Md. Abdullah-Al Mamun

MAP OUT THE BEST BI TOOL AND SPC SOFTWARE FOR A CASE COMPANY: SELECTION AND RATIONALIZATION PROCESS

Faculty of Information Technology and Communication Sciences
M. Sc. Thesis
May 2023

ABSTRACT

Md. Abdullah-Al Mamun: Map out the best BI tool and SPC software for a case company: selection and rationalization process
M.Sc. Thesis
Tampere University
Master's Degree programme in Computing Sciences
Major: Data Science
May 2023

Business Intelligence (BI) is about delivering relevant and reliable information to the right people at the right time to make better decisions faster. To do this, I require methods and programs to collect unstructured data, convert it into information, and present it to improve business decisions. There are many types of BI tools available on the market that perform these tasks. On the other hand, Statistical Process Control (SPC) is used to control the process with the help of statistical tools and techniques. It helps me monitor and control the process, reduce variations in the process, improve product quality, and so on. In this thesis, my main goal is to find the best BI tools and SPC software for Valmet Automotive, a Finland-based automobile manufacturing company.

Valmet Automotive is one of the world's top producers of automobiles and batteries. Our organization uses BI and SPC tools for data analysis, visualization, and processing. Nevertheless, we have faced challenges in employing these instruments at various periods. I started this thesis to find possible BI and SPC technologies for our organization so that we can solve the problem.

Every software must satisfy ISO 9000-3, an international software development and quality assurance guideline. Furthermore, every software must maintain ISO-9126, a quality model that determines the evaluation of software quality. My software selection processes are based on ISO 9000-3 and ISO-9126.

My first goal was to find the best BI tools and SPC software for our organization based on its specific needs. Therefore, to map out potential BI and SPC tools, I picked 30 BI tools and 13 SPC software from the huge amount of similar software in the market. At this point, all the needed map-out criteria and software names were organized in Excel, and I evaluated each tool on a scale of 5 for each criterion. I used math to get the total weighted score for each tool.

Furthermore, I used mathematical computation methods to complete the procedure. After completing the whole procedure in Excel, I enlisted the assistance of code. Consequently, I used the Python programming language to calculate the overall score. After computation, using Python visualization libraries, I identified the top five BI tools out of thirty and the top three SPC tools out of thirteen SPC software. In the case study, I also found the best BI tool and SPC software for our company by using visualizations. In the findings, Microsoft Power BI was the best BI tool, and SPC for Excel was the best SPC software for our case company. Therefore, our case company, Valmet Automotive, chose Microsoft Power BI as its leading BI solution. In addition, the research involved a comprehensive statistical analysis, including descriptive statistics, correlation analysis, hypothesis testing, and regression analysis, to examine the selection process of SPC tools and BI tools in the case company.

Mostly, the methods and calculations are done for our case company's best tool selection. However, in the future, any company that needs good quality BI tools or SPC software can follow my methodology and calculation methods to select the best BI tools and SPC software available on the market at that time for their needs.

Keywords: Business Intelligence, BI, Statistical Process Control, SPC, reporting, data analysis, automotive, industry.

The originality of this thesis has been checked using the Turnitin Originality Check service.

PREFACE

Bismillah Bismillah Hir Rahman Nir Raheem (In the name of Allah, the Most Compassionate, the Most Merciful). I am starting in the name of Allah (the God), the creator of heaven and earth. This thesis work was conducted at Valmet Automotive EV Power Oy, Salo, to fulfill the requirements for my master's degree at Tampere University. I want to express my heartfelt thanks to all who helped me with this work.

To manage my thesis work, the company appointed Henna Strömberg, Senior Specialist, Continuous Improvement, EV CF Operations Development as my thesis supervisor. After our first meeting, she proposed the thesis topic, "Map out current BI tools and SPC software and how that should be rationalized and improved." I was overwhelmed to find such an interesting thesis topic, and I have learned a lot during my entire thesis work at my company under Henna Strömberg's supervision. It would have been impossible to complete my thesis without her valuable suggestions and advice, so I want to thank her for helping me in every step of my thesis.

Secondly, I would like to thank my colleagues and team leader, especially Janne Sandell (Incoming Quality Lead), Salo battery factory, for their help in starting my thesis. I also want to mention the contributions of Marko Nurmenniemi (Manager, Production Planning, and Launch Management), Mikko Kopra (ICT Manager), Congleton Matthew (Production Director, Plant Production), and many others at my workplace.

Thirdly, I am grateful to my examiners, Timo Poranen, a university lecturer at Tampere University, and Martti Juhola, Professor at Tampere University, for their guidance that made it possible to successfully complete the thesis.

Finally, this thesis work and thesis writing were not easy tasks, but with the unwavering support of my family members, especially my wife, brothers, and sisters, it was possible. I want to dedicate this work to my parents, who are no longer with us.

Tampere, 31 May 2023

Md. Abdullah-Al Mamun

Author

CONTENTS

1. INTRODUCTION 1
1.1 Background of the research 1
1.2 Research problems and questions 2
1.3 Objectives and methodology 2
1.4 About the company 4
1.5 The structure of the thesis 6
2. THE BUSINESS INTELLIGENCE AND STATISTICAL PROCESS CONTROL 8
2.1 Business Intelligence 8
2.1.1 Cloud based Business Intelligence 10
2.1.2 Business Intelligence for business needs 11
2.2 Statistical Process Control software and its evolution 12
2.2.1 The total quality management 14
2.2.2 Six sigma approach 16
3. BI TOOLS AND SPC SOFTWARE 18
3.1 The software selection criteria 18
3.2 Selected 30 BI Tools 20
3.3 Selected 13 SPC software 31
4. TOOL SELECTION FOR THE CASE COMPANY 35
4.1 The different stages of the research 35
4.2 Primary study 37
4.3 Calculation methods 39
4.4 Phase Screening 1: selection of best 30 BI tools for the company 42
4.5 Final Screening 1: selection of best 5 BI tools for the company 43
4.6 Final Screening 2: selection of best 3 SPC software for the company 44
4.7 Statistical Analysis 48
5. RESULTS AND DISCUSSION 58

5.1 Findings 58

5.2 Analysis of findings..67

5.3 Validation of the selected tools to the company needs 69

5.3.1 Selected Tool 1: Microsoft Power BI 69

5.3.2 Selected tool 2: SPC for Excel...70

6. RECOMMENDATIONS..75

7. CONCLUSION 77

REFERENCES 79

Appendices

List of figures

Figure 1. *Inside the battery factory, Valmet Automotive EV Power Oy, Salo 4*

Figure 2. *Major responsibilities of the company 6*

Figure 3. *Articles evaluated by Scopus with the phrase "Statistical Process Control"(1980 - 2018) 13*

Figure 4. *Six sigma Approach 16*

Figure 5. *The software quality criteria according to ISO 9126 .... 19*

Figure 6. *Power BI dashboard 21*

Figure 7. *Tableau Dashboard 27*

Figure 8. *Pyramid Analytics 30*

Figure 9. *QDM SPC System work strategy (Single Site - Basic Setup). 34*

Figure 10. *The different stages of the research to find out best tools for the company. 36*

Figure 11. *Descriptive Statistics of BI Tools: Box Plot 49*

Figure 12. *Descriptive Statistics of SPC Software: Box Plot.................................... 49*

Figure 13. *Violinplot of Descriptive Statistics for Zoho Analytics (BI Tools). The violinplot showcases the distribution of data for all 30 BI tools. 50*

Figure 14. *Violinplot of Descriptive Statistics for Proficient (SPC software). The violinplot showcases the distribution of data for all 13 SPC software. 50*

Figure 15. *Correlation Matrix of 30 BI tools: Insights into Interrelationships. 51*

Figure 16. *Correlation Matrix of 13 Statistical Process Control (SPC) Software: Insights into Interrelationships. 52*

Figure 17. *Predicted Efficacy Scores for SPC software X. 56*

Figure 18. *Predicted Efficacy Scores for BI tool X. 56*

Figure 19. *Best 5 BI tools from best 30 (Vertical) for the company. 59*

Figure 20. *Best 5 BI tools from best 30 (Horizontal) for the company. 60*

Figure 21. *Best one BI tool from the best 30 (Vertical) for the company. 61*

Figure 22. *Best BI tool from the best 30 (Horizontal) for the company.................... 62*

Figure 23. *Best three SPC software from the best 13 (vertical) for the company. 63*

Figure 24. *Best three SPC software from the best 13 (vertical) for the company. 64*

Figure 25. *Best analytics tool from the best 13 (horizontal) for the company. 65*

Figure 26. *Best analytics tool from the best 13 (horizontal) for the company. 66*

Figure 27. *Example of bad products by station at Valmet Automotive EV Power Oy, Salo... 69*

Figure 28. *SPC for Excel, Example 1: C chart (Created by the author). 71*

Figure 29. *SPC for Excel, Example 2: Pareto chart (Created by the author). 72*

Figure 30. *SPC for Excel, Example 2: Histogram chart (Created by the author). 73*

Figure 31. *Some other charts and properties of demo version of SPC for Excel (Business version contains more properties and charts). 74*

List of symbols and abbreviations

AI	Artificial Intelligence
ANOVA	Analysis of variance
ABI	Analytics and Business Intelligence
APICS	American Production and Inventory Control Society
BI	Business Intelligence
C	Count
CRM	Customer relationship management
CAPA	Corrective and Preventive Actions
C-chart	Count charts
DOE	Design of Experiments
ERP	Enterprise resource planning
EIS	Extensive Information Systems
ETL	Extract, Transform, Load
EMA	Enterprise Management Associates
FMEA	Failure Modes and Effects Analysis
GAAP	Generally Accepted Accounting Principles
Gage R & R	Gage Repeatability and Reproducibility
IIOT	Industrial Internet of Things
I-MR	"Individual-Moving Range" chart, which is a statistical process control chart used for continuous data with a sample size of one.
I-MR-R	Individual-Moving Range-Range chart
I-MR-S	Individual-Moving Range-Standard Deviation chart
KPI	Key performance indicator
MSA	Measurement Systems Analysis
n	Total number of elements
NP	Not Proportion (Nonconforming units)
OS	Operating system
OEE	Overall Equipment Effectiveness
P	Proportion
P-chart	Proportion charts
RTBI	Real-Time Business Intelligence
SPC	Statistical Process Control
SaaS	Software as a service
SWOT	Strengths, weaknesses, opportunities, threats
TQM	Total Quality Management
Takt time	The rate at which a manufacture process must operate to meet customer demand.
x	Elements of the efficacy
Xbar-R	"Xbar-Range" chart, which is a statistical process control chart used for variables data.
Xbar-S	"Xbar-Standard Deviation" chart, which is a statistical process control chart used for variables data.
U	Units
Y	Weight
W	Weighted Score
X	Total Weighted Score

.

1. Introduction

The Introduction chapter provides background information about my thesis, including the research problems and questions, research objectives and methodology, background of the company, and the structure of the thesis.

Business Intelligence (BI) is the process of providing timely access to accurate information to make better decisions. To accomplish this, I require tools and programs that can gather unstructured data, transform it into information, and present it to help me make better decisions. Various BI tools are available in the market to perform these tasks. On the other hand, Statistical Process Control (SPC) uses statistical tools and methods to control the process. It assists in process management and monitoring, reduces process variance, improves product quality, and so on. My thesis aims to find the best BI tools and SPC software for the Finnish automaker, Valmet Automotive.

Valmet Automotive is one of the largest manufacturers of motors and batteries worldwide. The company employs BI and SPC technologies for data acquisition, analysis, and visualization. However, there have been difficulties in using these tools at different times. Therefore, I initiated this thesis to investigate potential BI and SPC solutions for the company.

1.1 Background of the research

Business Intelligence (BI) encompasses a collection of techniques, devices, and tools for handling business issues, including data analysis, reporting, business analytics, dashboard design, and more. Nowadays, it is hard to imagine a day without BI tools and technologies, whether for a large-scale or small-scale company [1]. On the other hand, Statistical Process Control (SPC) is a quality assurance approach that applies statistical techniques to track and regulate an operation. SPC ensures the process functions well, creating more items that meet specifications with very little waste. Therefore, SPC applies to any operation where the result of "qualifying products" (items that satisfy standards) can be quantified [2]. To understand how these tools and technology spread to the whole corporate level, I need to go back to the past. In the Business Intelligence and Statistical Process Control chapter, I will discuss how these tools and technology spread to the whole corporate level.

1.2 Research problems and questions

This section discusses the research problems and questions related to our organization's analytics and reporting tools. I aimed to address the need for better production follow-up, suitability for takt time production, and potential improvements. My research sought to answer these questions and tackle the identified problems:

I needed to determine what is lacking in our current analytics, reporting, and tools to achieve effective production follow-up. Additionally, I needed to identify the areas that require immediate focus and understand the risks contributing to organizational dysfunction.

There was uncertainty regarding the suitability of our existing analytics, reporting, and tools for takt time production, which involves handling vast amounts of data daily. I was unsure if the tools I was currently using were the best fit for this purpose. I also needed to explore potential ways to enhance the utilization of our existing tools. Furthermore, I needed to ascertain if additional tools should be integrated or if redundant tools could be consolidated. Additionally, I needed to determine what tools could be introduced to improve production visibility and drive improvement actions for better production control. Therefore, I had to address the question of tool combination and assess the potential impact of such combinations.

Throughout my research, I successfully answered these questions and resolved the identified research problems.

1.3 Objectives and methodology

Our main objective is to identify the best BI and SPC software for our case company, which generates a large amount of data daily. While we are currently using BI tools to analyze and report on this data, we need to determine if this tool is the most suitable option for the company, or if there is a better tool to handle real-time data. Additionally, the company is currently using an expensive Predisys analytic tool, so we need to find an affordable SPC software that meets their needs. Our focus will be on finding the best tools for the company, while also exploring ways to improve their current tools.

Our primary objective is to identify the 13 most popular analytics and 30 BI tools, and then narrow down our research to find the best tools for the company. We will provide recommendations to the company, which can choose whether to adopt our suggested tools or continue using their current ones.

To achieve our objectives, I have developed a work strategy that involves several categories: categories:

1. Primary study
2. Phase screening
3. Final phase screening
4. Selection and evaluation
5. Best tools selection

In the primary study section, I will conduct initial research on BI and SPC software available in the market. I will then select 30 possible BI tools and 13 SPC software options in the first and second phase screenings. In the final phase of screening, I will use mathematical formulas to narrow down my selection to five BI tools and three SPC software tools based on our target features.

I will select and evaluate the chosen tools in the selection and evaluation section before visualizing the results. In the result and discussion chapter, I will analyze and discuss the selected BI tools individually, according to the company's needs.

My software selection process is based on ISO 9000-3, which is the standard for software quality assurance. I will use a comparison model [1] that supports a general software selection process, maintaining software selection criteria and software qualities based on ISO 9126 and ISO 9000-3. More details on this process will be discussed in chapter three.

In the thesis, a comprehensive statistical analysis was conducted to guide the selection process of Statistical Process Control (SPC) tools and Business Intelligence (BI) tools for a case company. The analysis involved descriptive statistical analysis, correlation analysis, hypothesis testing, and regression analysis. Descriptive statistics provided insights into the distribution and outliers of the tools, while correlation analysis explored the interrelationships between them. Hypothesis testing determined significant correlations, and regression analysis examined the predictors' impact on efficacy scores. This rigorous statistical analysis forms the foundation for informed decision-making in selecting the most suitable SPC and BI tools for the company's specific needs.

1.4 About the company

Valmet Automotive Oy is a technology services provider for the automotive sector. Since my establishment in 1968, I have served as a full-service automobile manufacturer for prestigious original equipment manufacturers. Our priority is the production lines in Uusikaupunki, Finland, which have produced a total of 1.7 million cars, including those for Porsche, Saab, and Mercedes-Benz. In addition, my company emphasizes flexibility, nimbleness, and a responsible approach, making us a highly sought-after company in the automobile sector [3]. Figure 1 shows the inside of the battery factory at Valmet Automotive EV Power Oy in Salo.

Figure 1. *Inside the battery factory, Valmet Automotive EV Power Oy, Salo [5].*

Since I began making the legendary Fisker Karma in 2010, electric mobility has been my second focus. However, our recently built battery facility in Salo, Finland, is evidence of our increasing focus on this area. As a Tier 1 supplier, I develop and produce a large number of 48-volt batteries every year, in addition to offering high-voltage battery systems for fully electric and plug-in hybrid automobiles [3].

Thirdly, actuating is my third business line, which focuses on the roof and kinematic systems for the entire organization, emphasizing the significance of electric mobility even more [3].

Finally, the development of adjustable and various roof systems, dynamic bumpers, and lifting shutters are just a few applications for extremely complicated electric drives that are becoming more and more crucial. I am a Tier 1 system supplier, among the top providers globally [3].

Target and the work strategy of the company

The most critical assets of Valmet Automotive are strong client ties and an understanding of their needs. Furthermore, regarding my ability to serve as a strategic partner and how technically sound my implementation is. Moreover, my dedication to providing top-notch customer service has defined my company's ethos [3], [5].

The following principle is upheld by my 4,500 employees at Valmet Automotive facilities in Finland, Germany, and Poland. Consequently, we all have a passion for mobility, whether we are engineers in a battery testing lab in Bad Friedrichshall or workers on a manufacturing line in Uusikaupunki. Moreover, it is made possible by our persistent commitment [3], [5].

The world is moving more quickly than it ever has. The car industry has been in turmoil for a while now, and this is the "new normal." Consequently, there are repercussions for someone as experienced as Valmet Automotive. In this sense, I have long understood that electric mobility is a crucial driver. However, my objectives have undergone a significant change due to the development and production of battery systems for electric cars and the growing relevance of electric drivetrains for kinematic and roof systems. As a strategic, technical, and practical work tool, electric mobility has a very high position inside my company [3], [5].

Nevertheless, for my automotive clients, this work is significant. It is comparable with well-known manufacturers of agricultural and construction machines, both of which are undergoing substantial change. They all find partners who can meet their changing needs in ever-shorter time frames with quickness, flexibility, and unique specialization [3], [5].

Over the last several years, I have developed a robust and future-proof corporate culture for my expanding, internationally involved organization. Finally, we decided upon these fundamental principles together, which embody the uplifting nature of Valmet Automotive both now and in the future [3], [5]. Figure 2 provides the major responsibilities of the company. The major responsibilities of the company include continuous learning, showing entrepreneurial spirit, delivering the best products and services to customers, leading at all levels, and cultivating a culture of respect towards everyone in the business.

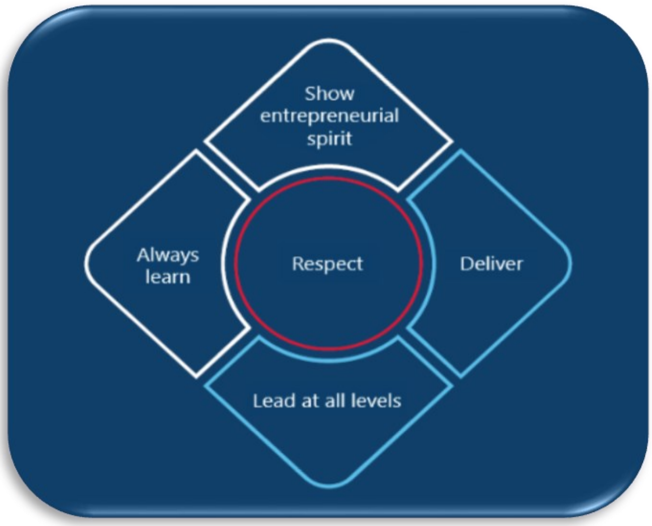

Figure 2. *Major responsibilities of the company [3].*

1.5 The structure of the thesis

My thesis consists of various chapters, sections, and sub-sections, following standard thesis writing conventions. The abstract provides an overview of my thesis.

The introduction chapter includes research problems and questions, objectives and methodology, the background of the research, information about the case company, the structure of the thesis, and other relevant details.

The Business Intelligence and Statistical Process Control chapter is a theory chapter based on a literature review. It covers Business Intelligence, Cloud-based Business Intelligence, Business Intelligence for business needs, Statistical Process Control software and its evolution, total quality management, the SIX Sigma Approach, and other related topics.

The BI tools and SPC software chapter is also a theory chapter, providing an overview of the primary selected tools (30 BI tools and 13 SPC software) for the company. I explain the tool selection criteria and standards followed to select quality software for the company.

The tool selection for the case company chapter explains the methodology of my work, detailing the different stages of my research and the tool selection process used.

The Results and Discussion chapter presents the results of my research and briefly discusses my findings.

The Recommendations chapter recommends my findings to the case company, including my research and findings and my recommended use of the best BI tools and SPC software.

The Conclusion chapter summarizes my findings, double-checking research questions to ensure they were properly answered, and includes the limitations of my research.

The References chapter provides a proper bibliography based on my research.

The Appendix includes my research's Excel sheet calculations, Python coding, and other related information.

2. The Business Intelligence and statistical process control

The Business Intelligence and Statistical Process Control chapter provides an idea of previous works consistent with my research. This chapter focuses on the background study of Business Intelligence, the evolution, and current trends of this technology to solve business problems. To make it easier, I have divided this chapter into two parts: Section 2.1 Business Intelligence and Section 2.2 Statistical Process Control (SPC) software and its evolution. Section 2.1 consists of two subsections: Subsection 2.1.1 and Subsection 2.1.2. Subsection 2.1.1 is about cloud-based Business Intelligence, and Subsection 2.1.2 explores Business Intelligence for Business Needs. The first section, 2.1 Business Intelligence, explores definitions of Business Intelligence, its history, and its evolution. In addition, Subsection 2.1.1 describes current trends in Business Intelligence based on cloud services. On the other hand, to fulfill my research questions, I introduce data analytics and Statistical Process Control and discuss their evolution in Subsection 2.1.2. Furthermore, Section 2.2 Statistical Process Control (SPC) software and its evolution consist of Subsection 2.2.1 The total quality management and Subsection 2.2.2 SIX Sigma Approach. Moreover, at the end of this chapter, I identify the research gap and present all connected studies.

2.1 Business Intelligence

BI is a combination of processes, methods, and technologies that convert unstructured data into usable and profitable information. It is a set of tools and apps that convert data into actionable knowledge and insight [1].

First, I came across the term "Business Intelligence" in a book named "Cyclopædia of Commercial and Business Anecdotes" in 1865 by Richard Millars Deven. He used this phrase to discuss the profit of Sir Henry Furness, a banker, who benefited from data analysis. In his book on page 210, Deven wrote, "Throughout Holland, Flanders, France, and Germany, he maintained a complete and perfect train of Business Intelligence. The news of the many battles fought was thus received first by him, and the fall of Namur added to his profits, owing to his early receipt of the news." Deven emphasized the importance of gathering and using data appropriately for Business Intelligence [6].

On the other hand, Hovi et al. [7] discussed the term "Business Intelligence" in their book "Tietovarastot ja Business Intelligence." They explored the word and its history, assuming that the term gained prominence after the establishment of data warehousing.

According to Webster's Dictionary, Business Intelligence is defined as "the ability to apprehend the inter-relationships of presented facts in such a way as to guide action towards a desired goal." Webster's Dictionary is one of the most popular English-language dictionaries of the twentieth century. This definition is significant because in 1958, a well-known researcher at IBM, Hans Peter Luhn, used the phrase "Business Intelligence" in his article [8]. Howard Dresner also employed the term "Business Intelligence" in 1989, describing it as an "umbrella term" encompassing "concepts and methods to improve business decision-making by using fact-based support systems" [8]. Turban et al. [9] define it as "an umbrella term that combines architectures, tools, databases, analytical tools, applications, and methodologies." They also emphasize that the primary objective of BI is to enhance interaction with company data to gain more knowledge for decision-making [9]. Similarly, Hancock et al. [10] define Business Intelligence as "a set of concepts, methods, and technologies designed to pursue the elusive goal of turning all the widely separated data in an organization into useful information and eventually into knowledge."

Solomon et al. [11] state that Business Intelligence (BI) can be defined as systems that combine data gathering, data storage, and knowledge management. These systems assess complex organizational and commercial data to present to planners and executives, aiming to improve the quality and efficiency of the decision-making process [11]. Evelson et al. [12] describe Business Intelligence as "a set of methodologies, processes, architectures, and technologies that transform raw data into meaningful and useful information used to enable more effective strategic, tactical, and operational insights and decision-making." Based on this concept, Business Intelligence involves data integration, analysis, data warehousing, data analytics, and more. However, according to Forrester Research [12], the Business Intelligence architecture stack does not include data preparation and usage, which distinguishes it from the market for Business Intelligence, consisting of "just the top layers of the BI architectural stack, such as reporting, analytics, and dashboards" [12].

According to Forrester Research [12], there are a few elements of Business Intelligence, including:

1. Aggregation and allocation of multidimensional data
2. Denormalization, annotating, and centralization

3. Original reporting with analytical notifications
4. A method for connecting to unstructured data sources
5. Statistical inference and probability - based modelling
6. Performance tuning of metrics and inter-process communication
7. Accessible product management
8. Version control

After delving deeper into the trends and technology of Business Intelligence, I came across a book [13] written by Rasmussen et al. in 2002. The book [13] mentioned that BI tools were initially utilized as analytical software packages in the eighteenth and nineteenth centuries. In the twentieth century, Microsoft Excel and Lotus 1-2-3 emerged as highly efficient and user-friendly programs for data analysis. Users could easily create models and analyze data using these software applications [13].

During the twentieth century, the Extensive Information Systems (EIS) system, also known as EIS, provided executives with crucial information on their desktops. However, despite its sophistication, the EIS system did not gain widespread popularity. In the late 1990s and early 2000s, the introduction of ETL tools, data warehouse technologies, and new end-user analytical software contributed to the increasing popularity of Business Intelligence tools. Spreadsheets continue to be popular today and are likely to remain so for many years. However, with the aid of web-based BI tools, successful BI can become an even more valuable tool in the future [13].

Currently, almost all businesses harness the power of Business Intelligence, and there is a strong trend toward developing BI solutions that automatically display data from various sources. The book [13] presents a list of constraints, concerns, and solutions. These include information overload, lack of information, lack of interaction, and lack of consistent cross-database SPC software. Modern BI systems incorporate capabilities to address these challenges by intelligently aggregating, analyzing, and filtering the data presented in BI reports. The book also discusses potential concerns that may arise in BI initiatives, such as overplanning, procrastination, relying solely on Information Technology, and feature creep. However, these difficulties can be effectively addressed through iterative planning and programming, as well as effective project management [13].

2.1.1 Cloud based Business Intelligence

After delving deeper into the trends and technology of Business Intelligence, I came across a book [13] written by Rasmussen et al. in 2002. The book [13] mentions that BI tools were initially utilized as analytical software packages in the eighteenth and nineteenth centuries. In the twentieth century, Microsoft Excel and Lotus 1-2-3 emerged as highly efficient and user-friendly programs for data analysis. I found that I could easily create models and analyze data using these software applications [13].

During the twentieth century, the Extensive Information Systems (EIS) system, also known as EIS, provided executives with crucial information on their desktops. However, despite its sophistication, the EIS system did not gain widespread popularity. In the late 1990s and early 2000s, the introduction of ETL tools, data warehouse technologies, and new end-user analytical software contributed to the increasing popularity of Business Intelligence tools. I also discovered that spreadsheets continue to be popular today and are likely to remain so for many years. Nonetheless, I believe that with the aid of web-based BI tools, successful BI can become an even more valuable tool in the future [13].

At present, I observe that almost all businesses harness the power of Business Intelligence, and there is a strong trend toward developing BI solutions that automatically display data from various sources. The book [13] presents a list of constraints, concerns, and solutions. These include information overload, lack of information, lack of interaction, and lack of consistent cross-database SPC software. I note that modern BI systems incorporate capabilities to address these challenges by intelligently aggregating, analyzing, and filtering the data presented in BI reports. Additionally, the book discusses potential concerns that may arise in BI initiatives, such as overplanning, procrastination, relying solely on Information Technology, and feature creep. However, I believe that these difficulties can be effectively addressed through iterative planning and programming, as well as effective project management [13].

2.1.2 Business Intelligence for business needs

According to Watson et al. [17], "BI is currently my top-most priority as a chief information officer." Consequently, this could be due to the advantages of BI, which I can see in the same article (such as saving time for data suppliers and becoming aware of what is going on in my business). In addition to comprehending the reasons behind specific facts and events and predicting what will happen in the future, all of this facilitates my strategic decision-making. Furthermore, according to the authors, the expenses of the hardware and software components of decision support systems are substantial [17].

Many businesses and organizations are growing in more complicated and competitive situations. Moreover, evaluating data in real-time is necessary to enhance my company's performance in such conditions [18]. According to Azvine et al. [18], I as a decisionmaker require insightful information from the appropriate people at the right time and location. In addition, they further said that technological advancements and current ICT (Information and Communications Technology) have made RTBI (Real-Time Business Intelligence) appear to be feasible [18].

Watson and Wixom [17] highlighted the argument, stating that many experienced BI specialists know my business management's requirement for more current data. Furthermore, real-time data warehousing and various information systems make it feasible to give me real-time data to enhance my decision-making [17].

Likewise, other articles and publications, such as [19] and [20], to name a few, discussed the concept of RTBI and how it is possible to use it in other industries. As a result, the requirement for decision support systems that can do real-time data processing is evident and urgent.

According to Azvine et al. [18], the meaning of RTBI is sometimes similar to the term "real-time" in the context of a particular company. They went on to give additional importance to the phrase [18], including:

- The need that a process has zero latency.
- That a process produces information whenever management needs it for managing or other processes.
- The capacity to generate essential performance measurements relevant to the present situation rather than some previous condition.

2.2 Statistical Process Control software and its evolution

In combination with SPC, a statistically based proactive management method [21] and [22], I utilize an improvement-oriented mentality, such as Six Sigma or Total Quality Management (TQM). The concept of using statistical tools to discover process management issues was proposed by Walter A. Shewhart in the 1920s [23] at Bell Labs. SPC was founded on this concept, applying statistical theory to the study of variation [24]. W.E. Deming, a renowned quality expert, further extended the principles of SPC and popularized them in the Japanese industrial sector during the 1950s. However, it was not until 1980 that the western corporate business began adopting SPC. Recently, SPC has gained interest as a field of study. Figure 3 in the article database displays the yearly publications from 1980 to 2018 where the term "Statistical Process Control" appeared in the article's title, abstract, or key phrases, as identified through a Scopus search [23].

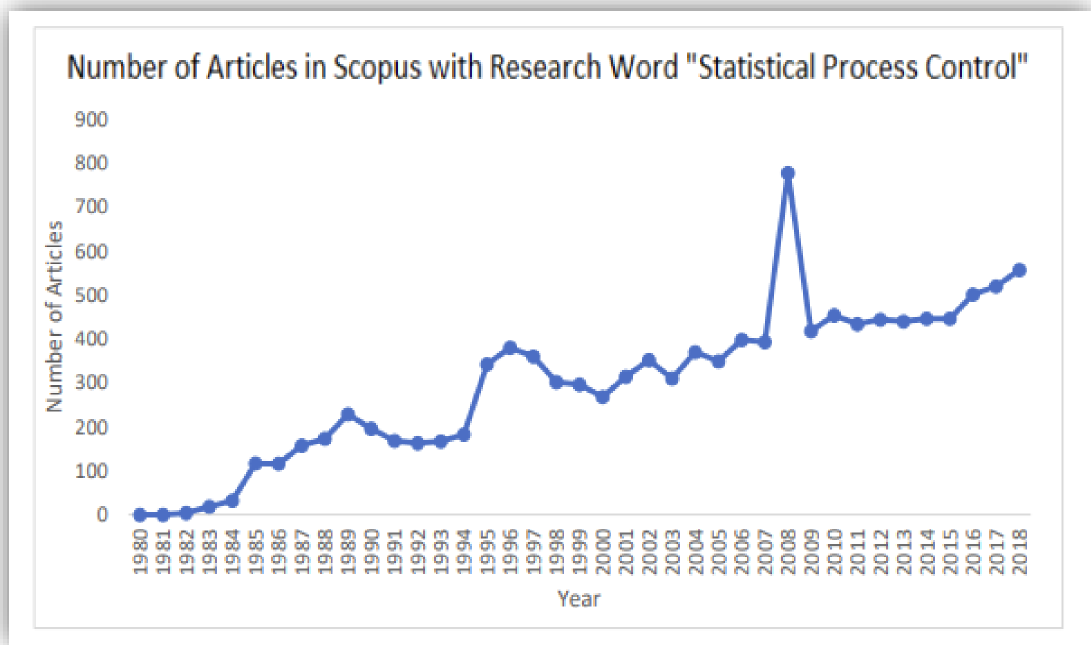

Figure 3. *Articles evaluated by Scopus with the phrase "Statistical Process Control"(1980 - 2018) [23].*

The popularity of SPC is on the rise across various industries, such as chemicals, automotive, food, healthcare, and general services. Moreover, SPC has expanded its presence in non-manufacturing enterprises, including finance and education [25]. However, the existing body of SPC research lacks cohesion and context. According to Ahmed and Hassan [25], only a small percentage of industrial organizations effectively utilize SPC, with the majority employing limited and basic SPC software. Nonetheless, incorporating different techniques and strategies within a management framework like TQM can contribute to achieving optimal SPC outcomes. Furthermore, SPC has faced criticism for various reasons, including:

i. The partial application of technologies and approaches fails to properly identify faults and defective goods (such as identifying problems that arise throughout the product usage) [25].
ii. The possibility for human error while using SPC (e.g., measurement and computation mistakes) and the lengthy nature of the procedure [25].

2.2.1 The total quality management

The popularity of Statistical Process Control (SPC) is increasing across diverse industries, encompassing chemicals, automotive, food, healthcare, and general services. Furthermore, SPC has expanded its application to non-manufacturing sectors like finance and education [25]. However, the existing body of SPC research lacks coherence and contextual understanding. Ahmed and Hassan [25] state that only a small percentage of industrial organizations effectively utilize SPC, while the majority rely on limited and basic SPC software. Nevertheless, integrating different techniques and strategies within a management framework like Total Quality Management (TQM) can enhance the effectiveness of SPC. Additionally, SPC has been subject to criticism for various reasons, including:

1. Quality inspection
2. Quality control
3. Quality assurance
4. Total Quality Management

As part of my organization's objectives to achieve customer satisfaction and organizational excellence, the Total Quality Management (TQM) strategy focuses on enhancing process efficiency and responsiveness to meet customer needs [25].

Collaboration among all elements within the organization is crucial for the successful implementation of the TQM concept. Each component, activity, and member of the organization influences one another. TQM has been recognized as a philosophy for modern competitiveness and has made significant contributions to the field of quality management, elevating its reputation to its current level of competitiveness [26].

The implementation of TQM can be divided into three phases:

1. Preparation stage
2. Planning stage
3. Execution stage

These three steps must be effectively carried out with the support of management, employee participation, and other factors such as training and communication [27].

The development of the Total Quality Management (TQM) approach has spanned a significant period of time. Table 1 provides an overview of the evolution of TQM, tracing its progression from quality inspection to total quality management and highlighting the key features associated with each stage. The evolution began in 1910 with the analysis of product quality and identification of sources, followed by the application of data analysis and statistical control methods in the 1920s. In the 1950s, quality risk analysis using FMEA (Failure Mode and Effects Analysis) was introduced, and by the 1980s, a comprehensive approach to quality management emerged, encompassing aspects such as staff involvement, customer relations, and commitment to development.

Table 1. *The progressive development of TMQ [27].*

TMQ	Year	Progressive development
Quality Inspection	1910	Beginning with a fundamental analysis of product quality and source identification, quality is established.
Quality Control	1920	During this time, the process is managed through the application of data analysis and statistical control methods, and quality planning is enhanced.
Quality Assurance	1950	During this time, quality management plan, inspections, and the implementation of quality risk analysis using FMEA are all carried out.
Total Quality Management	1980	Quality management, staff involvement, customer relations, and a commitment to developing were the foundational elements of a complete approach to quality management.

2.2.2 Six sigma approach

Since I first introduced the six-step method in 1988 as part of Motorola University's Design for Manufacturing training program, Six Sigma has evolved as an addition to Total Quality Management (TQM). Its applications have expanded beyond defect reduction to encompass a development management approach that focuses on enhancing consumer needs comprehension, productivity levels, financial performance, and other aspects in various industries. Initially, Six Sigma gained traction in the electronics sector with companies like Motorola and Texas Instruments. Over the past two decades, its implementation has become increasingly widespread in service industries, hospitals, local governments, and the public sectors, particularly in supply chain contexts [28].

The first stream of Six Sigma is characterized as a collection of statistical techniques employed in quality management to provide a framework for process improvement. By utilizing a range of data analysis tools, the aim is to enhance the performance metrics known as Critical to Quality (CTQ) at the Six Sigma level, which align with customer expectations. Statistical methods are employed to determine the key quality indicator, known as Parts per Million (PPM) of nonconforming items. To achieve a Six Sigma level, a process must produce outputs with fewer than 3.4 faulty parts per million. It is important to note that while Six Sigma is recognized as a problem-solving technique that utilizes quality and statistical tools for fundamental process changes, it does not always constitute a comprehensive management system [28].

Figure 4 depicts the Six Sigma approach, which involves defining goals, measuring the existing system, analyzing the system, improving the system, and controlling the new system.

Figure 4. *Six sigma Approach [28].*

There There are numerous advantages of Six Sigma, including cost reduction, shortened project timelines, improved outcomes, and enhanced data integrity. In many cases, the strategy of Six Sigma provides managers with solutions and methods for achieving practical improvements, enabling a comprehensive understanding of the system and effective business transformation. The use of Six Sigma can result in various benefits, such as reducing the overall cycle time of the manufacturing process, improving product development cycles and process design, and decreasing product lead times. It can also help identify and eliminate underlying causes of issues, thereby reducing process variability and preventing errors [28].

Additionally, there are organizational implications of Six Sigma. Its approaches provide instructions that aid employees in understanding their roles and preparing them to address potential issues, leading to increased morale and a decrease in human-related errors as they become more knowledgeable about the manufacturing process. Studies have shown that Six Sigma contributes to defect reduction in manufacturing systems by reducing the defect rate per unit (DPU) [28].

Both Six Sigma and TQM play crucial roles in Statistical Process Control (SPC), the development of SPC software, and maintaining high quality. Business Intelligence Tools (BI Tools) are widely used for data analysis, reporting, decision-making, dashboard development, data integration, and more. SPC serves as an industry-standard system for monitoring and managing quality throughout the production process. SPC software supports Statistical Process Control by collecting real-time data and notifying producers of outcomes that fall outside the acceptable range. It also aids in reducing process variance, enhancing throughput, and reducing overall production costs. Nowadays, businesses of all sizes rely on both BI tools and SPC tools, as they are essential for effective decision-making.

In this chapter, I have conducted a literature review related to our research questions and problems. By connecting the information mentioned above, it is evident that "Business Intelligence" is a term that has been in use for a long time, but its popularity increased significantly after the 1990s and has now become a global phenomenon. On the other hand, SPC has gained popularity in recent years, specifically since 2011, although its origins can be traced back to 1920.

The purpose of this research is to map the current state of Business Intelligence, SPC tools, and the process of rationalizing and improving them to meet the company's business needs.

3. BI tools and SPC software

In our primary selection process, I have chosen the top 30 BI tools and 13 SPC software for our analysis. In this chapter, I will explore the general criteria for software selection, the tools selection process, their features, advantages, drawbacks, and more.

To gather information for the preliminary study, online research was conducted. We started with web searches and examined hundreds of websites to generate a comprehensive picture of the available BI tools in the market. The selection of the 30 BI providers was based on the information gathered from their websites, blogs, and relevant news. During this process, we prioritized websites with appealing layouts and easily accessible information about the vendor's BI solution. Additionally, we assessed the company's sustainability in the BI market by examining documents, blog entries, and news stories.

3.1 The software selection criteria

I have drawn inspiration for most of the general software selection criteria from [1] and [3]. For calculations, I have relied on [2], [3], and several other sources. The selection process for identifying the best 30 BI Tools and 13 SPC software for our company was based on a preliminary study, selection criteria, and calculation methods. Once the initial selection was made, I analyzed the criteria of each software using calculation methods.

There are several general quality, feature, and selection criteria for software selection mentioned in the scientific literature. In particular, I have followed [1] and [4]. Additionally, most of the selection criteria align with the software quality criteria outlined in [1].

According to Alebeisat and others [1], software quality is determined by following factors:

1. Software quality is determined by a set of quality factors.
2. Software quality is determined by user satisfaction.
3. Software quality is determined by unexpected software performance or error.

According to Alebeisat and others [1], software selection criteria and software quality should be based on six characteristics:

1. Functionality
2. Efficiency
3. Maintainability
4. Portability

5. Reliability
6. Usability

There is a recognized standard for software quality assurance known as ISO 9000-3. This standard provides international guidelines for software development. In order to meet this standard, it is essential for software to satisfy most of the six characteristics outlined. Additionally, the evaluation of software quality is determined by the ISO-9126 quality model, as mentioned in [1]. Figure 5 illustrates the software quality criteria described in the ISO 9126 standard.

The ISO 9126 standard aims to address human biases in software development by clearly defining project priorities and goals. This is achieved by establishing a shared understanding of project priorities and converting them into measurable values.

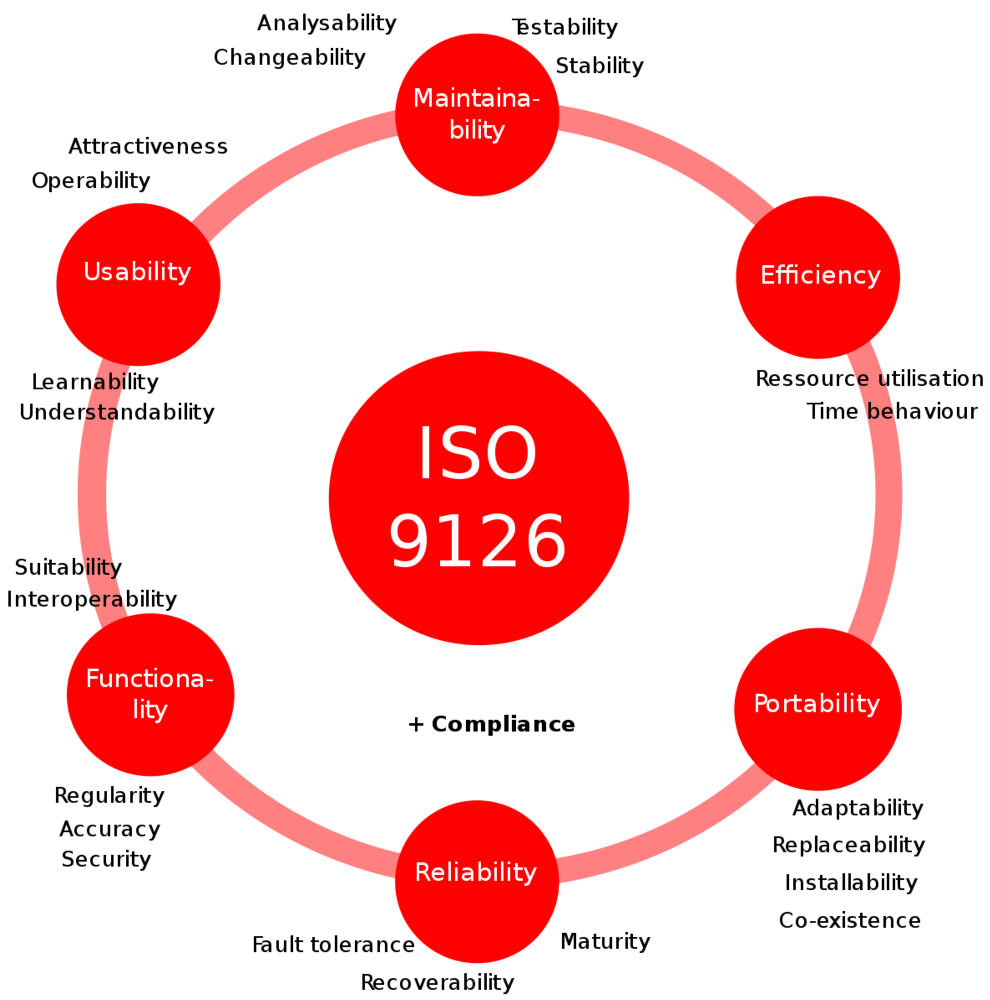

Figure 5. *The software quality criteria according to ISO 9126 [1].*

The software selection process I conducted includes mapping out criteria and sub-criteria that fully align with ISO 9126.

3.2 Selected 30 BI Tools

Based on my preliminary study and selection criteria [1], I have chosen 30 BI tools for the case company, Valmet Automotive EV Power OY. In this section, I provide a brief description of the thirty BI tools that were primarily selected. You can refer to Table 2 for a comprehensive list of these Business Intelligence tools.

Table 2. *Thirty Business Intelligence Tools.*

Zoho Analytics	Oracle Analytics Cloud
Microsoft Power BI	SAS
Yellowfin	Sisense
SAP BusinessObjects BI Suite	Tableau
MicroStrategy	Tibco Spotfire
Board	Looker
Pentaho	Google data Studio
Jaspersoft	DOMO
QlikView	Alteryx
Information Builders	Amazon QuickSight
IBM Cognos Analytics	ThoughtSpot
Dundas BI	Infor Birst
Style Intelligence	Apache Superset
Tellius	Pyramid analytics
Logility	Splunk

At this point, I am briefly introducing the following 30 BI tools:

Zoho Analytics

The Zoho, a well-known enterprise renowned for its CRM system, also offers an ABI (Analytics and Business Intelligence) platform called Zoho Analytics. This platform provides comprehensive data processing, visualization, and integrated predictive analysis capabilities. ABI platforms primarily focus on analytics, charts, graphical presentations, and related aspects. However, Gartner highlights Zoho Analytics' distinctive feature of language processing queries. Despite this strength, the solution faces challenges due to a limited product vision and certain product shortcomings. For example, according to market researchers, the lack of visual features like brushing and lassoing hinders its progress [29].

Microsoft Power BI

Power BI is the umbrella term for a range of cloud-based tools and services that enable organizations to collect, manage, and analyze data from various sources through a user-friendly interface. The Power BI REST API is utilized for maintaining and embedding its contents. Additionally, the REST API is used for performing administrative tasks. Business Intelligence products like Power BI have multiple uses. Its main function, however, is to gather, analyze, and present data in the form of insightful and visually appealing charts and graphs. This allows customers to create and distribute concise summaries of their company's current state. Power BI has the capability to connect to various data sources, including databases, on-premises and cloud-based applications, and Excel spreadsheets [30], [31].

Figure 6 provides an illustration of a Power BI dashboard, which presents a report view on a single page, effectively conveying a story through visualizations. It highlights key aspects of the story, with additional details accessible through related reports.

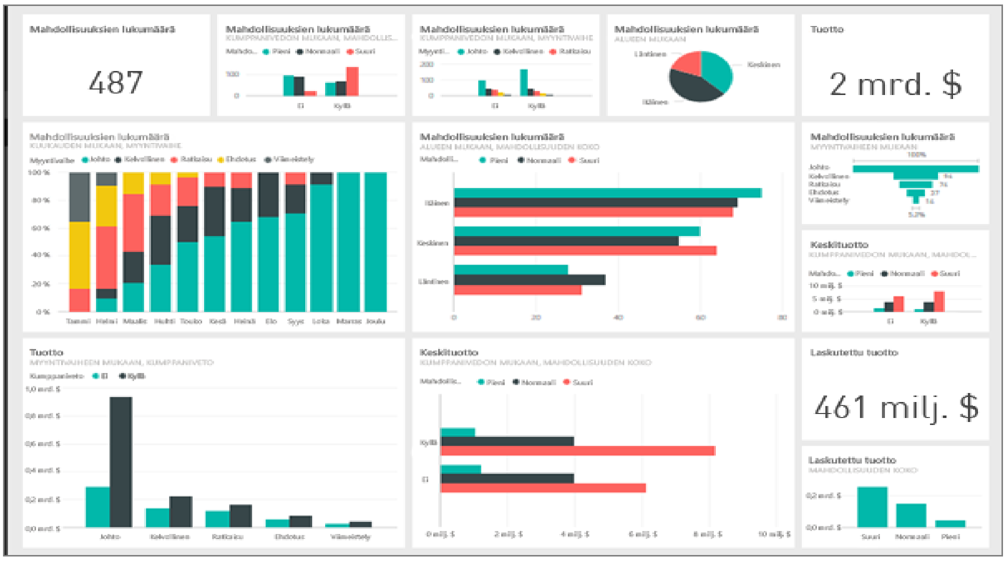

Figure 6. *Power BI dashboard [30].*

According to Datanyze, Power BI holds approximately 12% of the market share for Business Intelligence solutions, positioning it just behind Tableau and FactSet. Moreover, Gartner has consistently recognized Power BI as a leading player in the analytics and BI industry for the past eleven years. In Gartner's Magic Quadrant evaluations, Power BI is often referred to as the platform with the most comprehensive perspective [30], [31].

Yellowfin

Yellowfin is an analytics and BI system with a global focus on empowering product managers to enhance the analytical experiences of their applications through embedded BI. It aims to address enterprise analytics challenges and assist business professionals in understanding the "what" and "why" behind their data. The Yellowfin Java API is utilized for maintaining and embedding its contents, as well as carrying out administrative operations. Yellowfin is a highly intuitive, fully web-based reporting and analytics platform. It was founded in 2003 as a response to the challenges and costs associated with adopting and utilizing existing BI products. Presently, Yellowfin is used by over 25,000 businesses and 3 million end consumers across 75 nations [31].

SAP BusinessObjects BI Suite

SAP BusinessObjects Business Intelligence is a comprehensive solution that offers a consolidated package for data reporting, visualization, and sharing. It serves as the on-premises BI layer for SAP's Business Technology Platform, enabling data to be translated into practical insights that are accessible anytime, anywhere. The SAP BusinessObjects BI Suite REST API is used for maintaining and embedding its contents. Additionally, the API is also utilized for performing administrative tasks [32].

Microstrategy

MicroStrategy is a leading company in corporate mobility and analytics technology. Known as a pioneer in Business Intelligence and analytics, MicroStrategy provides innovative solutions that enable individuals to make informed decisions and enhance business operations. They offer global software and skilled systems to their corporate clients, enabling them to implement customized BI solutions. The MicroStrategy REST API is used for maintaining and embedding its contents. Additionally, the API is utilized for performing administrative tasks [33].

Board

Board is the Intelligent Planning Platform that has been adopted by over 2,000 enterprises worldwide. It enables these companies to achieve improved results, actionable insights, and more innovative planning. Through Board, top organizations can obtain critical insights that inform their business decisions and integrate strategy, finance, and operations for more effective planning and complete performance control. Notable global companies, such as Toyota, Coca-Cola, KPMG, Burberry, H&M, and many others, have digitally transformed their planning processes using Board. The Board REST API is used for maintaining and embedding its contents. Additionally, the API is utilized for performing administrative tasks [34].

Pentaho

Hitachi Vantara's Pentaho system brings together technology and business clients, allowing them to input, filter, combine, and monitor any information that impacts business results. This is achieved by closely integrating data integration with business analytics. Pentaho, with its open-source heritage, offers a modern, unified, and flexible analytics platform that helps organizations accelerate their analytics data pipelines. The Pentaho REST API is used for maintaining and embedding its contents. Additionally, the API is utilized for performing administrative tasks [35].

Jaspersoft

The ETL program utilizes models and a drag-and-drop designer to organize and integrate data from multiple sources into a data warehouse. As a result, customers will experience increased satisfaction, and the product will become more competitive as users can find solutions within their applications more quickly. By allowing engineers to focus on the core product instead of analytics with Jaspersoft, companies may achieve faster growth. The Jaspersoft REST API is used for maintaining and embedding its contents. Additionally, the API is utilized for performing administrative tasks [36].

QlikView

QlikView is the traditional solution for guided analytics, allowing for the rapid creation and distribution of interactive, guided analytics apps and dashboards. With QlikView, customers can ask and answer their own questions and find the path to enlightenment. By collaborating with their co-workers, they can make informed decisions. QlikView REST offers a REST connector for connecting and loading data, while SOAP over HTTP or HTTPS is used for all-purpose communications [37], [38].

QlikView may use to [38]:

- Create a versatile interface for end users to interact with a data warehouse.
- Obtain data relationship snapshots.
- Create data-driven presentations.
- Create graphs and tables that are dynamic.
- Analyze the statistical data.
- Integrate multimedia and descriptions with the data.
- Create the systems of expertise.
- Create new tables by combining information from several sources.
- Create the intelligence system for business.

Information Builders

With QlikView, reporting, analysis, and Business Intelligence become simplified, benefiting both end users and the IT department. QlikView enables the quick creation and distribution of interactive guided analytics applications and dashboards, making it easy for users to ask and answer questions and gain valuable insights. Additionally, colleagues can assist customers in making decisions. Information Builders also utilizes a similar REST connector like QlikView [38].

IBM Cognos Analytics

An artificial intelligence (AI)-powered Business Intelligence, analytics, and reporting system, IBM Cognos Analytics with Watson offers extensive data exploration capabilities, dashboards, expert report writing, and automated data preparation. Furthermore, IBM Cognos Analytics with Watson provides a single integrated platform that is highly secure, serving as a dependable business co-pilot, and aims to enhance decision-making abilities and speed through data. The IBM Cognos Analytics REST API is used to maintain and embed its contents [39].

Dundas BI

A Business Intelligence and data visualization platform, Dundas BI, includes dashboards, reporting tools, and data analytics. It is a product of Insight Software. Additionally, it provides end users with the ability to construct their reports, run ad-hoc queries, delve deeper into their data and performance indicators, and create dynamic, customizable dashboards. Businesses across various industry sectors and deployment levels can benefit from Dundas BI. The software also offers complete customization and integration support through its programmable, open API architecture, which includes .NET REST and JavaScript APIs. It was designed to be embedded. As a result, Dundas BI (SaaS) offers three deployment options: on-premises, Unmanaged Cloud, and Managed Cloud [40].

Style Intelligence

With the use of a data mashup engine, users of InetSoft Style Intelligence's BI software can create dashboards, visual analytics, and reports. This technology allows for real-time data integration from various sources, including relational databases, spreadsheets, OLAP servers, ERP applications, and web services. The Style Intelligence JSON and REST API is utilized to maintain and embed the software's contents. InetSoft's unique Data Block technology, which enables real-time data mashups, is integrated into Style Intelligence. This enables users to access interactive dashboards, enterprise reports, scorecards, and exception alerts based on the data. Additionally, users have access to various charts, including custom geographic mapping. InetSoft's Style Intelligence is available both as a local installation and in the cloud [41].

Tellius

Telus differentiates its ABI offering from others by providing customers with a "What?", "Why?", and "How?" type interface. The research also highlights its support for multiple personas, the speed at which augmented analytics deliver value, and the scalability of its cloud ecosystems. However, the market researcher identifies potential issues, such as shortcomings in the company's data storytelling and reporting capabilities and its limited access to external resources [42].

Logility

Logility assists firms in capitalizing on new opportunities, sensing and responding to changing market dynamics, and efficiently managing complex international operations by expediting the digital supply chain from product conception to customer availability. The Logility Digital Supply Chain Platform combines artificial intelligence (AI) and advanced analytics to automate planning, reduce cycle times, enhance accuracy, improve operational efficiency, break down organizational silos, and enhance visibility [43].

Oracle Analytics Cloud

The Oracle Analytics Cloud is a comprehensive and versatile platform that enables businesses to query data from any source, in any environment, and on any device. It seamlessly integrates with the ecosystem, providing cloud-based analytics and facilitating access to diverse data sources. The result is the optimal utilization of user data, regardless of its location. Additionally, Oracle Analytics Cloud offers a range of intelligent analysis solutions that are easy to set up and operate, making it a valuable tool for engaging a wider audience in analytics and expanding organizational knowledge. With Oracle Analytics Cloud, leveraging cloud analytics now and in the future becomes straightforward [44].

SAS

SAS Visual Analytics is a comprehensive solution that encompasses self-service data preparation, visual discovery, interactive reporting, dashboards, and easy-to-manage analytics. It enables non-technical users to create, distribute, and execute BI and Analytics workflows for interactive reporting and experimentation. Furthermore, SAS Visual Analytics promotes the sharing and collaboration of insights among decision-makers, allowing them to make collective choices as part of their duties, processes, or occupations. The primary goal is to enable everyone to respond decisively and remain adaptable in the face of fluctuating market conditions and rapidly evolving company demands [45].

Sisense

Sisense, as mentioned on its LinkedIn website, has offices in Israel and the United States. The company was founded in Tel Aviv in 2004. Sisense claims to offer a unique Business Intelligence platform that enables efficient preparation and analysis of large and diverse datasets. However, this claim seems contradictory as other BI products also provide similar functionalities. In their support communications, Sisense emphasizes their proficiency in various areas, including data analytics, which they claim is included in their BI package while other organizations may not have adopted it yet. By making such statements that are not entirely accurate, they unintentionally undermine their product's credibility. Additionally, Sisense promptly addressed inquiries regarding REST support and minor DB2 issues [46].

Tableau

Tableau was founded in 2003 as a result of a Stanford computer science project aimed at improving analysis efficiency and enhancing data accessibility through visualization. Tableau is considered a business transformation initiative that aims to change the culture and approach to data and decision-making within companies. One of the notable features of Tableau software is its user-friendly interface, which eliminates the need for technical or programming knowledge. As a result, individuals from various sectors, including business, research, and other industries, have shown interest in using this tool [27], [47].

The primary Tableau implementations and usages are as follows:

- Data Collaboration
- To handle extensive size metadata
- To import a massive amount of data
- To construct no-code data queries
- Real-time data analysis
- Data Blending
- Query translation into visualisation
- Business Intelligence
- Data Visualisation

Figure 7 showcases the Tableau application, which is specifically designed for monitoring and analyzing business metrics through visualizations. It provides interactive dashboards that allow users to combine salesforce reports with data from various other sources, resulting in a comprehensive view of the data.

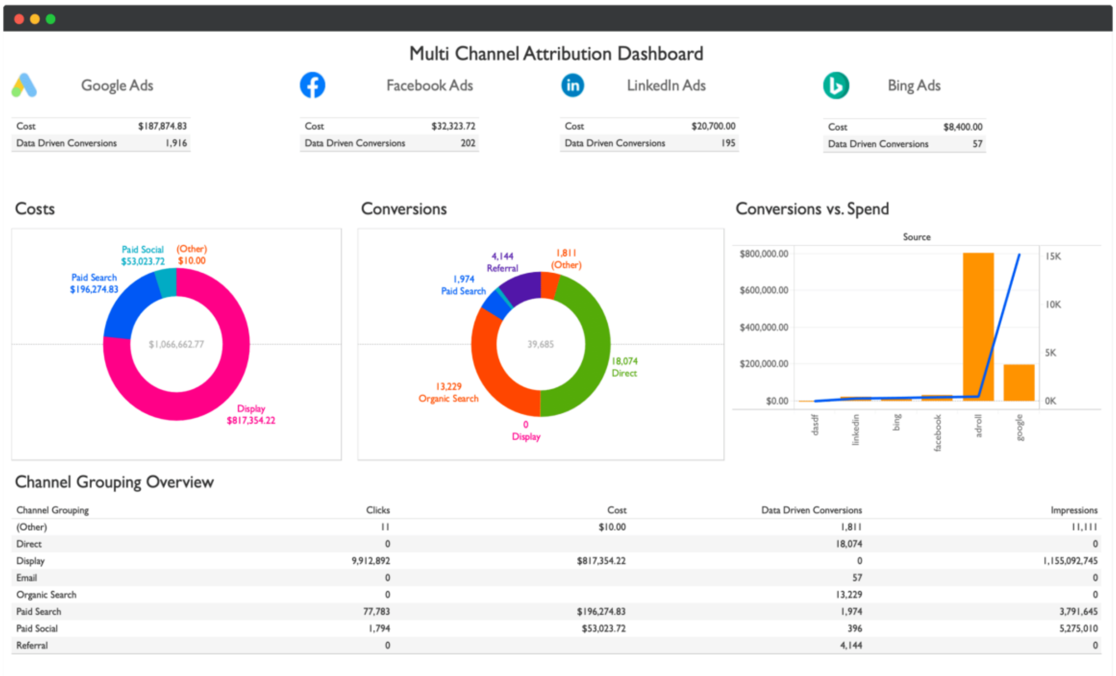

Figure 7. *Tableau Dashboard [27].*

Tibco Spotfire

Through immersive dashboards and cutting-edge analytics apps, TIBCO Spotfire allows decision-makers throughout the company to explore and visualize new data discoveries. Furthermore, with predictive analytics, integrated data science, geolocation analytics, and real-time streaming analytics, Spotfire offers scalable capabilities. Therefore, Spotfire is a platform that can grow in pace with company demands, never acting as a limitation for challenging requirements [48].

Looker

The contemporary firm must reimagine its approach due to Looker's outstanding Business Intelligence services, which is now a part of Google Cloud. Looker operates similarly to the web: it is a browser-based program that enables any employee to access the work of the best data analysts. However, Looker, which runs entirely inside databases, utilizes the newest, fastest analytic databases to provide quick and accurate findings. Furthermore, Looker's open architecture and lightweight design make it simple for developers to create, launch, and iterate on-demand bespoke apps [49].

Google Data Studio

A part of the corporate Google Analytics 360 suite, Google Data Studio is an online program made available by Google on March 15, 2016. It enables users to turn data into customizable dashboards and reports. Additionally, Google released a free version of Data Studio in May 2016 for individuals and small teams. Furthermore, the Google Marketing Platform includes Google Data Studio [50].

DOMO

According to Gartner, Domo has advanced significantly in the crowded market. The company cites the provider's swift deployment speed and focused consumer design attention as important criteria. This is because it wants to take advantage of the low-code or no-code revolution impacting decisions in corporate technology. However, Gartner asserts that the company trails market leaders due to its lack of a larger application ecosystem [51].

Alteryx

Alteryx is the only effective Business Intelligence platform for everyone, with self-service data preparation and fast predictive modeling. It streamlines the process of moving from data to reporting and dashboards, allowing for the publishing and dissemination of interactive analytics for use by both internal and external parties. Furthermore, the complete analytics lifecycle can be automated with Alteryx, from automated prep & blend through no-code and low-code data science [52].

Amazon QuickSight

By asking questions in simple English, exploring through dashboards and reports, or automatically looking for trends and anomalies using computer vision, Amazon QuickSight enables all organization employees to understand user data. It allows for natural-language queries, utilizes machine learning for visual presentation, enables accurate predictions and evaluations, and incorporates graphs, charts, reporting tools, advanced dashboard content creation, and speech recognition capabilities to enhance customer experience and access new market opportunities [53].

ThoughtSpot

In 2021, ThoughtSpot will launch a new "developer playground" that will provide businesses with the resources they need to create cutting-edge data applications. This is just one illustration of how the company realizes its customer-centric strategy, which Gartner highly commends in their study. Additionally, scalability and commercial acceptance as an enhanced analytics platform are mentioned as additional features. However, the research company warns that ThoughtSpot requires a more comprehensive data and analytics ecosystem [54].

Infor Birst

Infor Birst is an effective and highly regarded tool for handling an organization's data analytics requirements and digitally transforming complex data environments. The user experience with the tool has been excellent, and its enterprise reporting features, data visualization capabilities, and exploration features have significantly streamlined working environments. Its Business Intelligence capabilities empower organizations to increase agility, profitability, and operational efficiency. Additionally, it is more scalable and effective compared to other systems [55].

Apache Superset

Apache Superset is an open-source data analysis and visualization tool that can handle data at a petabyte scale (big data). It originated as a hackathon project by Maxime Beauchemin, the founder of Apache Airflow, while working at Airbnb. In 2017, the application was accepted into the Apache Incubator program. Furthermore, other top technology firms, including Dropbox and Lyft, have made significant donations to the initiative in addition to Airbnb. In 2021, Superset completed the incubation program and was elevated to the status of a top-level project at the Apache Software Foundation [56].

Splunk

Splunk is an accessible analytics program suitable for all types of businesses. It provides dashboards, plugins, automated data enrichment, monitoring, and alarms. Additionally, it offers special features such as data integration from multiple sources and insights into various business operations [57].

Pyramid Analytics

Pyramid Analytics OS is a customizable analytics platform that offers information and analysis tools based on user requirements and skills, while maintaining all data as a single resource. It provides enterprise-wide specific solutions for all users within organizations. Furthermore, Pyramid Analytics OS helps organizations prepare for future intelligence and technological challenges of digital transformation. It is an analytics platform accessible from anywhere and on any device. It consists of six distinct analytic modules (Model, Formulate, Discover, Visualize, Display, and Release), as well as an administrative board and content management system, to provide a fully integrated analytical environment [58].

Figure 8. *Pyramid Analytics [58].*

Figure 8 showcases the Pyramid Analytics platform, which is a versatile analytics tool that can be accessed on any device and in any environment. It encompasses six analytics modules, a management console, and a content management system, offering a comprehensive analytics experience.

3.3 Selected 13 SPC software

Based on the primary study and selection criteria [1], a total of 13 SPC software options have been selected for the case company, Valmet Automotive EV Power OY. In this section, a brief description of the primarily selected 13 SPC software will be provided. Table 3 presents the primary selection of the 13 best SPC software options for the case company.

Table 3. *Primary selection of 13 best SPC software for the case company.*

WinSPC
Predisys Analytical Suite
Enact
SPC for Excel
DataLyzer Spectrum SPC
IQMS MES
Intuitive ERP
iPASP Cloud SPC
RealTime SPC(Minitab)
Synergy SPC
SQCpack
ProFicient
QDM SPC System

At this point, I am briefly introducing 13 SPC software:

WinSPC

WinSPC helps manufacturers produce high-quality goods at an affordable price. Real-time Statistical Process Control (SPC) is used to monitor processes for unexpected changes. When a change is detected, WinSPC responds appropriately by assisting customers and their production team in preventing scrap and rework. It can direct employees to take remedial action, notify a supervisor via mobile device, adjust machine parameters, and more [58].

Predisys Analytical Suite

Predisys develops solutions for quality assurance, test data management, and manufacturing Business Intelligence, aiming to improve process efficiency, product quality, reduce compliance costs, and enhance manufacturing visibility across the supply chain. Predisys Statistical Process Control software is utilized by companies in various industries, including automotive, electronics, machinery, medical devices, and pharmaceutical sectors [59].

Enact

Enact is a cloud-native quality platform with Statistical Process Control (SPC) that has been recognized by Frost & Sullivan for its product leadership. Enact supports users in centralizing and standardizing operational data to empower on-site and off-site staff, boost efficiency, reduce costs, and enable faster and better decision-making. It is designed for quick setup and execution, transforming how users perceive their quality data regardless of their industry [60].

SPC for Excel

SPC for Excel is a user-friendly yet powerful SPC and statistical analysis software that supports process optimization initiatives in any industry, regardless of the user's skill level. It provides all the necessary charting and analysis tools, such as hypothesis testing, gage R & R, Pareto diagrams, histograms, data transformation, control charts, regression, DOE process capability, distribution fitting, and more. SPC for Excel is widely used in various industries and educational institutions worldwide by individuals interested in statistical data analysis, process improvement, Six Sigma, lean, and quality, ranging from beginners to black belts [61], [62].

DataLyzer Spectrum SPC

DataLyzer Spectrum SPC is a web-based SPC software that offers audit traceability for ISO and IATF16949 compliance, real-time data input, and rapid operator feedback. It integrates CAPA, OEE, FMEA, and MSA. Over 3000 companies worldwide utilize the SPC module of DataLyzer Spectrum SPC [62].

IQMS MES

IQMS MES is a fully-featured Manufacturing Execution software designed to support SMEs, enterprises, and agencies. It provides comprehensive solutions, combining resource management, forecasting, supplier management, and quality control in one system [63].

Intuitive ERP

Intuitive ERP, an Aptean ERP system, is built on the idea of supporting standard business cycles while offering adaptable and reasonably priced underlying technology. The software is developed using Microsoft technologies and incorporates well-established manufacturing and accounting procedures outlined by APICS and GAAP. It provides mid-market manufacturers with highly sophisticated solutions and financial value, featuring an intuitive user interface [64].

iPASP Cloud SPC

iPASP SPC enters industry 4.0 and supports a large amount of data in IIoT (Industrial Internet of Things) scenarios and high-precision detection data. It helps detect subtle changes in quality, whether through post-login analysis or real-time monitoring alerts, and provides high-quality output for factories. Furthermore, it features a user-friendly interface and visualization charts that help analyze the possibility of anomalous quality, increase inspection effectiveness, and decrease compliance inspection [65].

RealTime SPC(Minitab)

RealTime SPC (Minitab) offers the most effective analytical engine and smooth data automation. It is backed by the Minitab® Statistical Software control charts and analysis tools, which have been used by top firms for 50 years. All aggregated, blended, and quality data, including I-MR-R/S; Xbar-R; Xbar-S; I-MR; C, U, P, and NP, are instantly monitored through real-time control charts and dashboards. Control charts and dashboards are automatically updated in real-time for optimum operations and reporting, using collaborative tools for sharing insights and identifying concerns and underlying causes [3], [66].

Synergy SPC

The Zontec Synergy SPC software Suite offers a variety of real-time software options to meet the requirements of manufacturers from all industries. Synergy SPC products are easy to use and install. Additionally, Zontec Synergy values instant feedback and notifications, while also believing in the robustness and capacity of the user's approach. Utilize powerful SPC tools to increase productivity, reduce waste and rework, and improve quality [67].

SQCpack

Companies can leverage the proven Statistical Process Control tool SQCpack to utilize data processing for quality management objectives. SQCpack is a simple and expandable package that provides all the necessary tools to improve performance levels, adhere to important quality standards, reduce variability, and enhance profitability [68].

Proficient

Driven by a central SPC engine, ProFicient enables quality improvements on the manufacturing floor and across the organization. Utilize the on-premises solution to enhance accurate data collection and processing, effective management, long-term corporate strategy, and streamlined reporting. The cloud-based counterpart, ProFicient on Demand, offers a comprehensive set of SPC tools for assessing and controlling the capability and performance of production processes. Utilize the ProFicient dashboard view of KPIs and data to identify wasteful areas, hidden expenses, and improvement opportunities. Extend lines, locations, and vendors with quickly customizable reports and multi-layer data mining. Additionally, data slicing and dicing throughout the organization can provide strategic insights that can transform processes and enhance customer satisfaction [69], [70].

QDM SPC System

QDM SPC is a practical approach suitable for both small and large OEMs and producers to collaborate, analyze, and improve performance. QDM utilizes a centralized server for data storage and unification. This data is then accessible for real-time surveillance, assessment, monitoring, and issue resolution. Real-time monitoring of the production line provides continuous insight into the quality of user manufacturing. Identify out-of-specification components and trends with QDM. QDM provides both personalized and automatic reporting [70], [71].

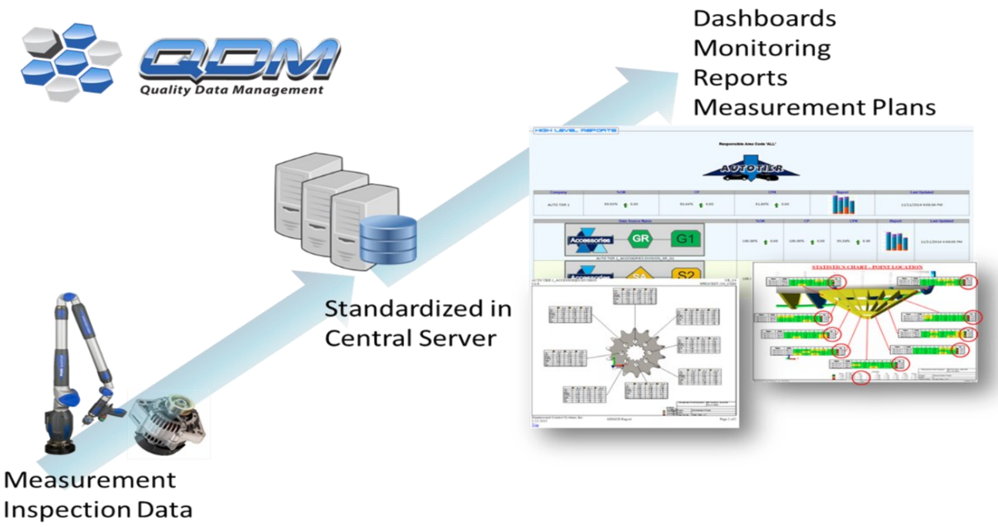

Figure 9. *QDM SPC System work strategy (Single Site - Basic Setup).*

Figure 9 depicts the diagram of the Single Site Basic Setup of the QDM SPC System. This setup is designed to facilitate small businesses and inspection labs in consolidating their data into a centralized server, thereby enabling convenient data standardization, reporting, and real-time monitoring. To cater to specific business requirements, customized modules can be incorporated into the basic setup.

4. Tool selection for the case company

In this chapter, I will discuss the different stages of my research, work strategy, and screening process based on my target. My objective is to narrow down the selection to five potential BI tools and three SPC software options for the company. I will delve into the various stages of the research, including the primary study, calculation methods, and phase screenings conducted to identify the best BI tools and SPC software for the company. Additionally, I will provide detailed explanations of the calculation methods and Python coding utilized in each stage.

4.1 The different stages of the research

To identify the best BI tools and SPC software for the case company, I have organized my research into several stages. In Figure 10, you can see an overview of these stages, which include Section 4.2: Primary study, Section 4.3: Calculation methods, Section 4.4: Phase Screening 1 - Selection of the best 30 BI tools for the company, Section 4.5: Final Screening 1 - Selection of the best 5 BI tools for the company, and Section 4.6: Final Screening 2 - Selection of the best 3 SPC software for the company. In the following sections, I will provide a detailed explanation of each stage.

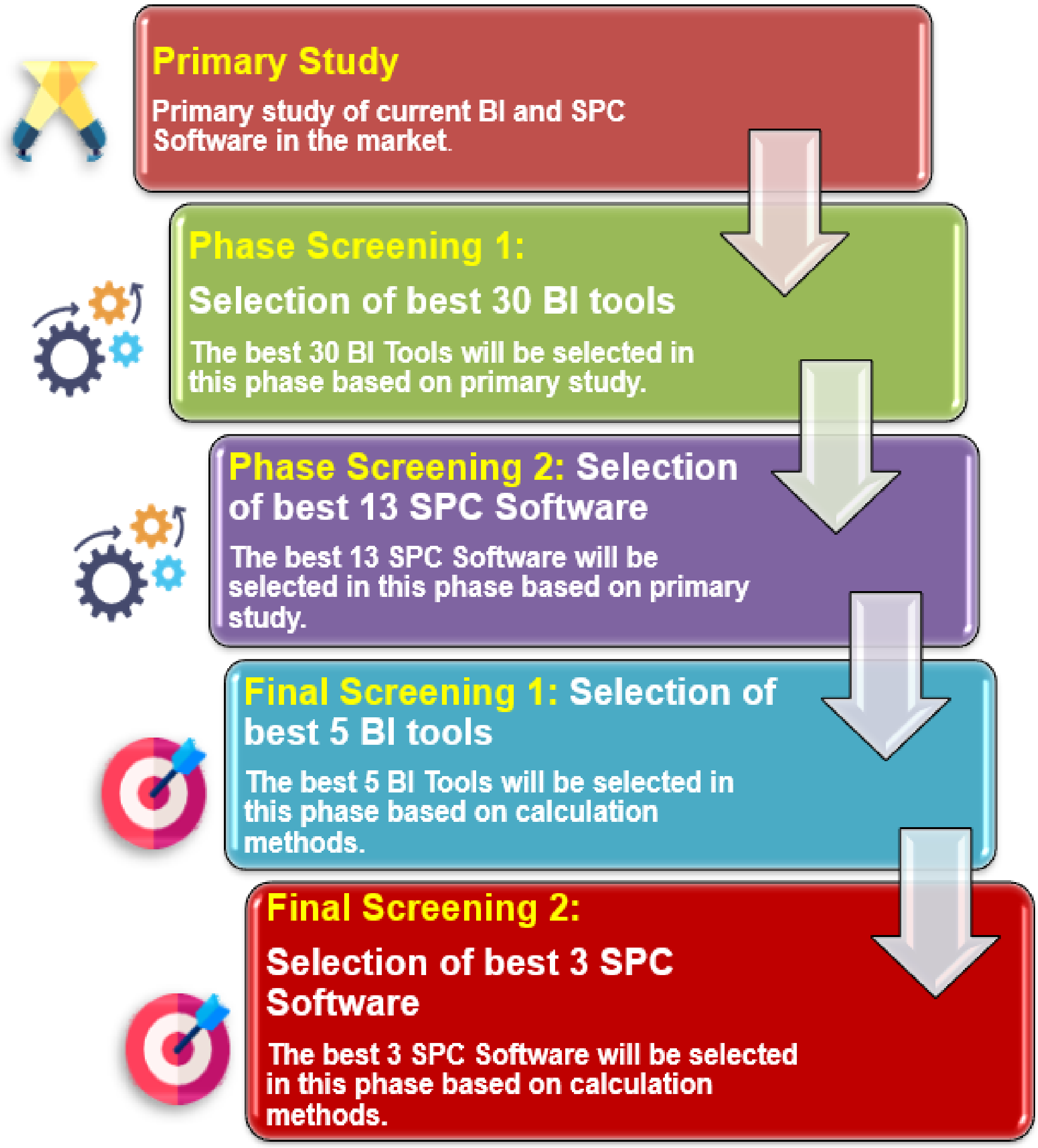

Figure 10. *The different stages of the research to find out best tools for the company.*

Figure 10 illustrates the various stages of the research process employed to identify the most suitable tools for the company. These stages include the primary study, calculation methods, and multiple screening phases.

4.2 Primary study

In this section, I will present the assessment techniques I employed in my thesis. I will also introduce the preliminary research, selection, and assessment methods. Figure 10 provides an overview of the evaluation steps. Through preliminary research, I selected 30 BI tools from a pool of over a hundred for the selection process. In the final step, I chose five BI tools for the evaluation phase. Similarly, I identified three SPC software tools out of the 13 options available for the case company.

The internet served as the primary source of information, including web searches and browsing through numerous websites. These sources were instrumental in selecting the desired tools. I based my selection of the 30 BI service providers on information gathered from their websites, blogs, and relevant news articles. Key factors at that time included the visual appeal of the websites and the ease of accessing information about the vendors' BI solutions. Additionally, I consulted company documents, blog posts, and news stories to verify the companies' viability as participants in the BI industry.

The initial research for this thesis began in May 2022. The next phase involved examining the market for BI and analytics solution providers. I extensively reviewed hundreds of web pages to gather first-hand information about BI solution providers. These web pages were primarily vendor websites. Furthermore, I relied on blog posts from platforms such as Quora and news websites like Louhia to gain a comprehensive overview of the market for BI and analytics tools. Additionally, I consulted various peer-driven rating and review platforms to gather software information and public reviews. Some of these platforms include:

- www.capterra.fi
- www.gartner.com
- www.softwaresuggest.com
- www.getapp.com

Those are the leading software evaluation websites.

Table 4 showcases the selection process for suppliers of Business Intelligence solutions, presenting the thirty BI tools and their corresponding vendors. The table demonstrates that the selection process prioritized suppliers capable of providing BI solutions that are in line with the project's goals and objectives.

Table 4. *Thirty Business Intelligence Tools and their vendors' information.*

30 BI tools	Solution Provider/Vendor
Zoho Analytics	Zoho
Microsoft Power BI	Microsoft
Yellowfin	Yellowfin BI
SAP BusinessObjects BI Suite	SAP
MicroStrategy	MicroStrategy
Board	Board International
Pentaho	Hitachi Vantara
Jaspersoft	Jaspersoft
QlikView	Qlik
Information Builders	TIBCO Software
IBM Cognos Analytics	IBM
Dundas BI	Dundas Data Visualization, Inc
Style Intelligence	InetSoft
Tellius	Tellius, Inc.
Logility	Logility, Inc.
Oracle Analytics Cloud	Oracle
SAS	SAS Institute
Sisense	Sisense
Tableau	Tableau Software
Tibco Spotfire	Tibco Spotfire
Looker	Looker Data Sciences, Inc.
Google data Studio	Google
DOMO	Domo, Inc.
Alteryx	Alteryx
Amazon QuickSight	Amazon
ThoughtSpot	ThoughtSpot
Infor Birst	Infor
Apache Superset	Apache Software Foundation
Pyramid analytics	Pyramid analytics
Splunk	Splunk Enterprise

Table 5 presents the selection of suppliers offering analytics solutions, showcasing thirteen SPC software options and their respective vendors. The table demonstrates that the selection process focused on identifying suppliers capable of providing analytics solutions that align with the project's specific requirements and specifications. Furthermore, the table provides crucial information about each software's vendor, facilitating well-informed decision-making.

Table 5. *Thirteen SPC Tools and their vendor's information.*

13 SPC software	Solution Provider/Vendor
WinSPC	Martin Přikryl
Predisys Analytical Suite	Predisys
Enact	InfinityQS
SPC for Excel	BPI Consulting
DataLyzer Spectrum SPC	DataLyzer International
IQMS MES	IQMS
Intuitive ERP	Aptean
iPASP Cloud SPC	Advant Analytics Tactics
RealTime SPC(Minitab)	Minitab, LLC
Synergy SPC	Zontec
SQCpack	PQ Systems
ProFicient	InfinityQS
QDM SPC System	Dimensional Control Systems

During this step, I looked for and analyzed relevant literature to identify existing knowledge. Simultaneously, I had several meetings and discussions within the organization to establish a common objective. These sessions aimed to understand the research gap in the field and assist in identifying research problems, solutions, and the development of the thesis. Through this stage, the purpose and scope of the concept became more specific. Additionally, I acknowledged that the evaluation and calculation methods are instrumental in selecting BI tools and analytic software for the company.

4.3 Calculation methods

This section will demonstrate how I have completed my calculation method.

In addition, I establish a scoring system for each capability and regularly evaluate each tool. Reviewing datasheets is one approach to assess specific capabilities. Conducting live demos and Q&A sessions can also help determine alternatives. Therefore, some capabilities need to be experienced firsthand in their respective environments [2], [3]. I use a matrix (shown below) to rate the functionality of each tool on a basic scale of 1 to 5. In this scale, 5 represents the highest value, while 1 represents the lowest. Moreover, effectiveness encompasses multiple features. Hence, I calculate a single capability score by averaging its respective features [2], [3]. Table 6 serves the purpose of showcasing how I rated each tool and calculated their overall weight, facilitating the selection process. The table provides a clear overview of the rating process and presents the total weight for each tool.

Table 6. *Rating the tools to find the total weight for each tool.*

Capabilities	Tool 1	Tool 2
Efficacy 1	4.13	3.75
Sub-Sections 1.1	5.00	3.75
Sub-Sections 1.2	2.50	2.00
Sub-Sections 1.3	5.00	5.00
Sub-Sections 1.4	4.00	4.00
Efficacy 2	3.50	4.00
Efficacy 3	3.00	4.00
Efficacy 4	4.40	4.53
Efficacy 5	3.50	4.20
Efficacy 6	4.00	4.00
Efficacy 7	4.50	4.40
Efficacy 8	2.50	3.50
Efficacy 9	4.00	4.50
Total Weight	**37.40**	**41.18**

After rating the tools based on these features, I proceed to create a shortlist. It is time to perform some calculations. I calculate the total weighted score to determine the overall evaluation of each tool [2], [3]. Table 7 provides an example of how the tools were rated and the total weighted score was calculated for each tool. This table demonstrates the quantitative evaluation criteria used in the selection process and aids in assessing the suitability of the tools for the project.

Table 7. *Rating the tools to find the total weighted score for each tool.*

Capabilities	Tool 1	Tool 2
Efficacy 1	30.90	30.88
Efficacy 2	26.18	32.94
Efficacy 3	22.44	32.94
Efficacy 4	32.92	37.26
Efficacy 5	26.18	34.59
Efficacy 6	29.92	32.94
Efficacy 7	33.66	36.23
Efficacy 8	18.70	28.82
Efficacy 9	29.92	37.06
Efficacy 10	28.99	35.41
Total Weighted Scored	**279.83**	**339.08**

Next, it is important to identify the "keepers" among the tools. In this case, tool 2 emerges as the top-scoring tool. However, tool 1 is on the edge of being excluded from the selection process because, despite performing well in certain areas, it falls short in others. These top-scoring tools meet the specified technical criteria and exhibit the desired attributes [2], [3].

Calculations

If there is a sub-section for an efficacy:

$$Z = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$$

$$Z = \frac{\sum_1^n x_i}{n} \quad (1)$$

x = elements of an efficacy

x_i = Individual element of efficacy, i.e., the value of the i^{th} element of the efficacy.

n= total number of elements

Otherwise,

Z = x

Total weight for all efficacies:

$$Y = Z_1 + Z_2 + Z_3 + \cdots + Z_n$$

Weight, Y = $\sum_1^n Z_i$ (2)

Total Weighted Score:

Weighted Score for efficacy 1:

W= (Weight / 5) * Score individual efficacy score

W=(Y/5) * Z

Total Weighted Score,

$$X = W_1 + W_2 + \cdots + W_n$$

$$X = \sum_1^n W_i$$

The cost factor has intentionally been disregarded until now, specifically in the selection of BI tools. However, when it comes to choosing the best SPC software for business use, cost considerations have been taken into account. The selection of the "keepers" among the BI tools was solely based on their technical capabilities, without considering the price [2], [3], [38].

Price is undoubtedly an important consideration in most businesses, taking into account all expenses that contribute to the overall cost of owning any item. It goes beyond the obvious upfront licensing fees. While open-source technologies may appear "free" due to the absence of license fees, it is important to consider all expenses associated with them. These include maintenance and support renewal, training for users and administrators, the number of administrators required for deployment, management, and upgrades, the technical skills required for platform administrators and engineers, and the overall cost of such personnel. Additionally, any actual additional hardware costs should also be considered [2], [3].

There are numerous advantages that are evident and relatively easy to quantify. However, it is important to also consider the "soft" advantages that are more challenging to measure. For example, would the company benefit from increased team engagement leading to employee satisfaction, improved transparency, compliance with industry standards, and enhanced reporting processes with accurate data, resulting in more informed decision-making? [2], [3].

4.4 Phase Screening 1: selection of best 30 BI tools for the company

In this section, I will discuss the selection of the top 30 BI tools for the case company, which was based on the primary study and calculation methods previously described. The preliminary study involved gathering information online, generating an overview of the available BI tools in the market by conducting web searches and exploring numerous websites. The selection of the 30 BI providers was made by considering the information obtained from their websites, blogs, and relevant news sources. During this process, key factors such as the layout and accessibility of information on the vendor's website played a significant role. Additionally, to assess the company's credibility as a participant in the Business Intelligence industry, I took into account their materials, blog posts, and news articles.

4.5 Final Screening 1: selection of best 5 BI tools for the company

In this section, I will explain the process of selecting the best 5 BI tools from the initial pool of 30 BI tools for the case company. To facilitate the selection process, I utilized a set of ten criteria, each consisting of multiple subsections. These criteria were labeled as Efficacy 1, Efficacy 2, and so on, for the purpose of calculation and presentation. Table 8 provides an overview of the criteria and subsections used in the selection of the best BI tools for the company, categorized according to Efficacy 1 to 10. Each efficacy includes specific criteria that were considered in the selection process to identify the most suitable BI tools.

Table 8. *The map out criteria for selecting the best 5 BI tools for the company.*

Capabilities	Map out criteria	Sub-sections of the map out criteria			
Efficacy 1	Software platform compatibility	Operation system	Language support	Screen Size and resolution of the software	Diverse data acceptance
Efficacy 2	Software configurability and customizability	Configurability	Customizability of coding		
Efficacy 3	Third-party software compatibility				
Efficacy 4	Public Review	www.capterra.fi	www.gartner.com	www.softwaresuggest.com	www.getapp.com
Efficacy 5	Flexibility to adapt to different techniques (Adaptability), versatility and usefulness				
Efficacy 6	Customer support				
Efficacy 7	User Experiences				
Efficacy 8	Community and Social media acceptance according to followers and likes				
Efficacy 9	Instruction materials, user guide, training and so on				
Efficacy 10	Other important capabilities:	Supports Big Data?	Computional and analytical abilities	Attractive visualization	Maintenance of security and confidentiality

The previous section has already outlined the methodology used for the primary computation, as discussed in [2] and [3]. In summary, each BI tool was scored based on its efficacy, and the desired outcome was obtained through the computation process. The computation process involved utilizing an Excel file and a Python program for calculation and visualization purposes. Detailed information regarding the Excel calculation and programming can be found in Annex A and Annex B, respectively.

After calculation, I have found the following best 5 BI tools for the company:

1. Microsoft Power BI
2. Sisense
3. QlikView
4. Tableau
5. Pyramid analytics

The list shows that Microsoft Power BI is the best of the best BI tools for Valmet Automotive EV Power Oy, Finland.

4.6 Final Screening 2: selection of best 3 SPC software for the company

In this section, I will discuss the process of selecting the best three SPC software options from the pool of 13 SPC tools available for the company. The selection process involved utilizing seven mapped-out criteria, each with its own subsections. To facilitate calculation and improve the visual presentation, I assigned labels to each criterion, such as Efficacy 1, Efficacy 2, and so on. These criteria were used to evaluate and compare the SPC software options.

Table 9 provides an overview of the criteria and subsections utilized in the selection of the best SPC software for the company. The table is organized according to efficacy 1 to 7, with each efficacy containing specific criteria for evaluating and choosing the most suitable SPC software option.

Table 9. *The map out criteria for selecting the best SPC software for the company.*

Capabilities	Map out criteria	Sub-sections of the map out criteria		
Efficacy 1	Charts and data analysis tools			
Efficacy 2	Quality control (real-time)			
Efficacy 3	Customer support			
Efficacy 4	Cost effectiveness			
Efficacy 5	User Experiences			
Efficacy 6	Other important capabilities	Customizability	Attractive Visualization	Specifications
Efficacy 7	Public Review	www.capterra.fi	www.getapp.com	

The main calculation process involved applying various calculations and methods to determine the desired result. Specifically, I assigned a score to each SPC software based on its efficacy according to the selection criteria. The scoring was done on a scale of 1 to 5 [2], [3]. The calculations were primarily performed in an Excel file, and for the overall calculation and visualization, I utilized Python programming.

Please note that the detailed calculations and programming can be found in the Annex section of the thesis.

After conducting the calculations, the following three SPC software options were identified as the best choices for the company:

1. SPC for Excel
2. ProFicient
3. QDM SPC System

Based on the calculations and programming, it has been determined that "SPC for Excel" is the top-performing SPC tool for the company.

Excel calculations

I have used Excel and Python programming to map out the BI and SPC tools. In Excel, I included a detailed criteria map (including subsections), scoring procedures, and calculation formulas on the BI tools sheet. All the scoring and calculations are present. I scored each tool according to each criterion and used formulas to obtain the final weighted score for each tool. The subsections in the BI were scored, and the total score was returned to the BI calculation sheet to determine the final weighted score.

Similarly, all the scoring and calculations for the SPC software are on the SPC sheet in Excel. Each tool was scored according to each criterion, and formulas were used to calculate the final weighted score. The subsections in the SPC were scored, and the total score was returned to the SPC calculation sheet to determine the final weighted score [2], [3].

The Python Coding for software selection process

Python programming language was utilized for calculating and mapping out the BI and SPC software, particularly for calculating the efficacies of multiple subsections.

I created the m_avg(lists) function to find the average. The function takes a list parameter called lists, which contains values. My goal was to calculate the average of these values and return it as a float. To achieve this, I iterated through the list, summing up the values in each sublist. Then, I divided the sum by the length of the sublist and stored the resulting average in a new list. Finally, I returned the list of average values as the output of the function.

For the dic_create(list1, list2) function, it requires two parameters. The first parameter, list1, represents the keys of a dictionary, while the second parameter, list2, represents the values of the dictionary. In this function, I created a dictionary by zipping the keys and values together using the zip() function and the dict() constructor. The resulting dictionary is then returned.

Moving on to the diction_value(dictiony) function, it takes a dictionary parameter called dictiony. My intention with this function was to calculate the sum of the values in the dictionary. To do this, I utilized the sum() function, which allowed me to add up all the values in the dictionary. The sum is then returned as a float.

Next, the another_dict(srt, dicts) function expects two parameters. The first parameter, srt, is a string representing a key in a dictionary. The second parameter, dicts, is a dictionary for which I needed to calculate the sum of the values. Inside the function, I retrieved a list of values from the dictionary using the values() method. Then, by applying the sum() function to the list of values, I obtained the sum as a float. This sum is returned as the output of the function.

Lastly, the final(tsil1, tsil2, tsil3) function takes three parameters: tsil1, tsil2, and tsil3. Within this function, I performed a series of calculations to determine a weighted score. This involved creating dictionaries, calculating average values, and applying a specific formula. Ultimately, I returned the final weighted score as a float.

To determine the final expected result, I used several functions and calculations. The names of the efficacies are listed as "efficacy1", "efficacy2", and so on in a list called "keys". Another list, "BI", contains the names of the 30 BI tools.

Now the machine is ready to launch, and I will use these functions to calculate the final weighted score for each tool. In Program 1, I can see the highlighted part of the coding functions used to calculate the final weighted score for each tool.

```
zohobd = [[5,2.5,5,4], [4,3],[3], [4.3,4.4,4.6,4.3],[3.5], [1], [4.5], [2.5], [1], [5,3,3.5,4]]

zoho=final (zohobd,keys, BI[0])

zoho

279.75
```

Program 1. *Example code to get the final score from a list contains scores of the zoho BI tools.*

In the "zohobd" lists, each list represents the scores for the subsections of the efficacies. These scores are obtained by passing the keys (efficacy names) and the name of the first BI tool from the list of tool names, BI[0].

Using the same approach, I have calculated the total weighted score for each tool. The name of each tool is used as a key, and its corresponding total weighted score is used as the value.

This process creates a dictionary of the 30 BI tools (Program 2).

```
best = sorted (thirty_BI_dictionary, key=thirty_BI_dictionary.get, reverse=True) [:1]

for i in best:

   print(i)

Microsoft Power BI
```

Program 2. *Example code of how I selected the best tool from 30 BI tools for the case company.*

In Program 2, I sorted the keys (names of the BI tools) based on their corresponding weighted values, allowing us to identify the tools with the highest weights among the 30 options.

For visualizing the findings, I utilized the matplotlib, seaborn, and NumPy libraries. Using the dictionary mentioned earlier, I created horizontal and vertical bar graphs to showcase the top five tools and the overall best tool out of the 30 BI options, as discussed in the findings section.

Similarly, I applied similar coding to determine the best three and the top-ranked SPC software for the company. The results were then visualized using horizontal and vertical bar graphs, as presented in the findings section.

4.7 Statistical Analysis

During the comprehensive analysis of the SPC tools and BI tools selection process for our case company, I conducted various statistical procedures, including descriptive statistical analysis, correlation analysis, hypothesis testing, and regression analysis.

Descriptive statistical analysis

For the descriptive statistical analysis, I calculated measures such as the mean, median, standard deviation, variance and identified outliers for both the SPC tools and BI tools. These results were visualized using box plots and Violin plots. Additionally, I gathered information about the DataFrames using the .info() method.

Figure 11 and Figure 12 displays a box plot representing the descriptive statistics of 30 BI and 13 SPC software. The box plot provides information about the distribution of data for each tool. The red dots on the plot indicate the presence of outliers, which are data points that deviate significantly from the majority of the data. The title, labels, and adjustments in the plot ensure clear visualization of the descriptive statistics.

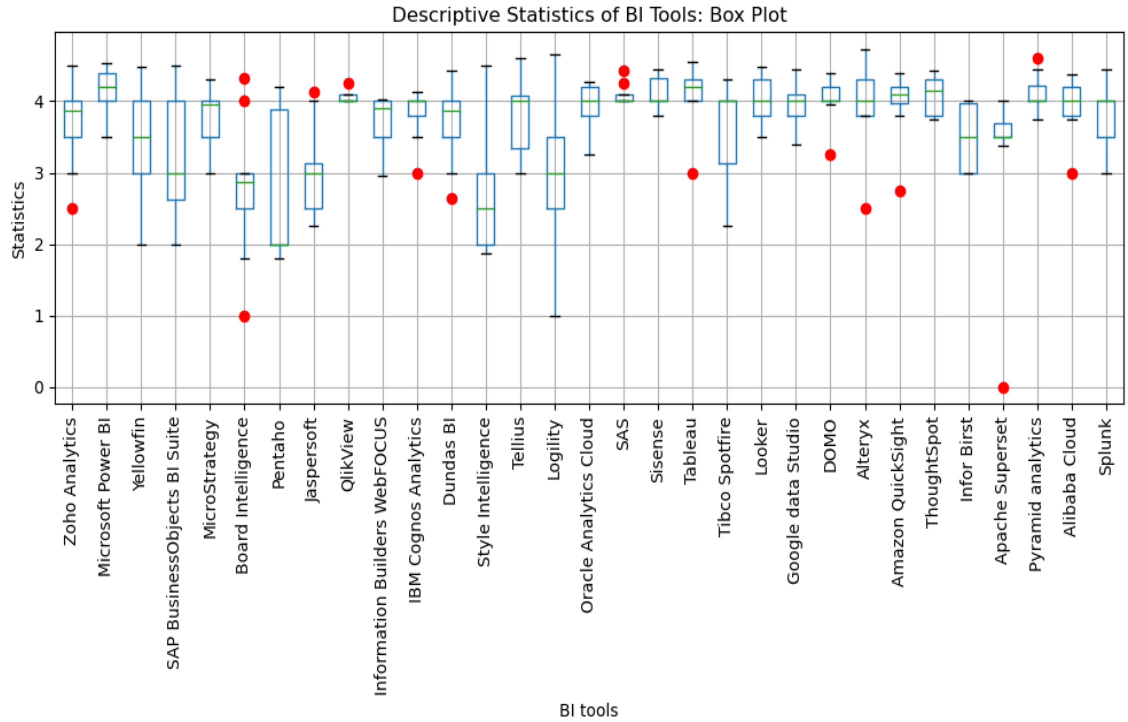

Figure 11. *Descriptive Statistics of BI Tools: Box Plot*

.

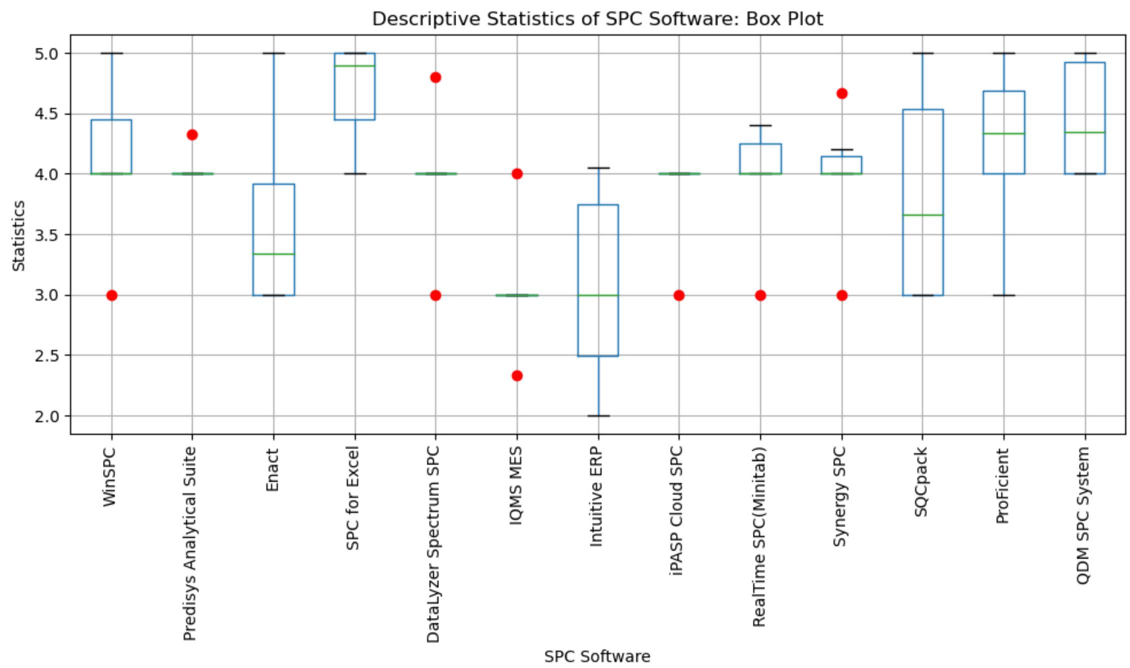

Figure 12. *Descriptive Statistics of SPC Software: Box Plot.*

Figure 13 and 14 present violin plots that depict the distribution of data for each of the 30 BI tools and 13 SPC software options respectively. Here I have present only one violin plot for each. The width of each violin reflects the density of data points, while the overlaid box plots provide additional information about the median, quartiles, and outliers. This visualization allows for a comprehensive understanding of the variability and distribution of data across the BI tools and SPC software.

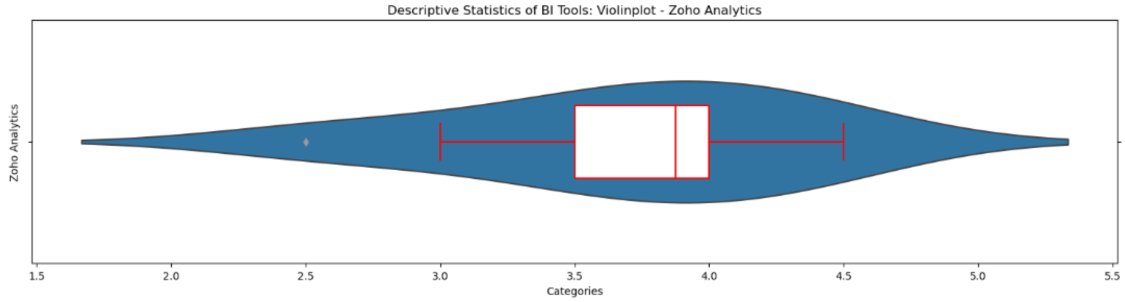

Figure 13. *Violin plot of Descriptive Statistics for Zoho Analytics (BI Tools). The violin plot showcases the distribution of data for all 30 BI tools.*

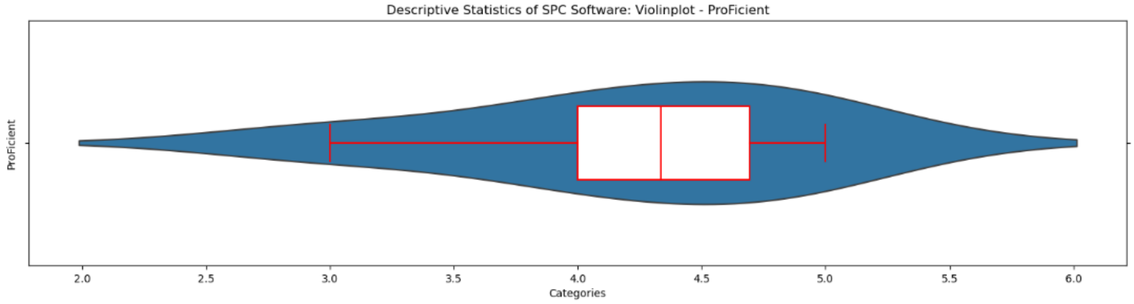

Figure 14. *Violin plot of Descriptive Statistics for Proficient (SPC software). The violin plot showcases the distribution of data for all 13 SPC software.*

The correlation analysis

In the correlation analysis, I examined the correlation matrices and visualized them for both the SPC tools and BI tools.

From Figure 15, I conducted an extensive analysis of 30 Business Intelligence (BI) tools and their correlations. The matrix reveals the interdependencies and relationships between these tools, providing valuable insights for decision-making. By examining the correlations, I gained a deeper understanding of how the BI tools interact and complement each other, enabling more informed choices in selecting and integrating the most suitable tools for specific business needs. Here are some key observations based on the correlation matrix:

- Zoho Analytics and Microsoft Power BI: These tools show a strong positive correlation of 0.87, indicating a strong relationship between them.

- Yellowfin and SAP BusinessObjects BI Suite: These tools exhibit a relatively high positive correlation of 0.88, suggesting a strong positive relationship.
- MicroStrategy and Board Intelligence: These tools have a relatively high positive correlation of 0.92, indicating a strong positive relationship.
- Pentaho and Jaspersoft: These tools demonstrate a high positive correlation of 0.89, suggesting a strong positive relationship.
- Oracle Analytics Cloud and SAS: These tools display a relatively high negative correlation of -0.87, indicating a strong negative relationship.

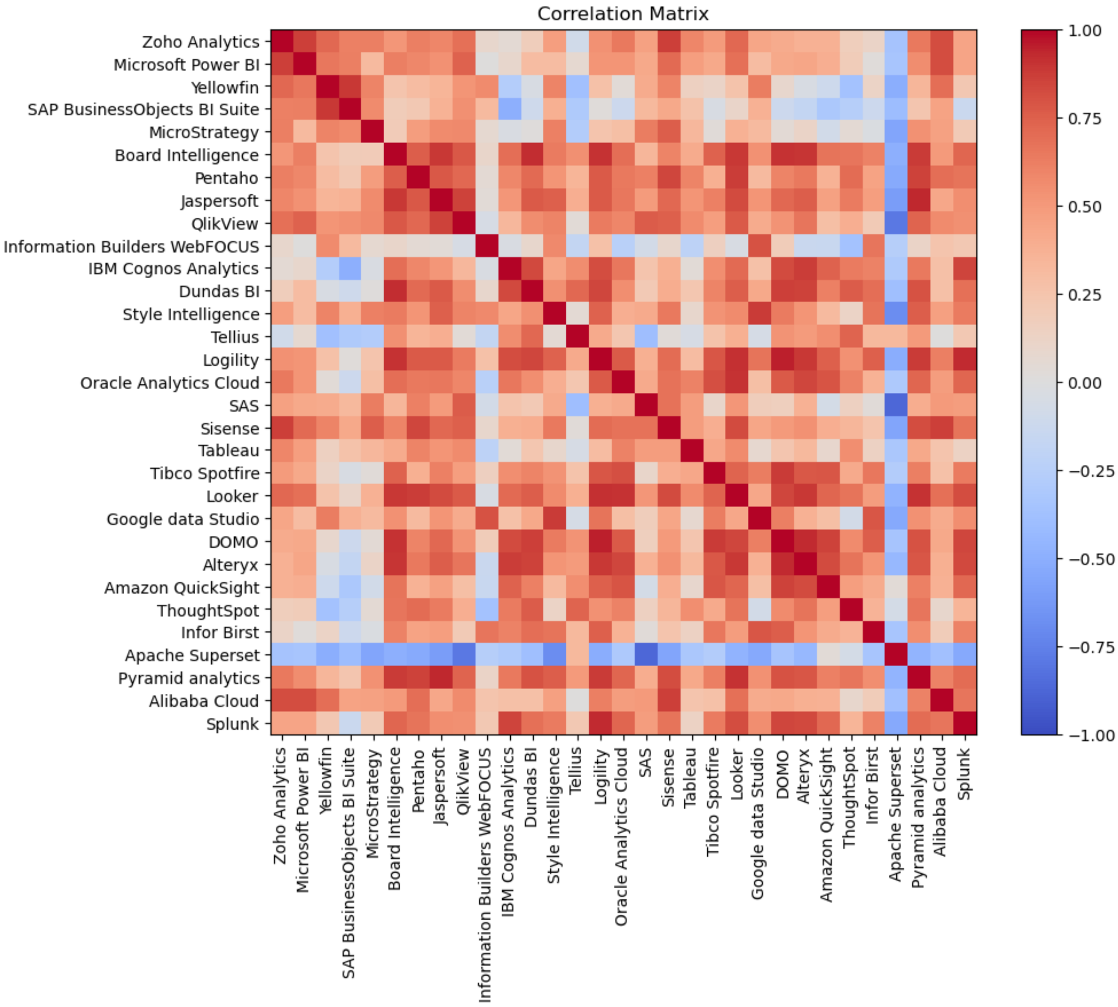

Figure 15. *Correlation Matrix of 30 BI tools: Insights into Interrelationships.*

From Figure 16, I analyzed the correlation matrix of 13 Statistical Process Control (SPC) software. The matrix provides insights into the interrelationships among these software tools, aiding decision-making processes. By examining the correlations, I gained a deeper understanding of how the SPC software interacts and complements each other, facilitating the selection of the most suitable tools for specific needs. Here are some key observations based on the correlation matrix:

WinSPC and ProFicient: These tools exhibit a high positive correlation of 0.79, indicating a strong positive relationship.

Enact and RealTime SPC (Minitab): These tools demonstrate a relatively high negative correlation of -0.85, indicating a strong negative relationship.

SPC for Excel and DataLyzer Spectrum SPC: These tools have a moderate positive correlation of 0.40, suggesting a moderate positive relationship.

IQMS MES and Intuitive ERP: These tools exhibit a relatively high positive correlation of 0.66, indicating a strong positive relationship.

QDM SPC System and Enact: These tools show a relatively high positive correlation of 0.65, indicating a strong positive relationship.

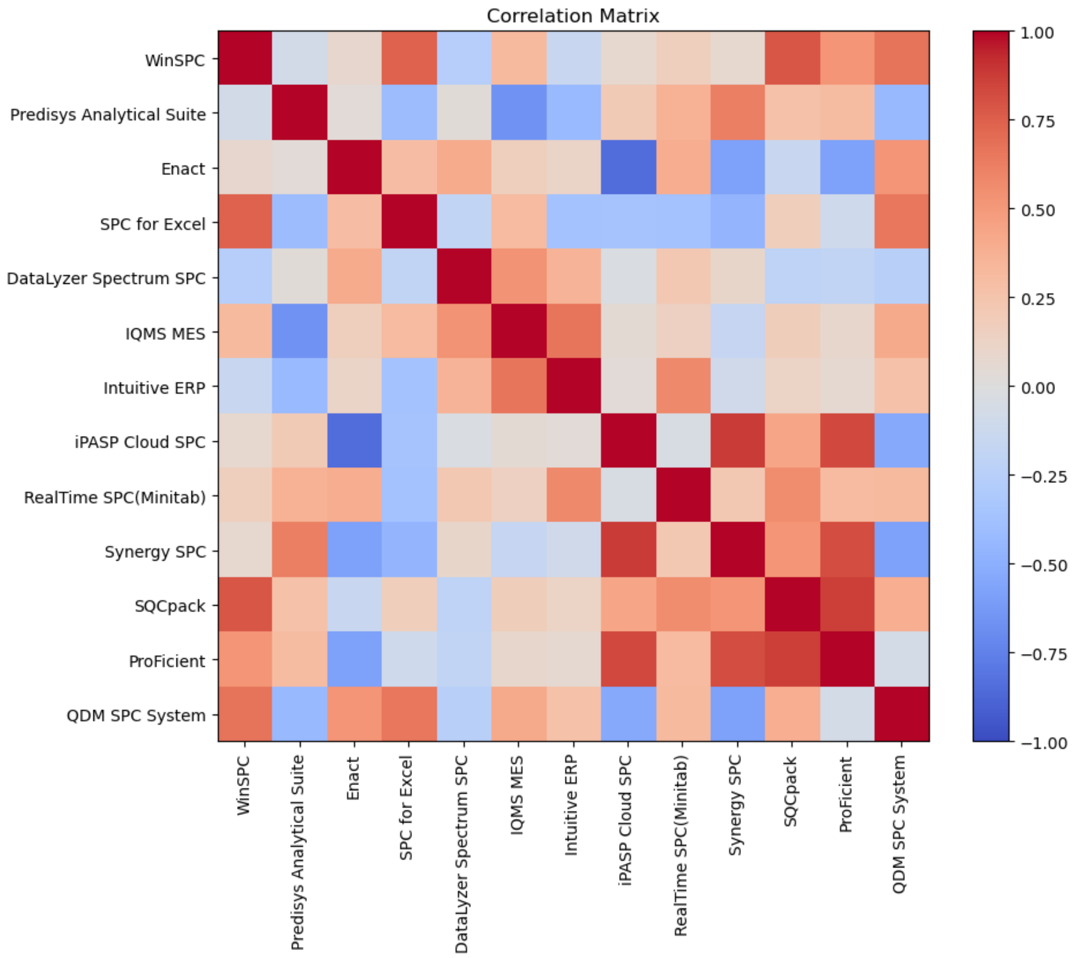

Figure 16. *Correlation Matrix of 13 Statistical Process Control (SPC) Software: Insights into Interrelationships.*

Hypothesis testing

Moving on to hypothesis testing, I created a list of all possible tool pairs and conducted hypothesis tests for each pair, separately for the SPC tools and BI tools. I compared the obtained p-values with the significance level to determine whether to reject or accept the null hypothesis. Specifically, I investigated whether there was a significant correlation between tool pairs in both the SPC tools and BI tools. Notably, we found that in the SPC tools, the null hypothesis was rejected for certain tool pairs, indicating a significant correlation. Similarly, in the BI tools, the null hypothesis was rejected for certain tool pairs, indicating a significant correlation. Below is the code snippet showcasing the implementation of the hypothesis testing:

```
import itertools

import scipy.stats as stats

# Creating a list of all possible tool pairs

tool_pairs = list(itertools.combinations(df.iloc[:-1].columns, 2))

# The significance level

alpha = 0.05

# Conducting hypothesis test for each pair of tools

for pair in tool_pairs:

    tool1 = pair[0]

    tool2 = pair[1]

    ratings1 = df.iloc[:-1][tool1]

    ratings2 = df.iloc[:-1][tool2]

    corr_coeff, p_value = stats.pearsonr(ratings1, ratings2)

    # Comparing the p-value with the significance level

    if p_value < alpha:

        print(f" Null hypothesis rejected. There is a significant correlation between {tool1}
and {tool2}.")

    else:

        print(f" Null hypothesis accepted. There is no significant correlation between {tool1}
and {tool2}.")
```

Output:
Null hypothesis accepted. There is no significant correlation between WinSPC and Predisys Analytical Suite.
Null hypothesis accepted. There is no significant correlation between WinSPC and Enact.
Null hypothesis accepted. There is no significant correlation between WinSPC and SPC for Excel.
………
Null hypothesis rejected. There is a significant correlation between Enact and iPASP Cloud SPC.
Null hypothesis rejected. There is a significant correlation between SQCpack and ProFicient.

Program 3. *Exploring the Predicted Efficacy Scores for BI Tools: An Analysis of Tool X*

The regression analysis

In this research, regression analysis was utilized to examine the correlation between predictors (tools) and efficacy scores in both SPC tools and BI tools. Linear regression was employed to analyze the relationship between predictors (tools) and efficacy scores in both SPC tools and BI tools. Moreover, Ridge regression was used to address multicollinearity and improve prediction accuracy in the models.

In the regression analysis, I selected the predictors (tools) from the DataFrames and identified the target variable (efficacy scores) for both the SPC tools and BI tools. I utilized the linear regression model in our analysis and fitted the predictors to the target variables separately for the SPC tools and BI tools.

Furthermore, I performed Ridge Regression Training and Efficacy Score Prediction for New Tools in both the SPC tools and BI tools. Successfully, I predicted the efficacy scores for the new tools in both cases. The predicted efficacy scores for the BI and SPC tools are as follows:

Predicted Efficacy Scores for Software X (SPC software):

	Software X
Efficacy 1:	2.80
Efficacy 2:	2.80
Efficacy 3:	3.89
Efficacy 4:	4.06
Efficacy 5:	4.17
Efficacy 6:	4.56
Efficacy 7:	4.69

Predicted Efficacy Scores for BI tool X:

	Software X
Efficacy 1:	4.11
Efficacy 2:	3.60
Efficacy 3:	4.40
Efficacy 4:	4.05
Efficacy 5:	3.71
Efficacy 6:	3.62
Efficacy 7:	4.03
Efficacy 8:	3.70
Efficacy 9:	3.71
Efficacy 10:	4.04

Moreover, I visually represented the predicted efficacy scores for the new tools in a figure in Figure 17 and Figure 18.

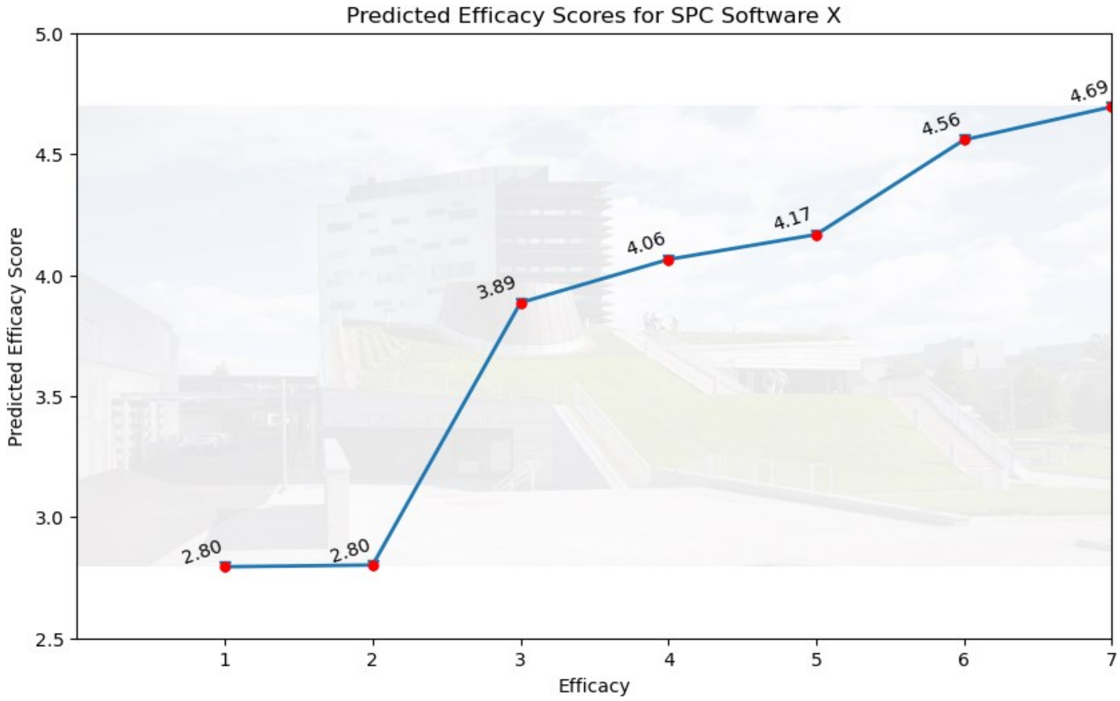

Figure 17. *Predicted Efficacy Scores for SPC software X.*

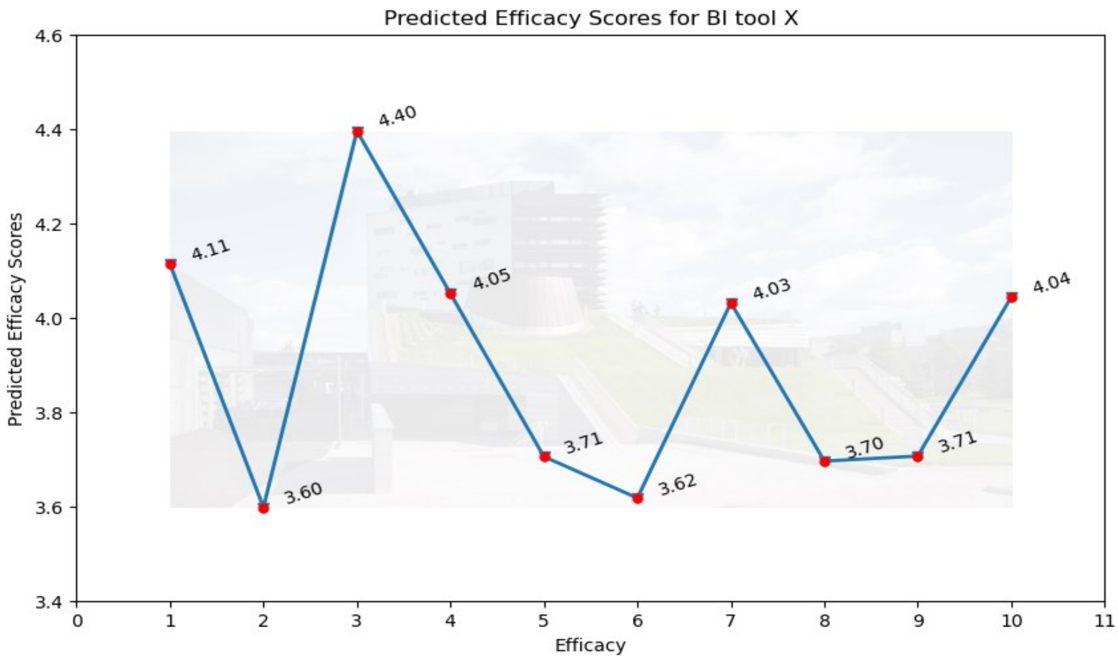

Figure 18. *Predicted Efficacy Scores for BI tool X.*

Model evaluation

To evaluate the performance of our models, I utilized the mean squared error (MSE) for both the SPC tools and BI tools. The results showed that the MSE values varied between the two cases, indicating differences in performance between the SPC tools and BI tools.

The evaluation of the linear regression and ridge regression models on the training and testing sets yielded promising results. Both models demonstrated relatively low mean squared error (MSE) values, with a MSE of 0.02 for the training set and 0.61 for the testing set. The similarity in MSE values suggests that both models perform comparably well in predicting the efficacy scores. Although these low MSE values indicate good performance, it is crucial to conduct further evaluation and validation to ensure the reliability and generalization capabilities of the models. The results of the MSE scores for the BI tools are as follows:

Linear Regression (Training Set) MSE: 0.02

Linear Regression (Testing Set) MSE: 0.61

Ridge Regression (Training Set) MSE: 0.02

Ridge Regression (Testing Set) MSE: 0.61

The evaluation of the linear regression and ridge regression models on the training and testing sets yielded promising results. Both models demonstrated relatively low mean squared error (MSE) values, with a MSE of 0.05 for the training set and 0.11 for the testing set. The similarity in MSE values suggests that both models perform comparably well in predicting the efficacy scores. Although these low MSE values indicate good performance, it is important to conduct further evaluation and validation to ensure the reliability and generalization capabilities of the models. However, due to time constraints and the scope of my thesis, I am concluding the analysis at this point. The results of the MSE scores for the SPC software are as follows:

Linear Regression (Training Set) MSE: 0.05

Linear Regression (Testing Set) MSE: 0.11

Ridge Regression (Training Set) MSE: 0.05

Ridge Regression (Testing Set) MSE: 0.11

5. Results and discussion

In this chapter, I will present the findings and validate the selected tools for the case company. I will analyze the results and provide a comprehensive discussion on the chosen BI tools and SPC software.

To begin, I will conduct a SWOT analysis of the top five BI tools and three best SPC tools identified through the findings. This analysis will highlight the strengths, weaknesses, opportunities, and threats associated with these tools.

Throughout this chapter, I will delve into the details of the findings, including the best five BI tools and three best SPC tools for the company. I will explain how these tools function, their uses, and the advantages they offer.

Additionally, I will address the validation process conducted to ensure the suitability and effectiveness of the selected tools. This validation will involve assessing various factors such as compatibility with the company's requirements, performance evaluation, and user feedback.

Furthermore, this chapter will cover other pertinent aspects related to the findings, including discussions on the potential implementation challenges, considerations for successful adoption, and recommendations for optimizing the utilization of these tools within the company's operations.

5.1 Findings

In the findings section, I present the findings regarding the best BI tools and SPC software for the case company.

Findings 1: Best 5 BI tools for the company

Figure 19 displays a chart that compares the top 30 BI tools for the company, along with their corresponding scores. Based on my analysis, the best five BI tools for the company are as follows:

1. Microsoft Power BI
2. Sisense
3. QlikView
4. Tableau

5. Pyramid Analytics

In Figure 19, the best five BI tools are represented by violet color, while the remaining tools are shown in dark cerulean color.

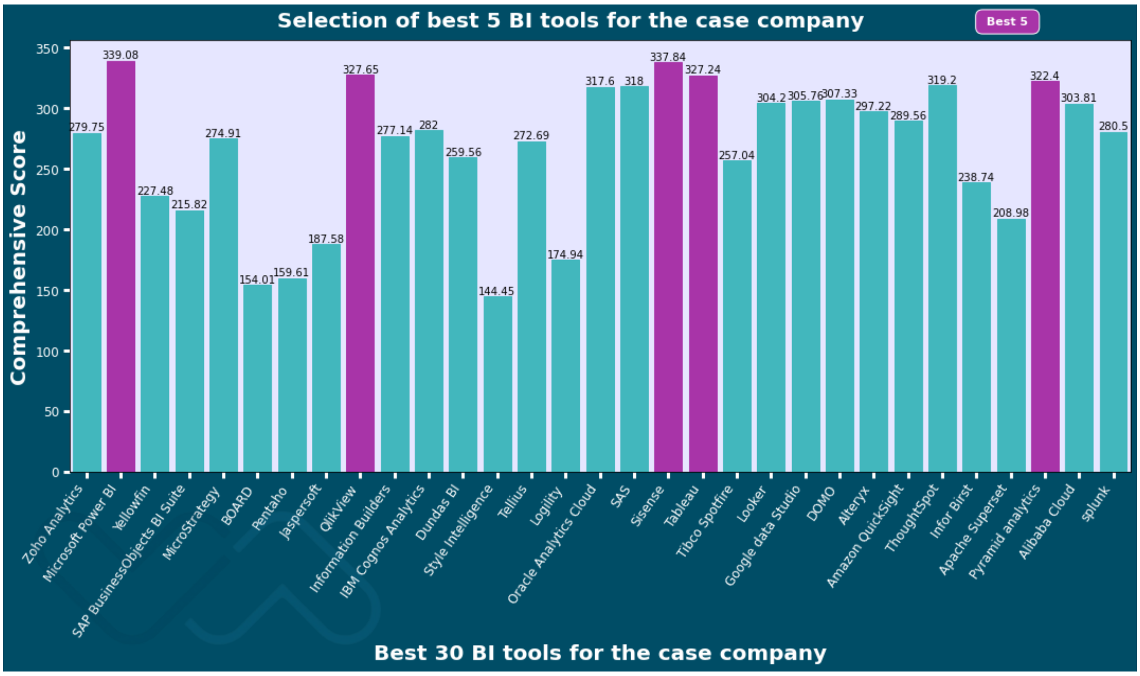

Figure 19. *Best 5 BI tools from best 30 (Vertical) for the company.*

In Figure 20, the horizontal bar chart illustrates the comparison of the top 30 BI tools for the company, along with their respective scores. By following our selection procedure and referring to Figure 20, I can identify the optimal tools for the company, which are highlighted in violet color. Conversely, the remaining tools are represented in dark cerulean color. The horizontal view clearly shows that the best 5 BI tools for the company are as follows:

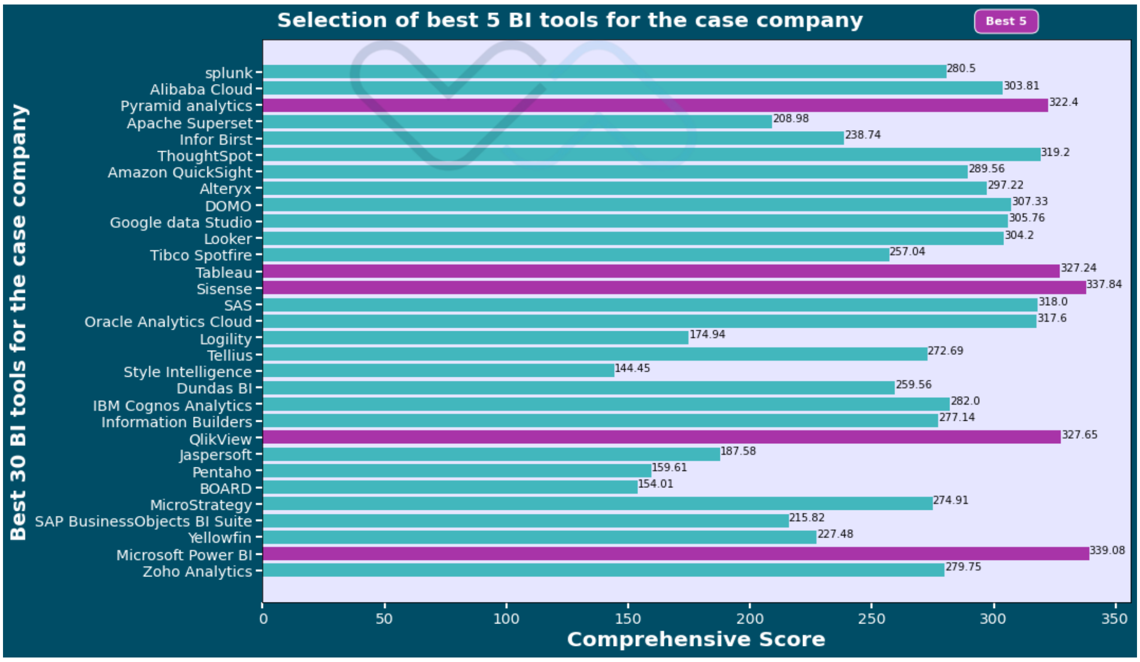

Figure 20. *Best 5 BI tools from best 30 (Horizontal) for the company.*

Even though Microsoft Power BI obtained the highest score of 339.08, four other tools (Sisense, QlikView, Tableau, and Pyramid Analytics) closely followed with scores of 337.84, 327.65, 327.84, and 322.4 respectively. Based on the selection procedure, the best five tools for the company are ThoughtSpot, Alibaba Cloud, SAAS, and Oracle, with scores slightly lower than the top five, ranging from 319.02 to 303.81. However, the remaining tools scored between 317 and 144.45. Consequently, Tellus received the lowest score among the 30 BI tools, with a score of 144.45.

Contrastingly, considering different scoring factors as discussed earlier and the overall score, Microsoft Power BI, Sisense, QlikView, Tableau, and Pyramid Analytics emerge as the best BI tools for the company. Therefore, they constitute the top 5 BI tools. Conversely, the remaining 25 tools scored lower than these five. Hence, Tellus acquired the lowest score.

Findings 2: Best BI tool for the company

In Figure 21, the chart illustrates a comparison of the top 30 BI tools for the company along with their respective scores. By referring to Figure 21 and following the selection procedure, it is evident that Microsoft Power BI stands as the best BI tool for the company. The best tool is highlighted in violet color, while the remaining tools are depicted in dark cerulean color.

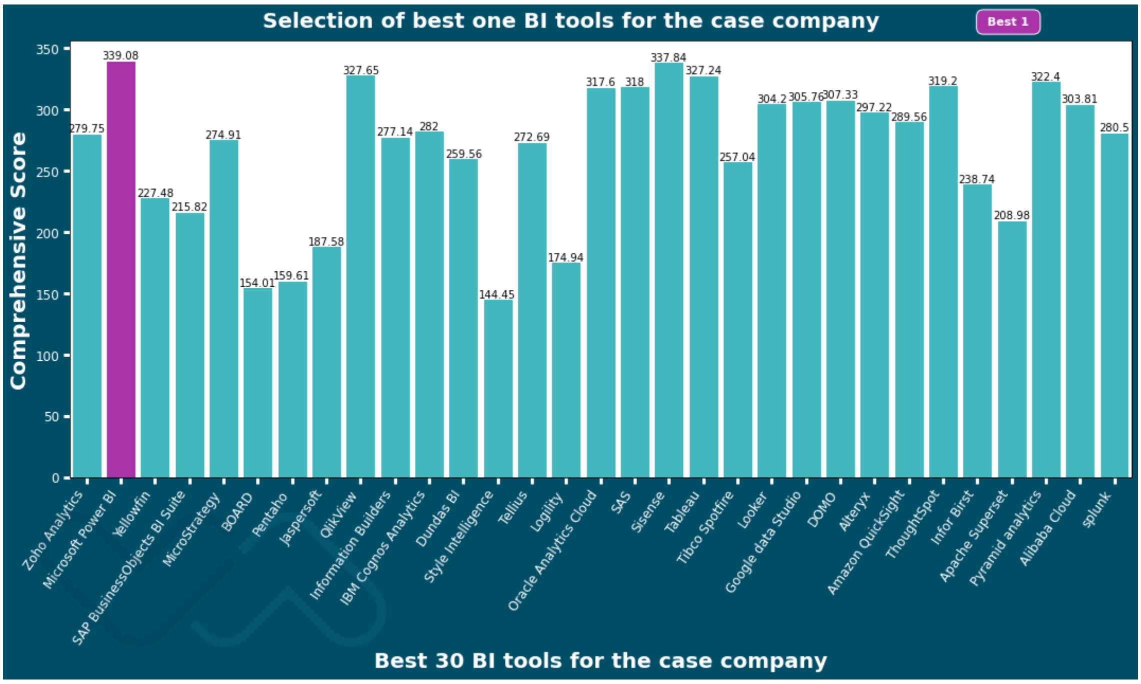

Figure 21. *Best one BI tool from the best 30 (Vertical) for the company.*

Even though Microsoft Power BI achieved the highest score of 339.08, the scores of other tools, such as Sisense, QlikView, ThoughtSpot, Alibaba Cloud, SAAS, and Oracle, were in close proximity with scores of 337.84, 327.65, 327.84, 322.4, 319.02, 303.81, and 318.6 respectively. However, the remaining tools received scores ranging from 317 to 144.45. Among the 30 BI tools, Tellus obtained the lowest score of 144.45.

In contrast, considering the different scoring factors discussed earlier, Microsoft Power BI emerged as the top-scoring tool among the 30 BI tools for the company. Hence, Microsoft Power BI is the best tool for the company, while the other 29 tools scored lower. Therefore, Tellus received the lowest score.

Figure 22 presents a horizontal bar chart comparing the top 30 BI tools for the company along with their respective scores. After conducting the research and applying the selection process, I have determined that Microsoft Power BI is the top-performing BI tool for the company. This tool is highlighted in violet color, while the remaining tools are depicted in dark cerulean.

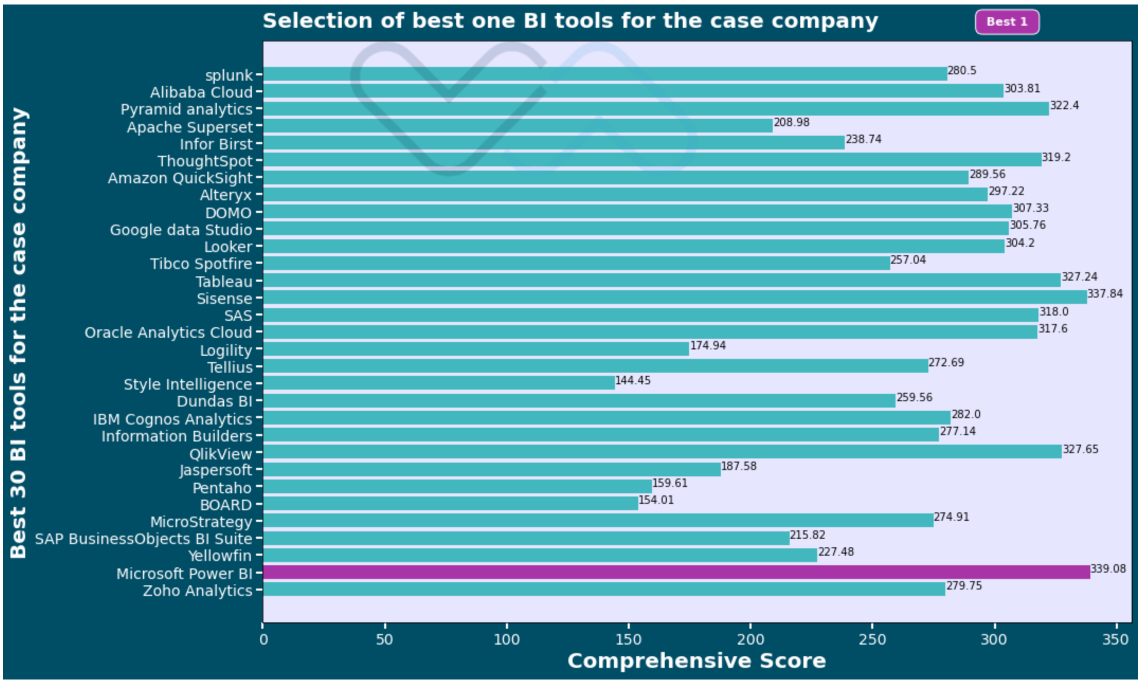

Figure 22. *Best BI tool from the best 30 (Horizontal) for the company.*

Findings 3: Best 3 SPC tools for the company

In the Figure 23, the chart compares the best 13 SPC software for the company with the consecutive score for each software. However, it can be seen that the best 3 SPC software for the company are the following:

1. SPC for Excel
2. ProFicient
3. QDM SPC System

The best three SPC software for the company is violet in colour. In addition, the rest of the software are in dark cerulean colour.

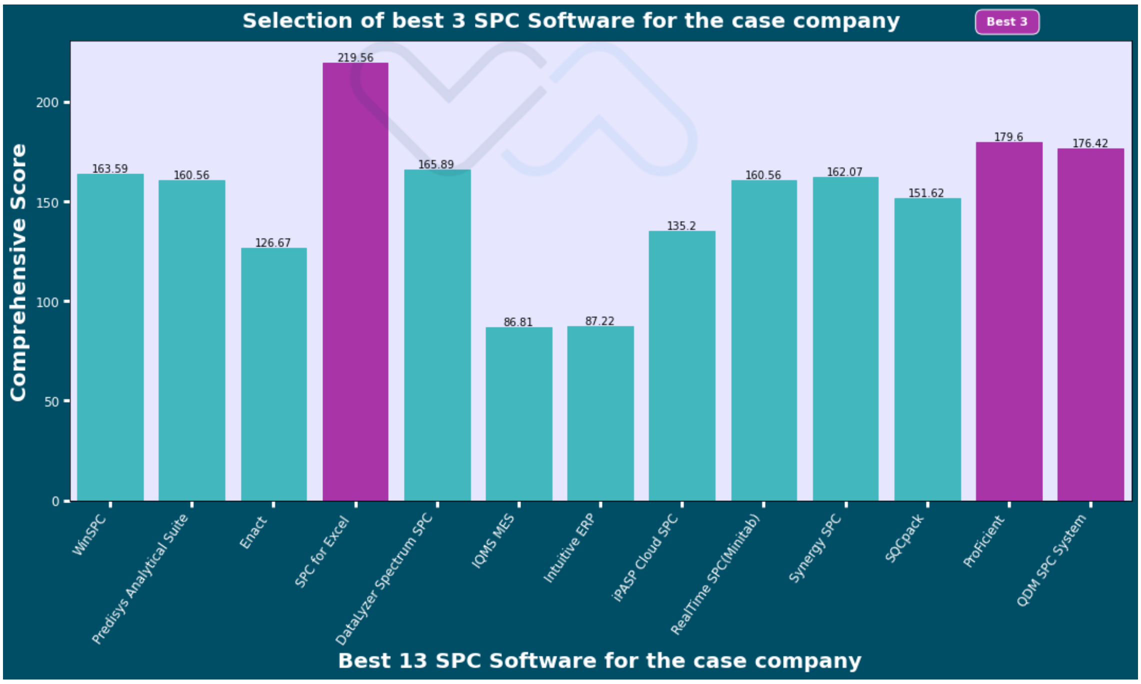

Figure 23. *Best three SPC software from the best 13 (vertical) for the company.*

Even though SPC for Excel received the highest score of 219.56, ProFicient and QDM SPC System scores are not as close to the highest score. Their scores are 179.6 and 176.42 respectively. Among the top three SPC software for the company, WinSPC, Predisys Analytical Suite, DataLyzer Spectrum SPC, RealTime SPC (Minitab), and Synergy SPC have scores of 163.59, 160.56, 165.89, 160.56, and 162.07 respectively. The remaining software received scores ranging from 160 to 87.22, with Intuitive ERP having the lowest score among the top 13 SPC software.

Based on the various scoring factors discussed earlier, the overall scores indicate that SPC for Excel, ProFicient, and QDM SPC System are the best three SPC software for the company. Conversely, 13 SPC software scored lower than the top three selections, with Intuitive ERP having the lowest score.

In Figure 24, the horizontal bar chart presents a comparison of the top 13 SPC software for the company and their consecutive scores. The best three SPC software are highlighted in violet color, while the remaining software are shown in dark cerulean.

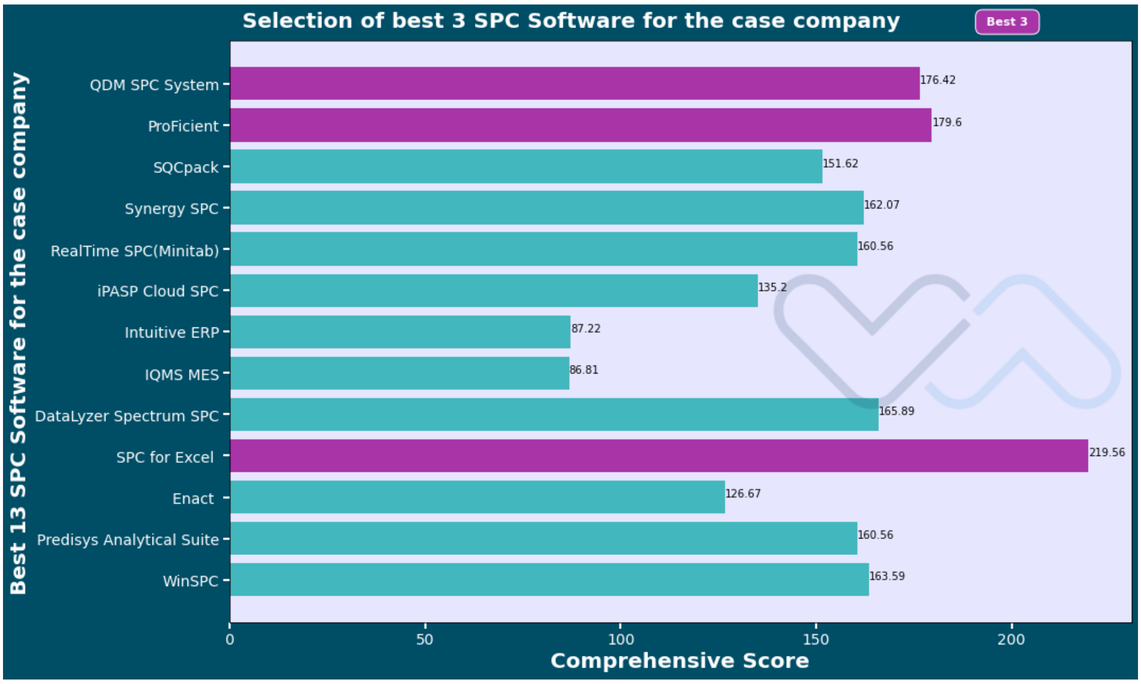

Figure 24. *Best three SPC software from the best 13 (vertical) for the company.*

Findings 4: Best SPC software for the company

In Figure 25, the horizontal bar chart depicts a comparison of the top 13 SPC software for the company, showing their consecutive scores. Based on the research and selection process, I have determined that the best SPC software for the company is SPC for Excel. It is represented in violet color, while the remaining software are shown in dark cerulean.

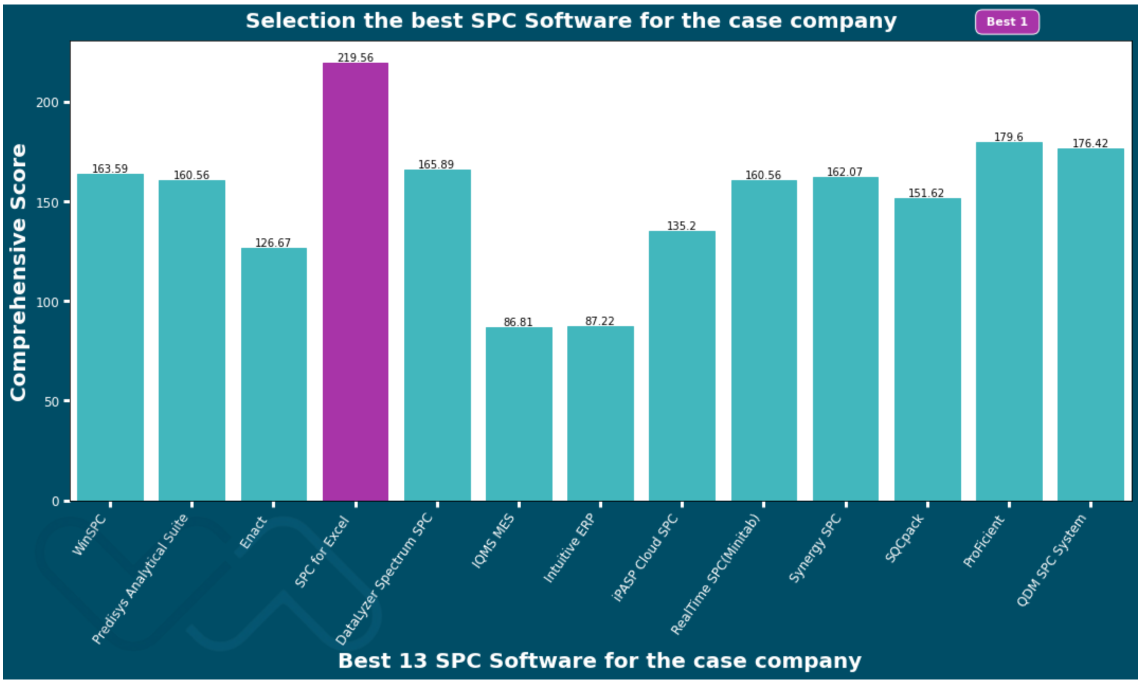

Figure 25. *Best analytics tool from the best 13 (horizontal) for the company.*

Figure 26, the horizontal bar chart presents a comparison of the top 13 SPC software for the company, displaying their consecutive scores. Based on the research and selection process, I have determined that the best SPC software for the company is SPC for Excel, which achieved the highest score of 219.56. ProFicient and QDM SPC System Scores, although not as close to the highest score, obtained scores of 179.6 and 176.42, respectively. Compared to the best three SPC software, WinSPC, Predisys Analytical Suite, DataLyzer Spectrum SPC, RealTime SPC (Minitab), and Synergy SPC had slightly lower scores of 163.59, 160.56, 165.89, 160.56, and 162.07, respectively. The remaining software programs obtained scores ranging between 160 and 87.22, with Intuitive ERP receiving the lowest score among the top 13 SPC software options.

Considering the different scoring factors discussed earlier, SPC for Excel stands out with the highest score, making it one of the top three SPC software for the company. On the other hand, the remaining 12 SPC software programs scored lower than SPC for Excel. Thus, Intuitive ERP received the lowest score.

Based on the research and selection process, Figure 26 clearly indicates that SPC for Excel is the most suitable SPC software for the company, represented in violet color. The other software options are depicted in dark cerulean.

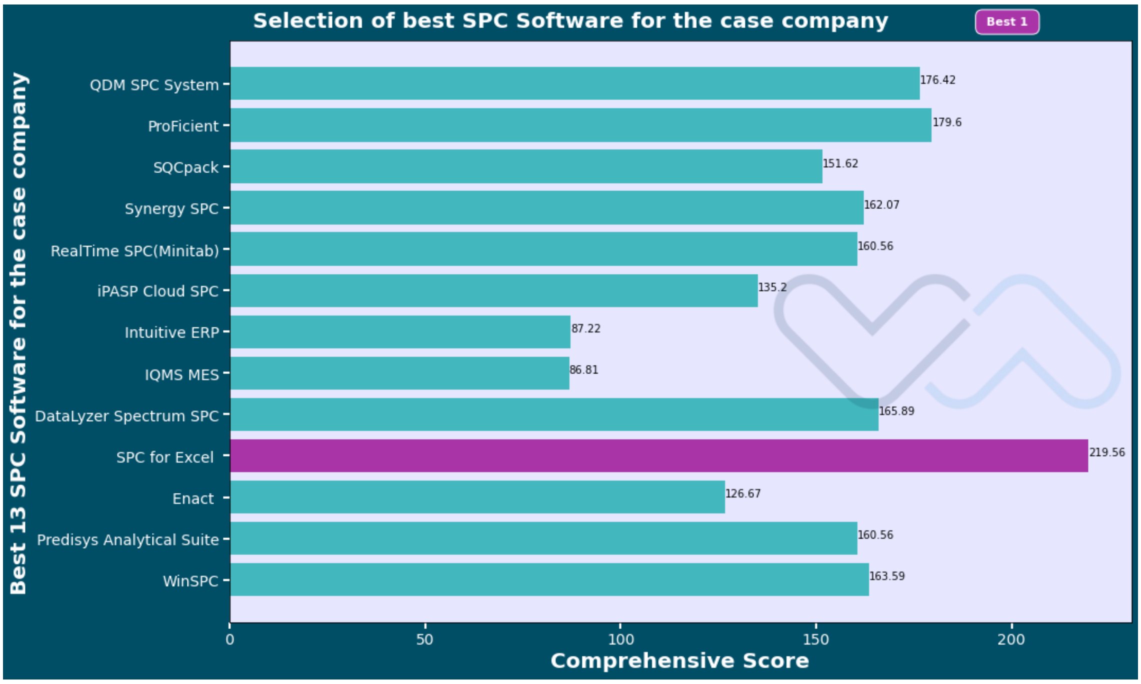

Figure 26. *Best analytics tool from the best 13 (horizontal) for the company.*

Furthermore, Descriptive statistical analysis was conducted to calculate measures such as the mean, median, and standard deviation for both the SPC tools and BI tools, and the results were visualized using box plots and Violin plots.

The correlation analysis revealed strong positive correlations between certain tool pairs in both the SPC tools and BI tools, providing insights into the interdependencies and relationships between these tools.

Hypothesis testing confirmed significant correlations between certain tool pairs in both the SPC tools and BI tools, further supporting the observed relationships.

Regression analysis was utilized to examine the correlation between predictors (tools) and efficacy scores, and linear regression and Ridge regression models were employed for analysis.

Model evaluation using mean squared error (MSE) indicated relatively low MSE values for both the SPC tools and BI tools, suggesting good performance of the regression models in predicting efficacy scores.

5.2 Analysis of findings

In Table 10, I have presented a SWOT analysis for the top three SPC software options for the case company, Valmet Automotive EV power OY. These software options include SPC for Excel, Proficient, and QDM SPC System. Based on the SWOT analysis (Table 10), SPC for Excel stands out for its extensive analytics and reporting features, all offered at a relatively affordable price point. Additionally, it provides strong customer support. On the other hand, Proficient offers simplified data collection and advanced reporting capabilities; however, its interface lacks intuitiveness. Furthermore, QDM SPC System is a cost-effective and user-friendly software that also provides advanced reporting and customer support, although it has limitations in retrieval options and platform support.

Table 10. *SWOT analysis: Best three SPC software for the company.*

Best 3 SPC software	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
SPC for Excel	Less Expensive Customer Support Extensive analytics and reporting.	Most of the genuine customers did not find any weakness.	Traditional and trustful tool to show to customers.	It would be nice to have user guides with examples and data sets for leading a hand with interpreting the advanced topics (p-values), Normality, Anderson darling, ANOVA, Hypot, DOE.
Proficient	Simplified Data Collection and Access, Flexible Monitoring and Analysis, Workflow Management, Advanced Reporting.	Manipulating the features of the program is not easy. It should be more intuitive.	Traditional and trustful tool.	Expensive
QDM SPC System	Less expensive, Easy to use, flexible. Advanced Reporting, Customer Support.	Retrieve option, and it is challenging to undo the option	Traditional and trustful tool to show to customers.	Do not support Android, IOS, et cetera.

Table 11 presents a SWOT analysis of the top five BI tools for Valmet Automotive EV power OY, namely Microsoft Power BI, Sisense, QlikView, Tableau, and Pyramid Analytics. In the analysis, I found that Microsoft Power BI provides good support and is easy to use; however, it can be expensive and may require additional investment for integration. Sisense and QlikView, on the other hand, are trusted and traditional tools, but they lack REST support and can be complex and costly. Tableau, despite having a high level of customer satisfaction, also lacks REST support. Lastly, Pyramid Analytics offers good support, but it may face challenges in an increasingly competitive market in the future.

Table 11. *SWOT analysis: Best five BI tools for the company.*

Best 5 BI tools	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
Microsoft Power BI	Best support More than traditional BI tools (trustful, well tested). Easy to use	No REST support Expensive Slow during analysing of big data	To integrate other services for data analysis and visualisation. Remote work solutions	Integration needs much money. However, there are some exceptions for a few apps. However, most of the cases need much money.
Sisense	Good support Traditional BI (trustful, well tested)	No REST support Traditional BI (expensive, complex)	Traditional and trustful tool.	Integration needs much money.
QlikView	Good support Traditional BI (trustful, well tested) Unique technology - associative search Highly differentiated product	No REST support Traditional BI (expensive, complex) Undiversified product portfolio	Potential for integration.	Highly expensive. Standardisations on enterprise BI platforms Prominent vendors leveraging in-memory BI Loss of focus
Tableau	Good support Traditional BI (trustful, well tested) High level of customer satisfaction.	No REST support Traditional BI (expensive, complex) Financial planning needs correctness and efficiency.	Lower inflation rate. Traditional and trustful tool.	New technologies developed by competitors or market disruptors could severely threaten the industry in the medium to long term.
Pyramid Analytics	Good support	No REST support	Rather than enter decision intelligence on mere buzz alone, Pyramid Analytics cites customers already deploying it for this use case, which validates it and provides a launch pad for further account wins.	The decision intelligence market is likely to heat up this year as more vendors enter it, providing a more challenging competitive environment for Pyramid Analytics to navigate in the future.

5.3 Validation of the selected tools to the company needs

In this section, I will validate the selected tools for the company's needs. Additionally, I will analyze the company's data (synthetic data) and present the corresponding reports. Based on my previous analysis, we have determined that Microsoft Power BI is the best BI tool for the company. Therefore, in this section, I will validate and visualize the company's data using Microsoft Power BI. I have obtained Figure 27 from my thesis supervisor at Valmet Automotive, which utilizes Microsoft Power BI for data visualization. Due to confidentiality concerns, we are not authorized to publicly disclose the company's actual data. Hence, we have intentionally blurred the data in Figure 27. Furthermore, I have identified SPC for Excel as the optimal SPC software for the company. In this section, I will also validate and visualize the synthetic data using SPC for Excel.

5.3.1 Selected Tool 1: Microsoft Power BI

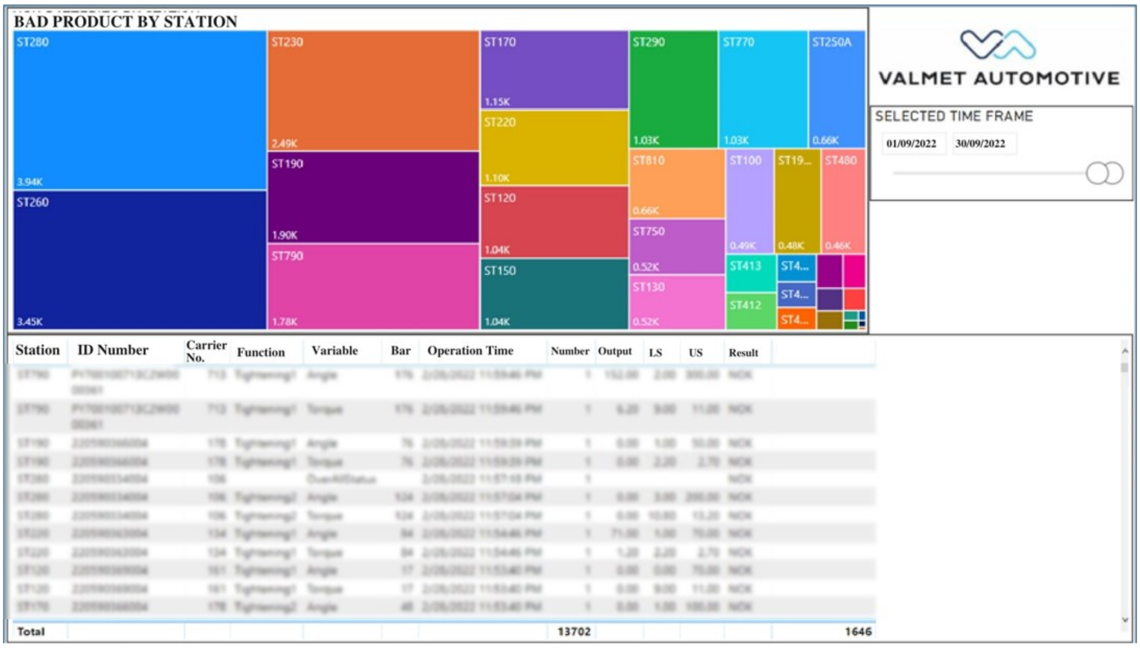

Figure 27. Example of bad products by station at Valmet Automotive EV Power Oy, Salo.

The charts depicted in Figure 27 display the data from the table and the tree map chart, presenting the occurrence of bad products by station within a specific time frame. It is evident from the chart that station ST280 has the highest number of bad products. Additionally, the chart provides information on products for all other stations in September 2022. Moreover, assessing process quality requires the utilization of various complex charts and visuals, such as P-charts, C-charts, and complex bar charts, among others.

P-charts, short for "proportion charts," are employed to monitor the proportion of defective items or units within a sample. Conversely, C-charts, or "count charts," are used to monitor the number of defects per sample. Both types of control charts are utilized in statistical process control to track the quality of a process over time.

5.3.2 Selected tool 2: SPC for Excel

I have downloaded the demo version of SPC for Excel to analyze sample data, resembling the company's actual data. Although it may have fewer features compared to the full version, the charts generated are still impressive. In addition, I have utilized SPC for Excel to create control charts, Pareto charts, and histograms, providing visual representations of the data.

Figure 28 presents the C-chart, which was generated using SPC for Excel software. A C-chart, also known as a count chart, is utilized to monitor data that can be counted, typically referring to the absolute number of discrepancies per element. It is also sometimes employed to track the overall number of occurrences within a specific period. In Figure 28, the abbreviation "UCL" stands for the upper control limit, while "avg" represents the average. Similarly, the lower control limit is denoted as "LCL," and in this particular case, it is indicated by the O-line.

According to Doty [72], the c-chart formulas are:

$$\bar{c} = \frac{\sum c}{\sum n} = \frac{\sum c}{m}$$

UCL = $\bar{c} + 3\sqrt{c}$

LCL = $\bar{c} - 3\sqrt{c}$

Where:

$\bar{c}$ is Defect count per unit, UCL is Upper control limit, Σ is summation, LCL is Lower control limit, n is the sample size and m are the number of subgroups.

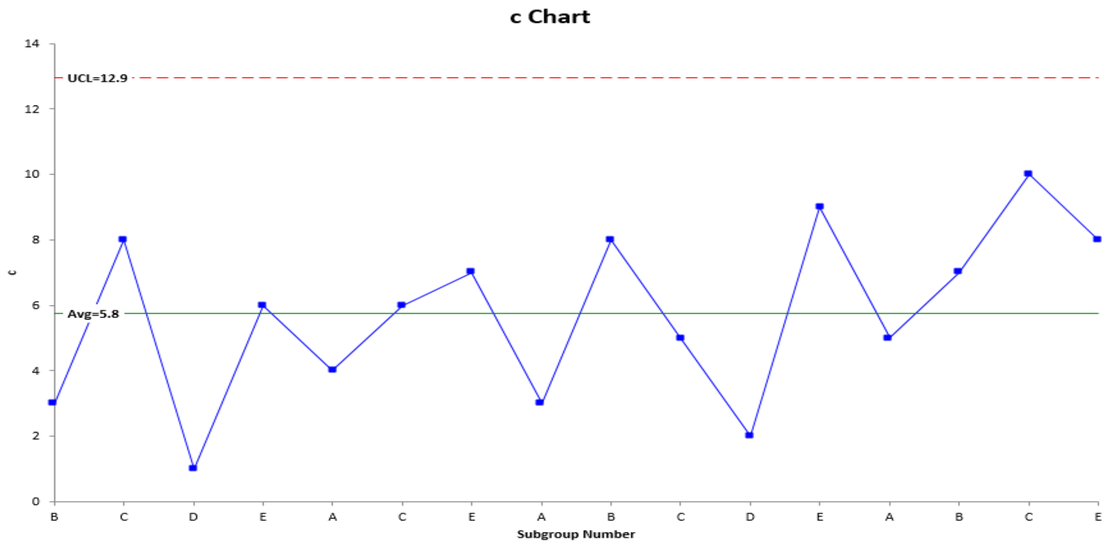

Figure 28. *SPC for Excel, Example 1: C chart (Created by the author).*

A Pareto chart is a combination of a bar chart and a line chart. The line graph displays the cumulative percentage of data in ascending or descending order, while the bar chart represents the frequency of occurrence or flaws. Figure 29 [72] includes both a bar chart and a line chart.

Based on the Pareto Principle, only 20% of causes account for 80% of the effects. Therefore, it is important to focus on the 20% of fault categories that contribute to 80% of all defects. Although the 80/20 rule may not be universally applicable, concentrating on two categories of flaws could eliminate the majority of defects (66%) [72].

In Figure 29, each bar represents a specific type of flaw or issue. The height of the bar indicates a significant measurement, typically the occurrence frequency or price. The bars are arranged in reverse order, from highest to lowest, allowing for easy identification of the most common problems. The line on the chart represents the cumulative proportion of flaws [72].

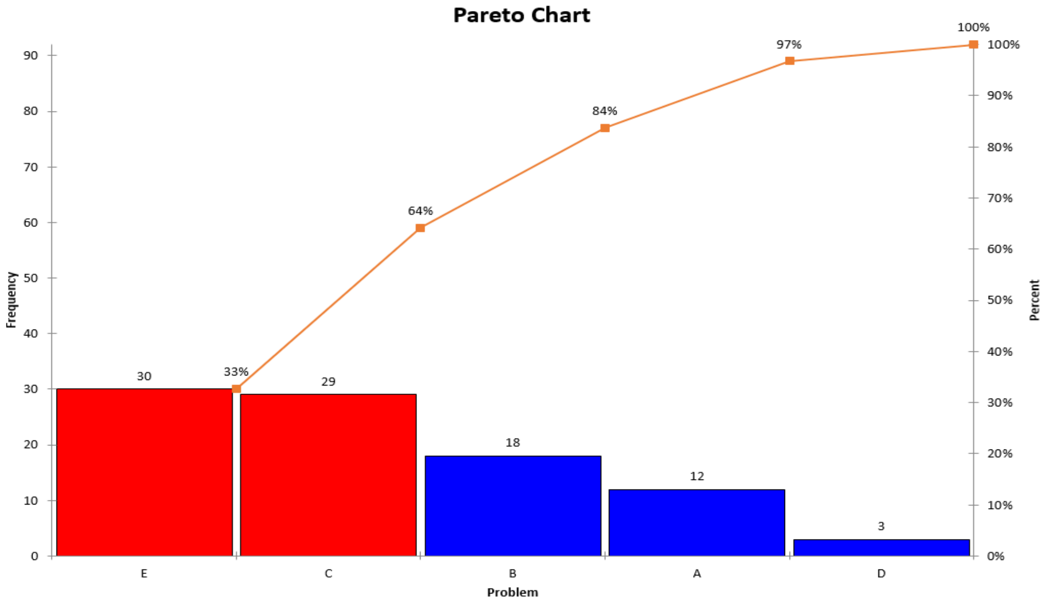

Figure 29. *SPC for Excel, Example 2: Pareto chart (Created by the author).*

Figure 30 displays the histogram chart generated in the SPC for Excel software. A histogram is a graphical representation of the frequency distribution of raw data. It illustrates how data is distributed, compares it to predetermined boundaries, and provides useful metrics and statistics to characterize the data set comprehensively. Histograms are commonly used in conjunction with SPC control charts to analyze data. The same data used for control charts can be used to create histograms. Unlike control charts that present data in chronological order, histograms condense and compare specific data items with technical specifications. Additionally, the histogram allows me to calculate the frequency density, which refers to the frequency per unit for each type of data [72]. The formula for calculating frequency density is as follows:

Frequency density, d = $\frac{w}{f}$

Here, w represents class width and f represents frequency.

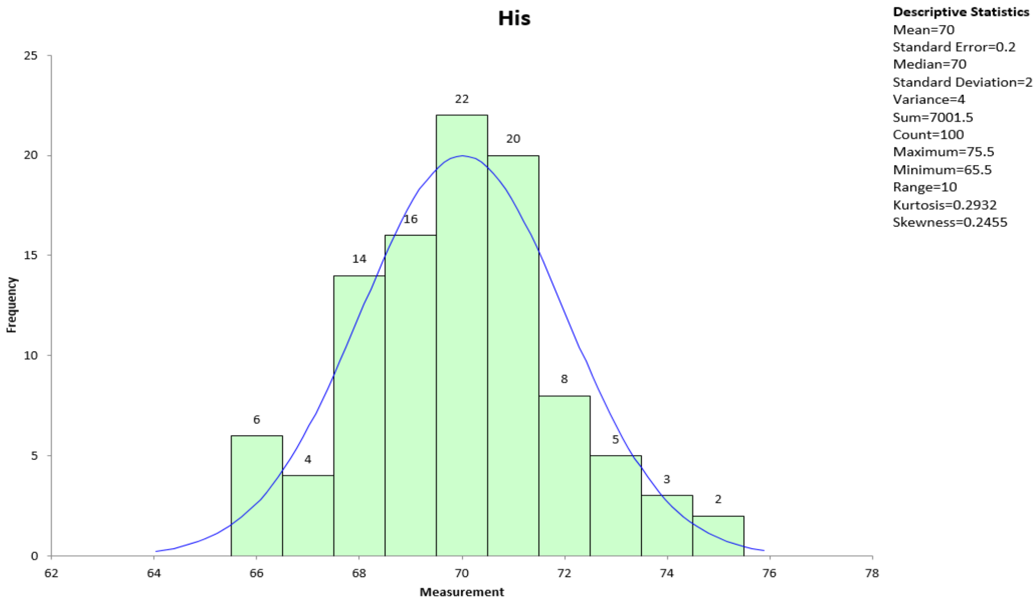

Figure 30. *SPC for Excel, Example 2: Histogram chart (Created by the author).*

From Figure 30, I observe that a histogram is a type of bar chart. Its vertical axis represents the frequency of a value occurring or falling within a range of values, while the horizontal axis displays the measurement's frequencies. Essentially, a histogram reveals:

- Which outcome (or group of outcomes) shows up the most often.
- What degree of variety there is.
- What the variation's form looks like.
- If any outcomes do not match the expectations.

Additionally, Figure 30 presents various descriptive statistics such as the mean, median, mode, standard deviation, skewness, and others. It also includes a frequency curve, which is a smooth curve with a total area assumed to be one [72].

Some other charts and properties of demo version of SPC for Excel are in the Figure 31:

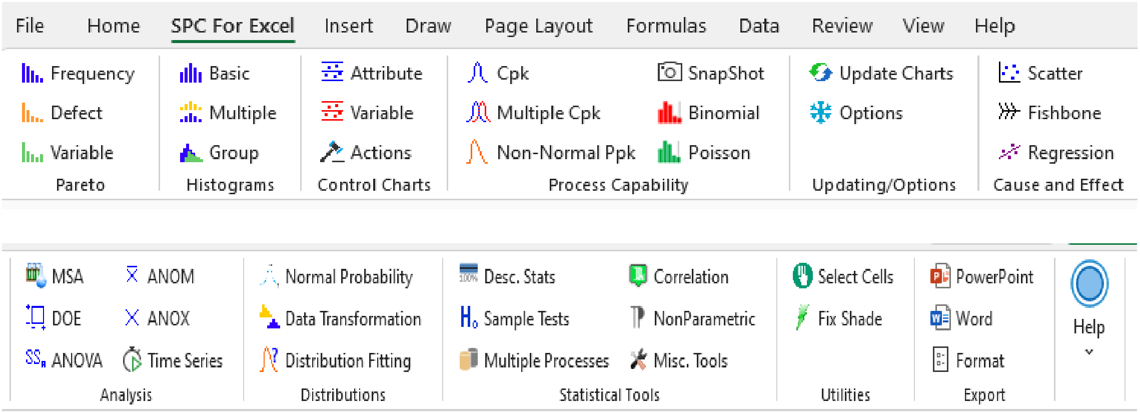

Figure 31. *Some other charts and properties of demo version of SPC for Excel (Business version contains more properties and charts).*

After utilizing SPC for Excel, I can confidently state that it is an exceptional software tool for analyzing real-time company data. Its data analytical capabilities are highly impressive, accompanied by visually appealing visualizations. Moreover, the cost of the software is comparatively affordable. These characteristics collectively establish SPC for Excel as the superior choice among the 13 best SPC software options for the company.

6. Recommendations

This section will discuss my recommendations for the current BI tools and SPC software for the company and how they should be rationalized and improved. Additionally, I will briefly discuss the feedback received from professionals working in companies with relevant experience. In this section, I will present both my recommendations and the recommendations of experienced professionals.

Valmet Automotive is a leading global automobile and battery manufacturer. Valmet Automotive EV Power Oy, a subsidiary of Valmet Automotive, focuses on manufacturing enhancements. The findings of this thesis primarily pertain to Valmet Automotive EV Power Oy and its manufacturing processes. The main research problem was to evaluate the existing BI tools and SPC software and suggest rationalization and improvements. To address this, I assessed 30 BI tools and identified the five best options, as well as evaluated 13 SPC software solutions to determine the top three for the case company. Among the BI tools, Microsoft Power BI emerged as the best choice, while SPC for Excel stood out as the most suitable SPC software. As a result, the company has adopted Microsoft Power BI as its primary tool for production visualization and reporting.

Regarding SPC for Excel, it was recommended as the most cost-effective and suitable analytics tool for the case company's requirements. The company agreed with my recommendation for Microsoft Power BI but expressed interest in exploring cloud-based services for SPC visualization, such as Azure cloud and Data Lake. They also inquired about the possibility of developing an SPC app with control charts and other advanced data analytics technologies, although app development was beyond the scope of this thesis.

To gain further insights into the current BI tools and SPC software landscape and identify potential rationalization and improvement strategies, I conducted interviews with highly experienced professionals from companies in Turku, Salo, and Uusikaupunki. These professionals possess extensive expertise in Business Intelligence and data analytics. They concurred with the assessment that Microsoft Power BI would be the best choice for the company, despite acknowledging its drawbacks. However, they recommended cloud-based SPC software as a more suitable option. Additionally, they highlighted the company's current use of Predisys analytics software, which is expensive, less intuitive, and has other limitations. Hence, they suggested that cloud-based analytics and SPC support would be a better fit. They also provided examples of cloud-based platforms to address analytical challenges. Moreover, they informed us that the company is undertaking a cloud data platform project aimed at finding a suitable cloud-based analytical solution and implementing advanced technologies like machine learning and AI. The plan involves implementing Data Lake and Microsoft Azure cloud services to address current analytical challenges, followed by the incorporation of machine learning and other advanced technologies.

However, I believe that these advanced technologies may entail higher costs compared to SPC for Excel. I have examined the costs associated with these advanced technologies. Nevertheless, the main reasons for considering a switch from Predisys analytical suite are its high cost and lack of intuitiveness. On the other hand, SPC for Excel is priced at only 269 USD per user [61], making it the second-lowest-cost option among all the SPC software analyzed. Ultimately, the decision lies with the case company, and I am satisfied that the case company appreciate the findings and will continue using Microsoft Power BI as their primary BI tool.

Finally, based on the statistical analysis conducted, it is recommended to consider the strong positive correlations observed between certain tool pairs, such as Zoho Analytics and Microsoft Power BI, Yellowfin and SAP BusinessObjects BI Suite, and MicroStrategy and Board Intelligence, when selecting and integrating BI tools. For SPC software, the high positive correlation between WinSPC and ProFicient suggests these tools can be considered together for effective implementation. Additionally, further validation and exploration of other factors, such as user requirements and cost-effectiveness, are suggested to make informed decisions regarding tool selection.

7. Conclusion

The Conclusion chapter provides an overview of the research questions and answers the research problems outlined. It also briefly explains the methodology and presents the findings and results. Additionally, it recommends the best reporting tools for the company. In this chapter, I will verify if the research questions and problems have been adequately addressed.

Valmet Automotive is a prominent global automobile manufacturer and battery production company. Valmet Automotive EV Power Oy, located in Salo and Uusikaupunki, is a subsidiary of Valmet Automotive. The author's workplace is Valmet Automotive EV Power Oy in Salo, where a substantial amount of production data is generated daily. The company utilizes BI and SPC tools to analyze, visualize, and process data. However, due to the sluggishness of their current BI tools, the high cost of SPC software, and other reasons, this thesis work was initiated in April 2022 to address the research questions and problems faced by the company.

The main research question was "How to identify suitable BI and SPC tools for the company?" These primary and secondary problems are detailed in the Introduction chapter. The initial objective was to identify the best BI tools and SPC software for the organization based on its requirements.

To identify potential BI tools and SPC software, I selected 30 BI tools and 13 SPC software solutions from a pool of over 100 similar tools in the software market. I established the criteria for mapping out the tools, assigned a score of 1 to 5 for each tool based on the criteria, and performed calculations to obtain the overall weighted score for each tool using Excel. Additionally, I utilized Python programming in Jupyter Notebook to assist in the process. After completing the calculations, I created a Python dictionary with the tool names as keys and their corresponding scores as values. Finally, I employed Python visualization libraries to visualize the top five BI tools out of the 30 options and the top three SPC software out of the 13 choices for the case company. Through this visualization, I identified Microsoft Power BI as the best BI tool and SPC for Excel as the best SPC software for the company.

Additionally, the comprehensive statistical analysis revealed valuable insights into the selection process of SPC tools and BI tools, including descriptive statistics, interrelationships among tools, and correlation analysis. The regression analysis demonstrated the effectiveness of linear regression and Ridge regression in predicting efficacy scores for both SPC tools and BI tools, as indicated by low mean squared error (MSE) values. Further evaluation and validation are recommended to ensure the reliability and generalization capabilities of the models.

The IT department, senior management, and the thesis supervisor from the company expressed satisfaction with the findings. After presenting the research findings to the company, they appreciated the work, leading them to select Microsoft Power BI as their primary BI tool for data analytics, reporting, and analyzing vast amounts of data on a daily basis. Since the existing tools meet the company's requirements, there is no immediate need for further improvements unless the company establishes a new station with entirely different objectives. Most of the research questions have been answered, although some became irrelevant after obtaining answers to the main questions. Moreover, I can apply the same methodology to map out BI and SPC tools for various companies.

References

[1] Alebeisat, F., Alhalhouli, Z., & Alrawashdeh, T. (2018). Review of Literature on Software Quality. World of Computer Science and Information Technology Journal (WCSIT), Vol. 8, No. 5, 32-42, 2018.

[2] Downs, J. (2016). Guest View: Five steps to evaluating and selecting software tools. Publishers: SD Times, Retrieved September 18, 2022, from https://sdtimes.com/evaluation/guest-view-five-steps-evaluating-selecting-software-tools/

[3] Laine, J. (2015). Integrating Business Intelligence services to insurance policy management system. M.Sc. thesis. Publishers: Tampere University, Remote: Trepo". Retrieved September 18, 2022, from https://trepo.tuni.fi//handle/123456789/23436

[4] Lai, V. S., Trueblood, R. P., & Wong, B. K. (1999). Software selection: a case study of the application of the analytical hierarchical process to the selection of a multimedia authoring system. Information & Management, 36(4), 221–232. https://doi.org/10.1016/S0378-7206(99)00021-X.

[5] Bongwald, O. (2021). Electrifying: the fast lane to future vehicles. Retrieved September 17, 2022, from https://www.valmet-automotive.com/wp-content/uploads/2021/05/tcg2021_bongwald.pdf.

[6] Devens, R. (2018). Cyclopaedia of Commercial and Business Anecdotes. Franklin Classics Trade Press.

[7] Hovi, A., Hervonen, H., & Koistinen, H. (2009). Tietovarastot ja Business Intelligence. Docendo.

[8] Luhn, H. (1958). A Business Intelligence System. IBM Journal of Research and Development. 2 (4): 314–319. doi:10.1147/rd.24.0314. Retrieved September 17, 2022, from https://web.archive.org/web/20080913121526/http://www.research.ibm.com/journal/rd/024/ibmrd0204H.pdf

[9] Turban, E., Sharda, R., Delen, E. & Dursun., A. (2011). Decision Support and Business Intelligence Systems. Retrieved September 17, 2022, from https://archive.org/details/DSandBI9edTurban.

[10] Hancock, J. & Toren, R. (2006). Practical Business Intelligence: with SQL Server 2005. Addison-Wesley Professional. Retrieved September 17, 2022, from Ebook: Practical Business Intelligence with SQL Server 2005.

[11] Negash, S. & Gray, P. (2008). Business Intelligence. In: Handbook on Decision Support Systems 2. International Handbooks Information System. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-48716-6_9.

[12] Evelson, B. (2008). Topic Overview: Business Intelligence. Retrieved September 17, 2022, from https://www.forrester.com/report/Topic-Overview-Business-Intelligence/RES39218.

[13] Rasmussen, N. H., Goldy, P. S., & Solli, P. O. (2002). Financial Business Intelligence: Trends, Technology, Software Selection, and Implementation (1st ed.). Wiley.

[14] Patel, P. R. (2017). Business Intelligence in the Cloud: Opportunities, Issues, and Challenges. International Journal of Computer Applications, 163(6), 29-36. https://doi.org/10.5120/ijca2017912993.

[15] Myers, J. (2015). Analytics in the Cloud. Retrieved September 18, 2022, from http://research.enterprisemanagement.com/rs/ema/images/EMA-CloudAnalytics-2015-RR.pdf.

[16] Thompson, W. J., & Van der Walt, & J. S. (2010). Business Intelligence in the cloud. SA Journal of Information Management, 12(1), 1-10. https://doi.org/10.4102/sajim.v12i1.414.

[17] Watson, H. J., & Wixom, B. H. (2007). The Current State of Business Intelligence. Computer, 40(9), 96–99. https://doi.org/10.1109/mc.2007.331

[18] Azvine, B., Cui, Z., Nauck, D., & Majeed, B. (2006). Real Time Business Intelligence for the Adaptive Enterprise. CEC/EEE 2006 Joint Conferences, 2006, 29–29. https://doi.org/10.1109/CEC-EEE.2006.73.

[19] Gardner, C., Beauchamp, T. J., Netsch, T. C., Nicholls, G. D. O., & Powers, C. R. (2007). Architecture for general purpose near real-time Business Intelligence system with client devices and methods therefor. US Patent 7272660.

[20] Watson, H. J., Wixom, B. H., Hoffer, J. A., Anderson-Lehman, R., & Reynolds, A. M. (2009). Real-Time Business Intelligence: Best Practices at Continental Airlines1. EDPACS, 40(6), 1–16. https://doi.org/10.1080/07366980903484935.

[21] Abdul Halim Lim, S., Antony, J., He, Z., & Arshed, N. (2017). Critical observations on the Statistical Process Control implementation in the UK food industry: A survey. International Journal of Quality & Reliability Management, 34(5), 684–700. https://doi.org/10.1108/ijqrm-03-2015-0035.

[22] Uluskan, M. (2019). Analysis of Lean Six Sigma tools from a multidimensional perspective. Total Quality Management & Business Excellence, 30(9-10), 1167–1188. https://doi.org/10.1080/14783363.2017.1360134.

[23] Horowitz, B. (2014). The hard thing about hard things: building a business when there are no easy answers. Harpercollins Publishers; New York, Ny.

[24] DeVor, R., Sutherland, J., & Chang, T. (2006). Statistical Quality Design and Control: Contemporary Concepts and Methods (2nd ed.). Pearson.

[25] Rahman, Z., R. M., Alias, A. M., & Nopiah, Z. M. (2015). Statistical Process Control: best practices in small and medium enterprises. Maejo International Journal of Science and Technology, 9(2), 193–208.

[26] Zairi, M. (1991). Total Quality Management for Engineers. Cambridge, UK: Woodhead Publishing Limited. https://doi.org/10.1533/9781845698911.

[27] Kumar, S., & Shanmuganathan, J. (2019). A structural relationship between TQM practices and organizational performance with reference to selected auto component manufacturing companies. International Journal of Management, 10(5), 123-139. https://doi.org/10.34218/IJM.10.5.2019/009.

[28] Tjahjono, B., Ball, P., Vitanov, V., Scorzafave, C., Nogueira, J., Calleja, J., Minguet, M., Narasimha, L., Rivas, A., Srivastava, A., Srivastava, S., & Yadav, A. (2010). Six Sigma: a literature review. International Journal of Lean Six Sigma, 1(3), 216–233. https://doi.org/10.1108/20401461011075017.

[29] Zoho (2002). Business Intelligence platform - Zoho Analytics. Retrieved September 18, 2022, from https://www.zoho.com/nl/analytics/

[30] Becker, L. T., & Gould, E. M. (2019). Microsoft Power BI: Extending Excel to Manipulate, Analyze, and Visualize Diverse Data. Serials Review, *45*(3), 184–188. https://doi.org/10.1080/00987913.2019.1644891.

[31] Deckler, G., Powell, B., & Gordon, L. (2022). Mastering Microsoft Power BI: Expert techniques to create interactive insights for effective data analytics and Business Intelligence. Van Haren Publishing.

[32] Glineur, Y., & Petibon, A. B. T. (2021). SAP BusinessObjects Web Intelligence (WebI) BI 4.3. ENI.

[33] Microstrategy (2022). Business Intelligence & Analytics Solutions. Retrieved September 18, 2022, from https://www.microstrategy.com/en

[34] Board International. (2022). Ventana Research Business Planning Value Index 2022 Validation. Retrieved September 18, 2022, from https://www.board.com/en

[35] Data Integration & Analytics (2022). Data Integration and Analytics Powered by Pentaho. Retrieved September 18, 2022, from https://www.hitachivantara.com/en-us/products/lumada-dataops/data-integration-analytics.html

[36] Jaspersoft (2022). Reporting and embedded Business Intelligence software. Retrieved September 18, 2022, from https://www.jaspersoft.com/

[37] Qlik (2022). View – Powerful Interactive Analytics & Dashboards. Retrieved September 18, 2022, from https://www.qlik.com/us/products/qlikview

[38] Garcia, M. A., Harmsen, B., Redmond, S., & Pover, K. (2018). QlikView: Advanced Data Visualization: Discover deeper insights with Qlikview by building your own rich analytical applications from scratch. Packt Publishing.

[39] Bluck, A. (2021). Installation, Upgrade, and Configuration of IBM Cognos Analytics: Smooth Onboarding of Data Analytics and Business Intelligence on Red Hat RHEL 8.0, and Windows Servers (English Edition). BPB Publications.

[40] Dundas Data Visualization, support@dundas.com. (2022). Premium Reporting & Data Analytics. Retrieved September 18, 2022, from https://www.dundas.com/

[41] Styleintelligence. (2022). STIQ Ltd. Retrieved September 18, 2022, from https://www.styleintelligence.com/

[42] Tellius (2022). AI-Driven Augmented Analytics & Decision Intelligence. Retrieved September 18, 2022, from https://www.tellius.com/

[43] Logility, Inc. (2022). AI-based Supply Chain Planning Solutions. Retrieved September 18, 2022, from https://www.logility.com/

[44] Oracle (2022). Choose Between Analytics On-Premises or in the Cloud. Retrieved September 18, 2022, from Oracle.com website: https://www.oracle.com/business-analytics/analytics-platform/

[45] SAS Visual Analytics (2022). A single application for reporting, data exploration and analytics. Retrieved September 18, 2022, from https://www.sas.com/en_us/software/visual-analytics.html

[46] Sisense (2022). Sisense - Infuse Analytics Everywhere. Retrieved September 18, 2022, from https://www.sisense.com/

[47] Taylor, D. (2022). What is Tableau? Uses of Tableau Software Tool. Retrieved September 18, 2022, from https://www.guru99.com/what-is-tableau.html

[48] Blokdyk, G. (2021). TIBCO Spotfire Complete Self-Assessment Guide. 5STARCooks.

[49] Looker (2022). Business Intelligence (BI) & Data Analytics Platform. Retrieved September 18, 2022, from https://www.looker.com/

[50] Google Analytics Solutions (2016). Announcing Data Studio: our free, new, Data Visualization Product. Retrieved September 18, 2022, from https://analytics.googleblog.com/2016/05/announcing-data-studio-our-free-new.html

[51] Domo (2022). The Domo Business Cloud | Domo. Retrieved September 18, 2022, from https://www.domo.com/

[52] Alteryx (2022). Self-Service Analytics, Data Science & Automation | Alteryx. Retrieved September 18, 2022, from https://www.alteryx.com/

[53] Samatas, M. (2022). Actionable Insights with Amazon QuickSight: Develop stunning data visualizations and machine learning-driven insights with Amazon QuickSight. Packt Publishing.

[54] Blokdyk, G. (2022). ThoughtSpot A Clear and Concise Reference. 5STARCooks.

[55] Infor Birst (2022). Next-generation enterprise industry analytics platform. Retrieved September 18, 2022, from https://www.infor.com/solutions/advanced-analytics/business-intelligence/birst

[56] Shekhar, S. (2018). Apache Superset Quick Start Guide: Develop interactive visualizations by creating user-friendly dashboards. Packt Publishing.

[57] Splunk (2022). The Unified Security and Observability Platform. Retrieved September 18, 2022, from https://www.splunk.com/

[58] Pyramid Analytics (2022). Retrieved September 18, 2022, from https://www.areto.de/en/expertise/data-analytics/pyramid-analytics/

[59] Predisys (2022). Predisys Quality Analytics & Real-Time SPC. Retrieved September 18, 2022, from https://www.predisys.com/

[60] Enact (2022). Enact | SPC Manufacturing Quality Platform by. Retrieved September 18, 2022, from https://www.infinityqs.com/products/enact

[61] SPC for Excel (2022). Enact - Simplified Statistical Analysis -Software, Training and Consulting. Retrieved September 18, 2022, from https://www.spcforexcel.com/

[62] Buttrey, S. E. (2009). AnExcelAdd-In for Statistical Process Control Charts. Journal of Statistical Software, 30(13). https://doi.org/10.18637/jss.v030.i13.

[63] DELMIAsWorks (2021). DELMIAsWorks Manufacturing ERP. Retrieved September 18, 2022, from SOLIDWORKS website: https://www.solidworks.com/delmiaworks-manufacturing-erp

[64] Aptean (2022). Ready for Industrial Manufacturing ERP. Retrieved September 18, 2022, from https://www.aptean.com/en-EU/solutions/erp/products/aptean-discrete-manufacturing-erp

[65] iPASP Cloud SPC (2022). Microsoft Azure Marketplace. Retrieved September 18, 2022, from https://azuremarketplace.microsoft.com/en-us/marketplace/apps/1647308231318.aat-spc-cloud?ocid=GTMRewards_WhatsNewBlog_aat-spc-cloud_041322

[66] RealTime SPC (2022). Microsoft Azure Marketplace. Retrieved September 18, 2022, from https://azuremarketplace.microsoft.com/en-us/marketplace/apps/minitabllc1614270009582.realtime-spc?ocid=GTMRewards_WhatsNewBlog_aat-spc-cloud_041322&tab=Overview

[67] Zontec (2022). SPC Software That Unlocks a Culture of Quality. (2022). Retrieved September 18, 2022, from Zontec website: https://zontec-spc.com/

[68] Pqsystems (2022). Improve your quality with cloud SPC & gage software. Retrieved September 18, 2022, from https://www.pqsystems.com/

[69] Infinityqs (2022). SPC software | Manufacturing Quality Software Platform. Retrieved September 18, 2022, from https://www.infinityqs.com/

[70] Proficient (2022). Proficient Software | SPC software | Quality Manufacturing. Retrieved September 18, 2022, from https://www.infinityqs.com/products/proficient

[71] Systems, D. C. (2022). QDM SPC System Overview | Quality Data Management. Retrieved September 18, 2022, from https://www.3dcs.com/en-gb/automated-spc-system-overview

[72] Doty, L.A. (1996). Statistical Process Control. New York: Industrial Press.

Appendix

This section summarizes the calculations conducted in the Excel sheet and the Python code used to identify the optimal BI tools and SPC software for the case company. The entire set of Excel calculations and Python code can be accessed in the author's GitHub repository.

Additionally, the author's GitHub repository includes Python code for performing statistical analysis. The Python code encompasses descriptive statistical analysis, correlation analysis, hypothesis testing, and regression analysis. These analyses were carried out to gain insights into the SPC tools and BI tools, assess their interrelationships, and predict efficacy scores.

Please note that for further details and access to the specific Python code and Excel calculations, it is recommended to refer to the author's GitHub repository for comprehensive information and reproducibility of the study.

https://github.com/Abdullah-TU/Masters-Thesis

Appendix A: Calculation methods in excel sheet to map out best BI tools and SPC software for the case company.

The highlighted part of the calculation methods in Excel Sheet to map out the best BI tools for the case company

1. *Map out criteria for selecting BI tools*

Table 1. *Section and Subsection of the map out criteria for selecting BI tools.*

Capabilities	Map out criteria	Sub-sections of the map out criteria			
Efficacy 1	Software platform compatibility	Operation system	Language support	Screen Size and resolution of the software	Diverse data acceptance
Efficacy 2	Software configurability and customizability	Configurability	Customizability of coding		
Efficacy 3	Third-party software compatibility				
Efficacy 4	Public Review	www.capterra.fi	www.gartner.com	www.softwaresuggest.com	www.getapp.com
Efficacy 5	Flexibility to adapt to different techniques (Adaptability), versatility and usefulness				
Efficacy 6	Customer support				
Efficacy 7	User Experiences				
Efficacy 8	Community and Social media acceptance according to followers and likes				
Efficacy 9	Instruction materials, user guide, training and so on				
Efficacy 10	Other important capabilities:	Supports Big Data?	Computional and analytical abilities	Attractive visualization	Maintenance of security and confidentiality

2. *Scoring procedure for selecting BI tools*

Table 2. *Scoring procedure for selecting BI tools.*

Scoring	
4 to 5	Outstanding
3 to 4	Good
2 to 3	Satisfactory
1 to 2	Poor
0 to 1	unsatisfactory

3. Scoring each BI tool based on selection criteria

Table 3. *Scoring BI tools based on selection criteria.*

Capabilities	Zoho Analytics	Microsoft Power BI	Yellowfin	SAP BusinessObjects BI Suite	MicroStrategy
Efficacy 1	4.13	3.75	3.00	3.13	3.13
Efficacy 2	3.5	4.00	4	4.5	4
Efficacy 3	3	4.00	3.5	3	3.5
Efficacy 4	4.40	4.53	4.48	4.40	4.30
Efficacy 5	3.5	4.20	3	2.5	3
Efficacy 6	4	4.00	3.5	2.7	4
Efficacy 7	4.5	4.40	4	4	4.2
Efficacy 8	2.5	3.50	2	2	3.5
Efficacy 9	4	4.50	3.5	4	3.5
Efficacy 10	3.875	4.30	2.75	2.625	3.95
Total Weight	37.405	41.175	33.725	32.855	37.08

The entire calculation for selecting best BI tools for the case company is in author's GitHub Repository.

The highlighted part of the calculation methods in excel sheet to map out the best SPC software for the case company:

1. SPC software selection criterias

Table 4. *SPC software selection criterias*

Capabilities	Map out criteria	Sub-sections of the map out criteria		
Efficacy 1	Charts and advanced data analysis criteria			
Efficacy 2	Quality control (real-time)			
Efficacy 3	Customer support			
Efficacy 4	Cost effectiveness			
Efficacy 5	User Experiences			
Efficacy 6	Other important capabilities:	Customizability	Attrative Visualization	Specifications
Efficacy 7	Public Review	www.capterra.fi	www.getapp.com	

2. Scoring procedure for selecting SPC software

Table 5. *Scoring procedure for selecting SPC software*

Scoring	
5	Outstanding
4	Good
3	Satisfactory
2	Poor
1	unsatisfactory

3. *Scoring each SPC software based on selection criteria*

Table 6. *Scoring each SPC software based on selection criteria*

Capabilities	WinSPC	Predisys Analytical Suite	Enact	SPC for Excel	DataLyzer Spectrum SPC	IQMS MES
Efficacy 1	4	4	3.50	5	5	2.5
Efficacy 2	4	4	3	5	4	3
Efficacy 3	3	4	3	4	4	3
Efficacy 4	4	4	5	5	4	3
Efficacy 5	5	4	3	5	3	3
Efficacy 6	4	4.33	3.67	4.33	4	2.33
Efficacy 7	4.6	4	4	4.8	4.8	4
Total Weight	28.6	28.33	25.17	33.13	28.8	20.83

The entire calculations to map out best SPC software for the case company is in author's GitHub Repository.