's give rise to the developments. Due to time and resource constraints, the testing the EF was not executed. This was because it requires a complete testing and analysis of the developed EF in the case company.

Despite the fact that the field of automation is extensive and diverse, the areas that were only targeted were automated handling, automated inspection, automated packing, and robotics (Koc, & Bozdag, E., 2009). Only one activity is considered at a time by the EF. I.e., instead of considering the entire production, it just evaluates the current and future state of a certain activity.

The selection of which boxes to focus on when using the EF is decided by the user. Based on the KPI, the PO boxes will display a negative (-1), neutral (0), or positive (+1) value depending on the impact of each KPI on respective PO(s). The EF is delimited in such that it cannot decide which KPIs have stronger effect compared with its sibling KPI (sibling KPIs are those that are connected to the same PO(s)). Meaning that some utilizers of this EF have to decide which KPI(s) should have stronger meaning to their intended solution or if they should have an equal meaning. E.g., some utilizer thinks that ***payback time*** should have a stronger meaning than ***inventory cost***. Then the EF can be programmed with IF-condition (programming constraints). I.e., the ***payback time*** comparison has -2 for negative and +2 for positive compared with ***inventory cost*** that has -1 & +1 values. This will mean that if the KPI ***inventory cost*** will increase in *cost* (which is a minus value) and the ***payback time*** have a positive value. When they are accounted for in the PO box the value will be +1 since utilizer considers ***payback time*** as a stronger KPI for intended solution. And a drawback about the developed EF is that the utilizers cannot adopt the EF freely since each KPI are connected to a PO. If a KPI were to be added, then it needs to be connected to a PO. This is because the EF devel-

oped considers companies strategic objective in terms of connection with the 5 performance objectives stated (see sub chapter 2.5.1). Lastly, the main reason behind why applying DRM to develop the EF is because it includes both LR for providing theoretical knowledge and case study to verify the developments of the EF.

6.4 Discussion of Methods

This thesis is qualitative in nature, which means that the data is presented in the form of words and figures in order to provide a better understanding of what is being developed. DRM is distinguished by its guidelines, which were required because the findings were presented as exploratory. In a subject where there was a lack of consensus on theoretical foundations, applying this method helped to address the RQs and fulfill the purpose. To address the first and second research questions data were gathered through analyzing the works of other researchers. Particularly their approach to structuring the process of implementing automated solutions in manufacturing environments.
DRM is viewed as a proper approach since it has two goals: (1) generate understandings and (2) develop support for activities (Blessing & Chakrabarti, 2009). DRM was used to aid the development of the EF where the goal was to use the findings from first two RQs and then combining them to generate a response for the third RQ. The negative aspect of utilizing this method when time is of the essence is the requirements for testing the EF. I.e., DRM demands longer time to develop a product such as an EF and then reviewing it after thorough testing's in more than one field or case situation. The time for testing the developed EF on more than one case was not sufficient enough for conducting this thesis. This is mainly referred to the fourth stage of the DRM which was not executed. Thus, focus group activity was not performed to test the complete applicability of the developed EF during the case study. DRM's stages provide different output with open-ended answers that could be connected to input in next coming stage. Such as how the founded theoretical support and function verification aided the designing phase. I.e., the outputs acquired in each respective stage of the DRM could be combined to develop a product, EF in this case.
LR was used for gathering information to address the first research question and lay the groundwork for the second research question. Because the initial part of this thesis's LR is to analyze theory and expand its applicability. Thus, the first stage of LR is to begin with a deductive process - analyze existing theory, collect data from literature, and form conclusions – but the goal was to use the findings as data for inductive conclusions (Karlsson, 2016). This thesis used descriptive mapping based on the idea of Booth et al (2016), through comprehensive words, in this case AMT-, KPI-, and PMS-related terms, to assess past research and find gaps between theory and research. The study used a screening approach, as illustrated in figure 6, to find the most relevant papers and acquire data. Throughout this process, it became clear how many different terms were connected to the thesis's topic appeared regularly. This supported the use of the snowball approach during the literature study to obtain a better understanding of key concepts. This thesis had to go through the screening process as well as the snowball strategy in order to find the most relevant literature in order to extract data. Because the topic of study was so broad, these processing stages took a long time to complete, which is one of the major drawbacks of LR conducted.
Conducting a case study was critical because the goal was to establish an EF for measuring the performance of the newly implemented automated solution. Observations and interviews, were used to observe, identify, and document elements that have an impact on deploying automated machinery solutions. Because of the importance of identifying

the current position the firm has, it was important to conduct the case study and thus helping to design the framework and check its validity. Interviews were done in order to obtain the data about specific KPIs that were identified and for understanding the manufacturing activity in detail. For that semi-structured and unstructured interview were performed respectively (see sub section 3.4.1). Whereas the observations performed was for collecting the numerical values for the KPIs and calculate it to see the validity of the functions that the developed EF has (see sub section 3.4.2). The observations conducted also had a purpose to document the steps inside the activity or process of interest. The case study that was conducted was beneficial in providing appropriate relevant information in response to the research questions and to verify whether the developed EF suits the company of interest. Since the company of interest has not yet installed the desired automated machine, conducting a case study has a few limitations, such as the current states being accurately calculated, and future states being calculated only using the company goals rather than testing it with the installed machine. This thesis validity and reliability have been considered. The unstructured, semi-structured interviews and observations were performed as advised by Patel and Davidson (2019) was to assure the validity of this research to an extent.

7 Conclusion

This thesis sought out to develop an EF for the usage of evaluating implementation of AMT practice compared with current manufacturing activity performance. This was done by identifying relevant KPIs for assessing manufacturing activities of AMT practices and identify and characterize used PMS. In order to achieve the purpose of this thesis, the established 3 RQs were: **RQ1**: Which are the PMSs, presented in literature, that are currently used in SMEs in order to measure the performance? **RQ2**: Which KPIs are needed to be consider in order to ensure that companies at SME level fully evaluate the successfulness of newly implemented automated solution at novice level? **RQ3**: How can an evaluation framework for measuring the successfulness of adopting automated solution be formulated?

This thesis highlights the fact that the EF is relevant during these days since AMT adoption is increasing, making the chance for more SMEs to implement solutions that are not adequately aligned with their strategy. Today's manufacturing organizations, particularly SMEs, invest in a variety of technical solutions in the hopes of easing their manufacturing challenges, but they have no idea whether their solution is in line with their strategic goals. Therefore, the thesis's industrial contribution was an evaluation framework that SMEs can use to assess a newly implemented automated solution and determine whether it is beneficial. Additionally, this thesis also provides KPIs, and performance measurement systems allocated. This supports the process SMEs has to go through in order to analyze how KPIs are connected to POs and how to utilize PMSs.

The process for evaluating the performance of particular manufacturing activities using the defined framework is part of the academic contribution. This includes correctly identifying the characteristics of existing methods and creating a link between various performance indicators and the company's strategic goals. The arguments for the applicability of this EF are based on the source of findings. I.e., they are identified from literature where research has been done in SMEs, hence proving the applicability. Only that the functions – plot in values in the variable list to verify that it is connected to respective KPI box, which eventually is connected to a PO box – have mainly been tested on the EF. In order to strengthen the validity and reliability, interviews, observations, and LRs were conducted. Internal validity was improved using the LRs, which served as a tool that supports inspirations acquired by the case study. The validity of the developed EFs was primarily assessed through observations. As a result, using these methods improved the validity and verification of the developed EF. One of the thesis' delimitations is that it exclusively focuses on manufacturing activities. Additionally, the developed EF will not be fully tested at the case company in order to demonstrate its full applicability.

To conclude, the literature study conducted as part of answering to RQ1 provided two primary findings: 1) there are no appropriate performance measurement systems that helps in assessing the successfulness of an AMT implementation; and 2) existing performance measurement systems characteristics have been summarized and used as inspiration for constructing the EF. Answering RQ2 through LR helped in identifying the relevant KPIs that needs to be considered while implementing an automated solution. The connection between the POs and the KPIs, that have theoretical support will aid the user of the EF for evaluating whether AMT solution is aligned with company’s strategic goal. The finding for RQ3 was used to construct the EF using DRM. The findings of the first research question motivated the inclusion of scoring, MCDM, and the placement of KPIs and PO boxes on the framework. The second research question led

to the main function of the EF, which includes all the KPIs and required variables for comparing different manufacturing states.

7.1 Further research

This thesis highlighted delimitation, presented in 1.4 delimitation, that the methodology for developing the EF, was limited to the third of its four stages. For that reason, it is encouraged to further research and to test the applicability of the EF on SMEs to increase the validity. Since that is more done in the fourth stage of the DRM. The source of encouragement comes from the desire to evaluate if what the PO boxes presents reflect company's performance.

Performance objectives have two perspectives: internal and external. If a company increase or decrease a PO based on a KPI affection of respective PO. This will affect the company's performance different depending on internal or external perspectives. Which is not something that has been considered. If further research were to be done in this subject it would be advised to e.g., extend the function of the EF or test it on a case company.

Another suggestion for further research, is to include more databases and a focus group(s). The source of encouragement for this suggestion lies in the idea of this might provide more relevant KPIs and performance measurement systems. By identifying more databases, an include more methods for the identification of KPI and performance measurement systems. The EF could eventually be expanded to include more characteristics and KPIs thar are relevant for SMEs, in firsthand. Additionally, this could increase the connection between the KPIs and PO further which makes the POs values more reliable. Thus, provides better argument to whether implemented manufacturing solution is truly aligned with company's strategic goal.

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9 Appendices

9.1 Appendix 1 – Brainstorming session

This figure below illustrates combined conclusions for the brainstorming sessions which were conducted in the first stage of the DRM, research clarification. The overall purpose for this thesis was to develop a framework that are to be used for assessing if intended solution for a manufacturing activity is aligned with company's strategic goal. The brainstorming sessions were carried out in parallel with literature review since it provided interesting topics to conduct thorough reviews. These topics were studied carefully so that when this thesis was to develop and design the framework, it made sure important aspects, such as characteristics of PMS, were not left out.

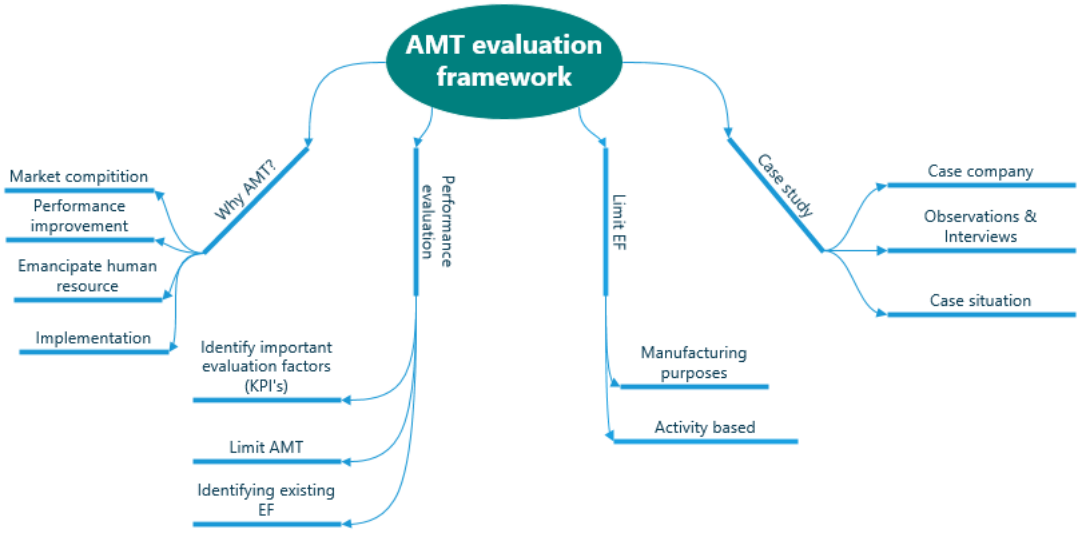

Figure 9.1. Brainstorming session with the four main topics of interest.

9.2 Appendix 2 – Conceptual design

The figures that are presented in this appendix showcase the conceptual designs that were done in an early phase of this thesis. When implementing a solution of AMT manufacturers will have two state performance. Where the first state is the state that the company is performing currently, and the second state is the intentional performance that the company wish to perform at. Before finalizing the current design of the EF, the KPI boxes were based on the output value of each KPI equation or how it should be measured. For instance, ***unit labour cost*** presents it values in two dimensions where the one being monetary (wages) where the second being unit is (quantity) while others such as ***production cost*** is presented in one dimensional, which is monetary. The first complete conceptual design of the EF is in figure 9.3. Where all the KPI boxes are listed – KPI inventory turnover rate and inventory cost are two separate KPIs in this conceptual design – with their categories presented in colour coding. *one dimensional*, is the blue boxes and are KPIs that are measured in either time, percentage, and quantity; *monetary*, are boxes in green and are measured in currency of choice; *two dimensional*, meaning that the answers of the KPIs are measured in unit is per X, where X could be any unit e.g., time; *area*, is a measure for the floor space that the solution take up to compare the area that activity is performed currently.

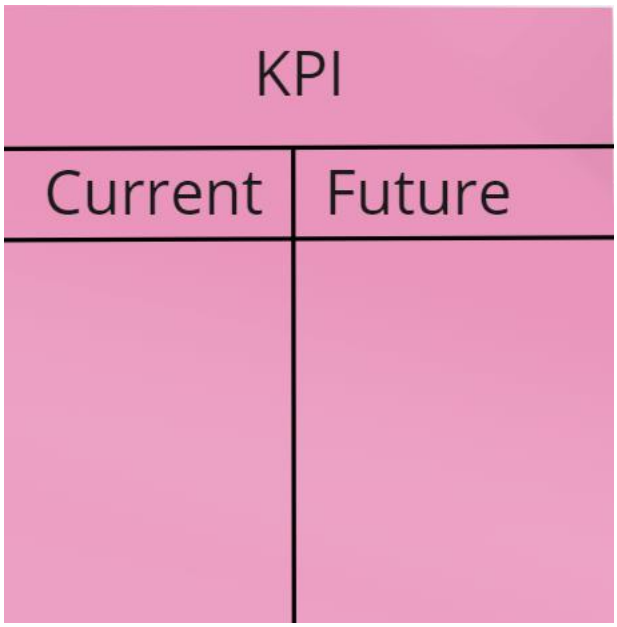

Figure 9.2. A conceptrual design of a KPI box that that illustrates current- and future state, where performance data should be presented below.

Figure 9.3. The first complete conceptual design of the evaluation framework

9.3 Appendix 3 – Interview questions

The table listed below are the interview questions used during the observations to acquire figure for variables.

Table 9.1. interview question categorized by KPI related, observation dependent, and company dependent.

Category	KPI	Questions
KPI-based	7	What is the daily cost for running the production?
	8	How many employees does the company have in the production?
	11	What is the average monthly product output?
	11	What are your direct costs for producing one product?
	11	What is your average stock volume?
	11	How much are you producing on average every month?
	11	How much are you shipping on average every month?
	12	What is your inventory lead time and takt time?
	13	What is your throughput time?
	14	How do you interpret the variables of productivity?
	15, 20	How many products have you produced over latest six month?
	15, 20	How big is your output over last six month?
	15, 20	How much output have you planned for coming six months?
	16	What is your level of profitability currently on average from your products?
	17	What are your expenses on having an inventory?
Observation-based	13	What is your throughput time?
	19	What is your TPT?
	1	What are the preparing activities related to the wrapping station?
	3	How long does it take to fill means (in this case a pallet) used for material handling?
	4, 6, 15	What does it cost for the company to perform the activity as a current state?
	9	Where in the production facility do company receive material needed to perform activity?
	9	Are they placed on a position near the station of interest or in inventory?
	9	How long does it take to transport material from receiving position (e.g., gate) to activity/station of interest?
	9	How long does it take to transport output of activity to next coming station, e.g., FGI?
	10	What is product lead time?
	7	What does it cost for the company to perform the activity as a current state?
	18	How much area does the machinery solution take up?

Company-based	4	What is the budget for the project to acquire a wrapping machine?
	5,6	What is the interest rate if money has to be borrowed to install the machine?
	11	What are is the average material cost for one product?
	4	What is the average cost of one product? Or what is the average price of one of your products?
	7	Daily production, utilities, and employees cost in average?
	11	How many products are produced on average of every month?
	16	What is your level of profitability company having, currently?
	2	Is the company preforming any quality inspection in regard to activity of interest?
	6,15	What is the average salary, including taxes and employer fees? When it comes to running producing?

9.4 Appendix 4 – the evaluation framework

The next coming figure is the developed evaluation framework with the variable list showcased to the right of the figure. Users of this framework as supposed to execute the interview questions and performed observation of activity of interest. Then fil out the variables that are presented with values acquired from variable collection methods, observations, and interviews. The KPI boxes are the 20 listed that includes rows of current respective future. While the PO boxes are the five listed at the bottom with two rows that states the name of the PO and in the lower row, the positive or negative value – in some cases neutral (o) value – of the PO based on intended solution.

Figure 9.4. The developed evaluation framework.