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Dashboard development for managing performance outcomes.

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Loose Attachments
BPOS Dashboard
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Abstract

This bachelor's thesis focuses on developing a dashboard for managing performance outcomes of the business process operations simulation game. The paper employs the Design Science methodology to create a practical artifact by applying dashboard design principles and user experience. The practical part involves developing the dashboard in Excel. The evaluation involves several feedback rounds. The outcomes are applied to refine the dashboard. This iterative process ensures the artifact's relevance and usability, highlighting areas for future research to further enhance its functionality and applicability.

Keywords: dashboards, KPIs, design guidelines, UX

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List of Abbreviations

3D .... Three Dimensional
AA .... Augumented Analytics
AI .... Artificial Intelligence
BPOS .... Business Process Operations Simulation
ID .... Identity Document
KPIs .... Key Performance Indicators
ODBC .... Open Database Connectivity
OEM .... Original Equipment Manufacturer
UX .... User Experience
VR .... Virtual Reality

1 Introduction

In today's data-driven world, dashboards are critical for visualizing and interpreting data (IBM Deutschland GmbH, 2023). A well-designed dashboard allows the user to grasp important and complex information at a glance and to communicate insights comprehensively and effectively to support decision-making *(Few, 2006, p. 34; Pauwels et al., 2009, p. 179)*.

Today many information dashboards are not performing well, primarily due to poor visual design rather than technological limitations (Few, 2006, p. 4). An important aspect of dashboard design is the data-ink ratio concept. It outlines that almost all the ink in a graphic should represent data (Tufte, 2007, p. 93). The right choice of visual attributes, such as graphs, diagrams, or colors, also plays a key role in the data representation. Design guidelines provide improvements and insights in design, show how to communicate information, and explain when and why some graphs are better than others. Overall, they help to improve the visual performance (Tufte, 2007, p. Introduction). Design mistakes such as overloading screens, providing insufficient data context, using inappropriate display media, and overusing visual effects negatively affect the usefulness of dashboards (Few, 2013, p. 34), while the usage of design guidelines helps developers to prevent described mistakes.

Specifically for the Business Process Operations Simulation (BPOS) game, a dashboard could help to create transparency, control, and monitor teams' performance and efficiency. The dashboard enables the instructor to compare the group results, provide advice or guidance where needed, and help each group to optimize its processes. The BPOS dashboard aims to present the relevant Key Performance Indicators (KPIs), graphs, charts, and additions such as filtering options, in a way that is easy to understand and provides the required information quickly in a well-designed visual representation. In specific, the dashboard aims to support BPOS instructors. Therefore, I apply design principles and elements that prove particularly relevant and practicable for the BPOS dashboard. The central research topic is: "Dashboard development for managing performance outcomes”.

Therefore, the structure of the thesis is described as follows: The introductory chapter is followed by the theoretical foundations, which cover the basics and principles of dashboard design. The next section describes the process of identifying the current literature followed by describing how I applied the design science methodology. Next, within the results, I describe the dashboard design and evaluation. In chapter five, I discuss the results with the foundations and principles of dashboard design, followed by an outlook on future research, limitations, and a conclusion.

2 Theoretical Background

A dashboard presents critical metrics, such as revenue or profit margin, and performance factors, such as innovation rate or operational efficiency, that represent the short- and long-term interests of the user (Pauwels et al., 2009, p. 177; Pauwels & Reibstein, 2023, p. 11). In general, dashboards illustrate the most important information at a glance to track and achieve objectives (Few, 2006, p. 34). In this chapter, I will discuss dashboard design guidelines, starting with guidelines for tables and charts, complemented by looking at the mistakes developers must avoid while designing dashboards. This is followed by user experience (UX) components, consisting of customization, interactive and feedback features, alerting, accessibility for different audiences, and information grouping. At the end of this chapter, I conclude with an outlook on possible applications of artificial intelligence (AI) and virtual reality (VR) in dashboards.

2.1 Principles of Dashboard Design

This subchapter covers the basics of dashboard design, providing the essential information to design user-friendly and objective-oriented user interfaces. Visualizations present many insights if carefully selected and developed (Muralidharan, Gregor, Shrestha, & Soar, 2023, p. 1413).

First, I explain the concept of the data-pixel ratio and its importance for UX. Then, I list design guidelines for charts and conclude by describing design mistakes. While the data-pixel ratio is the base, the design guidelines and mistakes guide developers through the design process and help them avoid mistakes to ensure user-friendly and decision-supporting dashboards.

2.1.1 Data-Pixel Ratio

In 1983, TUFTE introduced the "data-ink ratio" concept in his book 'The Visual Display of Quantitative Information' (Tufte, 2007, p. 93). He divides the ink on a chart into data-ink and non-data ink. Data ink is the essential and irreplaceable ink on a chart that is needed to understand the chart; the non-data ink is not required for understanding the chart and is, therefore, unnecessary (Tufte, 2007, p. 93). The data-ink ratio is the proportion of data-ink in the chart to the total ink of the chart (Tufte, 2007, p. 93). In 2006, FEW picked up on this concept in his book 'Information Dashboard Design: The Effective Visual Communication of Data' because this concept applies to dashboards with a bit of adjustment. He replaced the word "ink" with "pixels" because dashboards are displayed on screens, not paper (Few, 2006, p. 101). The concept consists of three rules: (1) logically expand the data pixels to their full potential, (2) logically reduce non-data and redundant pixels, and (3) revise the non-data and data pixels that are left (Few, 2006, pp. 101-107; Tufte, 2007, pp. 96-100).

First, expanding the ratio of data pixels helps convey the purpose of a dashboard. Every pixel on a dashboard needs to have a purpose; generally, that purpose should be to display critical information. The more data pixels on each chart, the easier the dashboard is to use, as users get insights at a glance rather than having to deconstruct the visualization to understand it *(Few, 2004, p. 101; Tufte, 2007, p. 96)*.

Second, logically reducing non-data and redundant pixels provides space for (new) information. Items that do not provide information are not interesting to the audience (Tufte, 2007, pp. 96-100). Developers can remove elements in the charts that do not cause the loss of insights (*Few, 2006, p. 118*). Elements such as third dimensions, grid lines in bar graphs, grid lines in tables that separate data into individual cells, color gradients, color variations, fill colors in alternating rows or fill colors to outline sections in graphs, or complete borders around data regions of a single graph are unnecessary in most cases (Few, 2006, pp. 102-106).

Last, revising the non-data and data pixels can improve the structure and readability of a chart**.** On the one hand, not every non-data pixel is always unnecessary, but to avoid distracting too much from the data pixels, the non-data pixels should be chosen carefully. For instance, muting colors or consistent elements automatically move to the background. On the other hand, data pixels must remain the focus. Therefore, the data pixels need to be enhanced to ensure that the data pixels are either more contrasting or greater than the rest, for example, by highlighting the most critical information with color intensity, size, line width, hue, orientation, border, or additional markers (Few, 2006, pp. 109-116; Tufte, 2007, pp. 93-105).

According to FEW and TUFTE, following these rules shifts the focus to the essential information (Few, 2004, p. 119; Tufte, 2007, p. 96). Developers need to be aware that minimizing any perceived distractions may inadvertently weaken the chart's impact. An oversimplified chart quickly becomes as confusing as an overloaded chart (Epstein, Martin, & Schneider, 2006, pp. 1851-1861).

2.1.2 Guidelines for Tables

Depending on the information developers want to present, some charts are more appropriate than others. For example, tables are better at showing detailed and summarized values (Few, 2004, p. 153; 2006, p. 121; Malik, 2005, p. 46 f.). Accordingly, instead of using many bar charts, developers can build one large table (Tufte, 2007, p. 178 f.). Table design consists of two main parts: *data and table arrangement and alignment,* as well as *formatting and presentation*.

In general, developers have many options for data **arrangement**: alphabetical, hierarchical, numerical, time-based, or location-based. The most efficient way to arrange numbers, dates, or times is ascending, descending, or in a typical order for the user. Alphabetical order should only be used when no other order makes sense, as there is almost always a better way to arrange data (Few, 2004, p. 146; Tidwell, Brewer, & Valencia, 2020,

p. 32 ff.; Tufte, 2007, p. 178). If developers have to work with space constraints and a large table with many subdivisions, the optimal way to arrange the table is to put the subdivisions in columns one below the other. Otherwise, they can put them in several columns next to each other. To improve readability, developers can divide these categories into logical groups and create multiple tables. Choosing the proper ***alignment*** of the data enhances its structure and readability. Subdivisions of tables are best readable on the very left side of the table, with the related data on the right side. Furthermore, if there is a relationship between data, it is best presented hierarchically from left to right. In general, developers should place any calculation to the right of its source column. Category names and information that contains neither dates nor numbers are optimally legible left-aligned, while quantitative values are best read right-aligned (Few, 2004, pp. 140-147).

The chosen level of the data ***format***, whether annually, quarterly, monthly, or daily, ought to be used throughout the entire dashboard. This level only needs to be as detailed as necessary to analyze the data. The chosen font and date format should be as legible as possible; therefore, the size should not be smaller than 10 points (Few, 2004, p. 152; Rasmussen, 2009, p. 101; Tidwell et al., 2020, p. 267). Furthermore, the chosen font should be either sans serif or serif. Developers should never use similar fonts in one dashboard; after they choose a font, they can work in different styles, such as cursive or bold to highlight or differentiate important data. Serif font styles have small lines at the beginning and end of each letter, and sans serif font styles do not have these small lines. Hence, serif font styles are better for heavy texts because the small lines on each letter guide the reader's eye, while sans-serif font styles are more legible when developers work with smaller font sizes. Rounding large numbers to the nearest thousand, million, or billion and using commas every three digits simplifies the presentation and improves the readability of the values (Few, 2004, pp. 149-154; Tidwell et al., 2020, p. 266 f.). Adding sums, averages, occurrences, distributions, or comparisons provides helpful information (Few, 2004, p. 153; Tufte, 2007, p. 179). To indicate negative values, developers can choose between using parentheses or minus signs, and to indicate percent values, developers must use percentage signs placed directly to the right of the value (Few, 2004, p. 149). For a clear and understandable ***presentation*****,** white space can help. White space can indicate the reading direction by enlarging it where needed. Enlarged white space between the columns makes the reader go through the columns, and enlarged white space between the rows gets the reader to read row for row. If white space is not enough to make the data legible, shading, fill color, or grids help, but also decluttering the information (Bremser & Wagner, 2013, p. 67; Few, 2004, p. 136 ff.). Fill color also helps to highlight and group related data. Headings should be repeated on every page if the table extends over several pages (Few, 2004, p. 154).

2.1.3 Guidelines for Graphs

Graphs have a solid visual character and can quickly convey considerable information when designed correctly. If several small graphs, so-called small multiples by TUFTE, are placed next to each other, they can reveal interactions or combined effects. Graphs make it easy to compare values and ensure that an otherwise large data matrix is easy to understand (Few, 2004, p. 166; Tufte, 2007, p. 175).

Following are some ***basic guidelines*** for graph design: As already mentioned in the subchapter *Guidelines for Tables*, the chosen font and date format should be as legible as possible, not be smaller than 10 points, and sans serif and serif font styles should not be mixed in one graph (Few, 2004, p. 152; Rasmussen, 2009, p. 101; Tidwell et al., 2020, p. 267). Users most easily understand graphs when they are displayed horizontally and wider than high. (Tufte, 2007, p. 186). When developers intend to display a large amount of information, it works best with a large data matrix and high data density. This means the database must be extensive and include many values (Tufte, 2007, p. 168). Nevertheless, the graph should represent a maximum of five to eight data sets to prevent overload. If developers want to display two values with different units in one graph, two y-axes or x-aches work best. If they are going to display values with significant differences, a logarithmic scale displays them optimally; otherwise, they can use a linear scale (Few, 2004, p. 216). As mentioned earlier, developers should change one graph into many related small graphs instead of overfilling an already large one. They should use the same design on the small multiples to represent their relation. For better readability, the small graphs need to be placed side by side if the quantitative scale is horizontal and if the quantitative scale is vertical, one below the other. The index variable can only be displayed in order or by rank, depending on the user's needs. Finally, developers should only consider grid lines when white space alone is not enough to ensure the readability of the graph, but even then, only very sparingly (Few, 2004, p. 230; Tufte, 2007, p. 175).

When using ***point graphs***, developers face one main difficulty: making every point visible enough. To solve this problem, enlarging the points or changing their shape can help. Expanding the graph, shrinking the points, or reducing fill colors helps to prevent the points from overlapping. When lines overlap the points, the points can be enlarged for better visibility (Few, 2004, pp. 176-181).

Line graphs visualize best continuity or flows or show patterns over a specific time (Bremser & Wagner, 2013, p. 67; Few, 2004, p. 191). Simple line graphs are more efficient in presenting outcomes than any three-dimensional (3D) chart (Tidwell et al., 2020, p. 79). To make the line graph a good visualization tool, the lines must be easily distinguishable; a developer can use different color hues or intensities and line styles. High-low and trend lines must stand out; this can be achieved through color intensity, line type, or thickness. The lines can work independently and do not require a current bar or line, but it is no mistake to show them anyway (Few, 2004, pp. 191-195).

Bar graphs visualize distinctness or rankings (Bremser & Wagner, 2013, p. 67). They need to be displayed horizontally when they do not fit near each other or if the order of the bars is descending. The bars work best when they start at zero unless they intentionally show a range. If the graph has categories along the axis to display and differentiate them clearly, the white space between the bars should be about 50 percent less or more, or at least the same width as the bar itself. No white space is needed if the categories are not along the axis. Developers must ensure that the bars never overlap and that fill colors are used only when necessary and with easily distinguishable colors of the same hue. Borders around bars can be helpful when the bar's color is not different from the background color of the graph or when the border is used to highlight a bar (Few, 2004, pp. 214-216).

Legends, tick marks, and additional text support almost every graph with further information or better readability. ***Legends*** can outline the categories if they are not shown on the axis or at the graph's direct data points. They work best with the information close to the graph to clarify where the legend belongs. Developers need to keep their attention on the actual information objects by using, for example, less intensive colors or omitting borders around the legends (Few, 2004, pp. 205-216). ***Tick marks*** are only needed at quantitative scales. They work best kept simple and outside the axis to avoid drawing too much attention. Developers should use them carefully because too many tick marks can quickly clutter a graph (Few, 2004, p. 214 ff.). Some graphs or tables show complex information; ***additional text*** supports interpreting the complex data (Few, 2004, p. 126). Sometimes, the charts themselves could be easier to understand. Therefore, it is essential to provide an explanation by using additional text. It can also make some information stand out or guide the user through the graph if the reading direction is in a different order than usual. Adding additional text is helpful in almost every case because it can improve or complete the graph (Few, 2004, p. 125 ff.; Tufte, 2007, p. 180).

2.1.4 Common Design Mistakes

As mentioned in the introduction, the performance of many dashboards needs better visual design (Few, 2006, p. 4). Poor visual design includes the selection of inappropriate charts or elements within the charts. Poorly chosen charts can fail to deliver insights from easily understandable data; for instance, pie charts fail to represent data along a visual dimension and, therefore, should not be used. As well as the third dimension for graphs or elements in the graphs (Few, 2013, p. 119; Tidwell et al., 2020, p. 79; Tufte, 2007, p. 176). Ignoring the skill gap of future users can lead to different results when users work with the dashboard and not using the user's common vocabulary and unfamiliar graphs could also be a reason that causes the dashboard to fail (Few, 2006, p. 99; 2013, p. 66).

Bad-designed charts visualize more than eight data sets at a time and need a better balance of visual and textual elements (Few, 2004, pp. 175, 216). Charts also become inappropriate when they give too much context or the data on the charts is highlighted too much or too little. Misaligned and irregularly placed elements, such as text in a table that is aligned not horizontally from left to right, or the overload with visual effects, such as unnecessary grid lines or fill colors, overwhelm the user (Few, 2013, pp. 34 f., 175; Tidwell et al., 2020, p. 212). Not using the user's common vocabulary and unfamiliar graphs could also be a reason that causes the dashboard to fail (Few, 2006, p. 99). Also, changing the aspect ratios of the X and Y axes is confusing and, therefore, should not be done because the user cannot use the dashboard properly because it is too difficult to read (Allio, 2012, p. 26; Few, 2004, p. 216; 2013, p. 35).

The dashboard size should be, at most, the maximum display size because the data loses meaning if the user cannot see everything at a glance (Berinato, 2019, p. 37; Few, 2004, p. 35). Furthermore, too many KPIs on one dashboard quickly become useless and confusing. Suppose the dashboard is too colorful or colorless or contains too many or too few visual effects, as well as not having a well-chosen background color or shading, high density, or poor alignment of the data and the charts. In that case, the user needs more time to understand the data, and the dashboard becomes an ineffective tool for insight generation (Tidwell et al., 2020, p. 209 ff.). Developers also need to avoid using colors that are too similar or intense or only the colors green and red to indicate changes because only using green and red disadvantages color-blind people. At the same time, too intense colors cause eye weakness (Tidwell et al., 2020, p. 258 ff.).

While designing dashboards, developers often work statically, so they fail when they are supposed to work dynamically with constantly updating data (Froese & Tory, 2016, p. 83). Sometimes, the performance of a dashboard is also delayed when the data updates too often, causing too long server actualizations (Tidwell et al., 2020, p. 79).

Consistent user interfaces meet the user’s needs and are easier to handle, reducing errors. However, staying consistent in design over several user interfaces weakens the performance and limits innovative design ideas that may be more effective (Froese & Tory, 2016, p. 89; Huran, 2014, p. 6). As well as allowing too many customization options that let the generation of insights suffer (Tidwell et al., 2020, p. 79). Avoiding design mistakes makes the dashboard achieve the objective of giving insights about the data quickly and extensively (Tidwell et al., 2020, p. 179).

2.2 User Experience

To ensure an appropriate UX, developers must design dashboards based on different aspects. Therefore, it is mandatory to know the basics and to differentiate between the right (1) customization, (2) interactive features, (3) alert features, (4) accessibility for different audiences, and (5) information grouping.

Customization ensures the effectiveness of dashboards, while interactive features help users obtain and gather information. In addition, alert features support users by pointing out meaningful events (Allio, 2012, p. 32; Few, 2013, pp. 67, 177). Moreover, developers must consider different audiences regarding the accessibility of dashboard solutions and design it as readable as possible with the help of grouping methods (Tidwell et al., 2020, pp. 34, 213).

Firstly, the ***basics*** that improve the overall UX. An important aspect is using natural language; it makes the dashboard accessible to any user (Ruoff, Gnewuch, Maedche, & Scheibehenne, 2023, p. 1502). If the developed dashboard is updated more than once per day, a timestamp should be integrated into the dashboard to show the latest update (Few, 2013, p. 159). Different sizes, positions, densities, background colors, line widths, or color intensities can be used to support information that needs to stand out (Bremser & Wagner, 2013, p. 212; Tidwell et al., 2020, p. 209 f.). Users tend to look first at the upper half of the dashboard. Therefore, the most critical information needs to be placed there (Tidwell et al., 2020, p. 212). The placement of the dashboard elements is crucial because it ensures a targeted work behavior. Hence, they have to be placed based on the workflow or the main concerns of the user and be balanced between data and visual elements (Bitzer, Lehmann, Hirdes, & Thillainathan, 2012; Rasmussen, 2009, p. 102). For efficient insights, it is crucial to involve general criteria through the dashboard that show something is either positive or negative or remains the same, for example, with the inclusion of icons. The most outlining are the ones that show on/off and up/down (Few, 2013, pp. 74, 177). Sparklines are the most effective way to show the development of a KPI at first glance (Few, 2013, p. 159). The chosen metrics and units, for example, euro or dollar, and, as mentioned earlier, the font should be used through the dashboard (Few, 2004, p. 152; Pauwels et al., 2009, p. 179). If the dashboard has more than one page, each page has to include information about the page number, the responsible person, the time the information was collected, and a statement headline; the more significant the headline, the more important it appears (Few, 2004, p. 128 f.; Tidwell et al., 2020, p. 211).

Depending on the number of future users, the amount of ***customization*** possibilities can affect the usefulness of dashboards positively because they allow the adaption of some elements to the specific needs of each user while still being consistent across the dashboard (Few, 2013, p. 67; Muralidharan et al., 2023, p. 1413). A well-designed dashboard has to be customizable to meet the requirements and aims of every user (Few, 2006, p. 98). Customization possibilities, such as customizable KPIs, charts, layouts, and filters, might also close the gap between new dashboard users and those already specialists and, therefore, be beneficial (Allio, 2012, pp. 25-29; Tidwell et al., 2020, p. 34). Nevertheless, developers should consider the earlier-mentioned design mistake of adding too many customization options (Tidwell et al., 2020, p. 79).

Interactive features such as drill-downs, filters, or the function of high-level summarization into detailed view support data analysis (Froese & Tory, 2016, p. 87). Interactive features can also reduce malfunctions with the help of tooltips, such as message boxes that pop up to re-ask the executed command or progress indicators and undo features (Muralidharan et al., 2023, pp. 1413-1427). Developers need to make the most frequently used interactive features visible so that users do not have to search for them, while those less frequently used can be placed more hidden (Tidwell et al., 2020, p. 33). The most prominent place on a dashboard is the upper left area, as shown in a study by the Journal of Association for Information Systems; therefore, as already mentioned earlier, the most needed features and information should be placed there (Toreini, Langner, Maedche, Morana, & Vogel, 2022, p. 542). A dashboard needs to have interactive features to be effective (Malik, 2005, p. 56).

Alert features can make issues or opportunities more visible by highlighting them (Bremser & Wagner, 2013, p. 67). The issue alerts work best if they adapt to complex situations and can provide fast forewarnings (Malik, 2005, p. 62). They can also appear as audio alerts or time-stamp alerts. Users do not look all the time at the dashboard when a critical alert pops up; an audio can get the user's attention back to the dashboard; also, a time stamp to look up when the alert appears is sometimes useful (Few, 2013, p. 200 f.). As some alarms work with color schemes, developers should select colors everyone can distinguish, including color-blind users (Person, 2013, p. 141).

As a further aspect, it is essential to make the dashboard ***accessible to different audiences***, including colorblind and older people, audiences with high or low expertise, or audiences consisting of one or multiple users (Few, 2013, p. 66; Person, 2013, p. 141; Tidwell et al., 2020, p. 34). The dashboard is only helpful if it meets the audience's needs. Developers can only meet these needs if they are aware of their future dashboard users and therefore use known graphs, design with adjusted complexity, or, as already mentioned, colors that are easy to differentiate or additional icons for colorblind and older people (Few, 2006, pp. 66, 99; Person, 2013, p. 141). The last point is not to be underestimated, as 8 percent of all men and 0.4 percent of all women suffer from color vision disorder (Bundesministerium für Gesundheit (BMG), 2021). If a dashboard is designed to meet only one person's needs, it can be customized entirely according to how that user wants it to be (Few, 2013, p. 67; Tidwell et al., 2020, p. 34).

Information Grouping is one of the key elements of dashboard navigation because it indicates the relation between information (Malik, 2005, p. 54). Information Grouping works with *Gestalt Principles*, invented by the psychologists WERTHEIMER, KOFFKA, and KOHLER (Interaction Design Foundation, n. d.; Tidwell et al., 2020, p. 217). I describe the principles of proximity, similarity, continuity, and closure in the following. Proximity works by placing elements near each other, which indicates that they belong together; the other way around makes the elements stand out individually. As the word similarity already indicates, similar elements, for example, in size, color, or shape, suggest that they belong together, and elements that are not similar indicate that they are separated. The principle of continuity describes that elements arranged on a line or curve look like they belong together. The closure principle says that a developer or designer should use identifiable patterns because the human brain automatically completes the missing pieces to a visualization. These rules outline how grouping and alignment work for the human brain and how developers can use them to improve their dashboard visualizations (Bremser & Wagner, 2013; Tidwell et al., 2020, pp. 218-220).

2.3 Outlook on Artificial Intelligence and Virtual Reality

The following section will give an overview of integrating AI and VR into dashboards. AI algorithms can analyze vast amounts of data for pattern recognition and insight generation (Colace, De Santo, Gaeta, Loffredo, & Petti, 2024, p. 343). While VR provides an immersive environment to visualize and interact with these insights for further decisions (Palmquist, Jedel, Chris, Perez Colado, & Soellaart, 2024, p. 267).

2.3.1 Artificial Intelligence

Recently, AI improves business processes in many industries by making them more automated or faster overall (Papadakis, Christou, Ipektsidis, Soldatos, & Amicone, 2024, pp. e10-11 f.). AI helps developers develop dashboards by analyzing statistical data, generating charts, providing reports based on the data, and formulating hypotheses for further analysis (Pauwels & Reibstein, 2023, p. 17). Integrating AI streamlines the development process and improves the UX and functionality of dashboards (Fischer & Lanquillon, 2024, p. 32).

AI-driven dashboards, which are dashboards with integrated AI, analyze user behavior to personalize the user interface by providing quick access to the most critical data and improving the UX by adapting the layout to the user's needs and work behavior. Personalized user interfaces are more likely to help achieve objectives because they present relevant data to the users in their preferred view (Drzyzga, 2024, p. 134). In future research, further integration of AI will enhance the ability to personalize dashboards and improve data presentation (Boerner et al., 2023, p. 17).

Dashboards in organizations work in this era with data from internal systems that they can easily access (Hoffman, 2016, p. 1. Better Organizational Dashboards). With the integration of AI, companies can access more complex data that needs to be extracted first or find hidden trends in large data sets. Users can analyze the emotional tone of internal communications to determine the most frequently discussed topics, potential risks, and planned use of resources (Colace et al., 2024, p. 343). In summary, AI can reduce the workload associated with developing dashboards in collecting and compiling all the data (Kasztelnik & Campbell, 2023, p. 64).

AI can improve decision-making from intuitive to more data-driven decisions (Papenkordt, 2024, p. 240). Future AI-driven dashboards can have the ability to provide more predictive insights; in combination with predictive analytics, the dashboards can provide a foresight of future trends and risks and also show possible market changes to ensure competitive advantage and significantly improve the decision-making process (Fischer & Lanquillon, 2024, p. 37 f.). Dashboards can also display possible developments or even the best possible development, which users can select for further elaboration (Adreani et al., 2024, p. 5).

Dashboards also can integrate an AI-driven chatbot. An AI-powered chatbot is an interactive conversational tool that is algorithm-based, automated, and understands natural language. It can help identify trends and risks. The chatbot can work by asking multiple questions for users to answer. Using the answers, it can display relevant data on the dashboard. A team from the University of California at San Francisco built an AI-driven chatbot to look at the behavioral health needs of employees and systematically assess and prioritize them according to urgency (Jackson-Triche, Vetal, Turner, Dahiya, & Mangurian, 2023, pp. 1-10).

Advanced AI capabilities combined with business intelligence, also known as augmented analytics (AA), can improve the entire dashboard development process. It can help save time by automating business analysis cycles, visualizing and modeling data, and generating more accurate insights by consolidating and transforming data from multiple sources. This development improves the UX and allows employees with less expertise to take on analytical tasks as the AA automatically does much of the work. Future research can improve the usability of dashboards through AA to enable anyone to gain insights from large amounts of data without analytical skills (Alghamdi & Al-Baity, 2022, pp. 2-18).

The growing importance of integrating AI into dashboards is undeniable. It helps to access more complex data and gain more predictive insights; it also improves personalization for better UX and faster analytics results. With AI-powered chatbots and AA integration, dashboards can reach a new efficiency level.

2.3.2 Virtual Reality

VR transforms the industry by enabling touch feedback, capturing motion, and providing immersive experiences (Wang & Wen-Shin, 2023, p. 4). Some dashboards have VR already integrated. It improves data understanding and decision-making through a better UX by creating a 3D environment where users can analyze complex data (Kobayashi, Jadram, & Sugaya, 2024, p. 213).

VR creates new possibilities for developers. With VR, they can perform an in-depth error analysis by diving into the data. They can place themselves into the dashboard, the data, or the code displayed in 3D, understand how the computer indicates errors, and enhance their ability to find and improve the mistakes (Toshiki et al., 2024, pp. 209-220).

VR also opens up new possibilities for data analysis (Li et al., 2024, p. 237). With many sensors providing visual, auditory, and tactile feedback, users dive into a virtual environment that allows them to interact with the digital world in a real-world scenario (Gbashi & Patrick Berka, 2024, pp. 7, 10). As mentioned above, haptic feedback is a part of VR; it can appear in the form of a short vibration. It can guide the user's attention through a task and improve their multitasking ability. Movements such as gaze can be captured and responded to with an immersive effect, such as the appearance of arrows to direct the line of sight. These immersive technologies associated with VR make data analysis more successful in guiding users to understand and analyze data sets, leading to better decision-making (Mori, Ando, Otsu, & Izumi, 2024, p. 62 f.).

With the integration of VR, data can be displayed in 3D and users can dive directly into the data. The haptic and immersive effects bring the user closer to computer functions and help them understand how they work. This improves the user's intuition, and with this ability, they can enhance their analytical skills and their ability to work with complex operational processes (Pedersen, Lyk, & Auerbach, 2024, p. 244 f.). VR also improves user engagement by mimicking real-world environments through realistic interactive experiences (Palmquist et al., 2024, p. 269). Integrating immersive environments also opens up new opportunities for data visualization for developers because design possibilities for a 3D environment are more flexible and extensive (Sun & Weidner, 2024, p. 298).

The ability to create 3D dashboards and dive into the data as a user to work with it interactively, with the dashboard responding to the user's gaze or body language and also providing direct feedback, can develop new skills or enhance existing ones, as well as deepen and accelerate the understanding of the data. Overall, VR dashboards improve performance.

3 Research Method

Design science is a research approach that aims to introduce innovative design artifacts, such as systems, models, methods, or constructs, and to improve development processes, thereby improving the environment. This research approach is based on three interrelated cycles: the relevance cycle, the rigor cycle, and the design cycle (Hevner, 2007, p. 1 f.).

The relevance cycle identifies the artifact's requirements and approval standards and provides the impetus for design science research (DSR). The rigor cycle represents existing knowledge to ensure the artifact is innovative, not just routine designs based on known approaches. The design cycle describes the process of building and evaluating the artifact to continuously improve it depending on the evaluation results (Hevner, 2007, pp. 2-5).

In this paper, I applied the design science approach to build a dashboard for the BPOS game. The theoretical background provides an overview of design guidelines for specific dashboard elements and the user interface. In the practical part, I built the dashboard by applying the provided theory and extending it with new insights that emerged during the development process. In the next part, Tobias Engel evaluates the artifact. In this thesis, chapter two focuses on the theoretical background, and chapter four discusses the development and evaluation process.

Figure 1 visualizes the approach of HEVNER, with a little adaptation to the mentioned context. The environment defines the requirements of the artifact, which includes the people involved in developing and evaluating the design artifact, which is the end user, Tobias Engel and other professors, and myself, who is building the dashboard. It also includes the organizational systems, which are the processes that will be improved by the insights provided by the dashboard, as well as technical systems, which are the data source used and the information technology (IT) infrastructure. MySQL Workbench is in the data source, and Excel is the IT infrastructure. Problems include the difficulty of updating the database with a new dataset, too large datasets that can weaken performance, and the possibility of designing a dashboard that is too complex and, therefore, provides a poor UX. Opportunities include increased efficiency and improved decision-making. Design science research is centered on the design cycle, which iterates between creating and evaluating a design artifact. The design artifact's construction includes the dashboard's development process, which iterates with the continuously performed evaluations with subsequent dashboard improvements based on the evaluation results.

The knowledge base ensures that the designed artifact is based on a good fundament of scientific theories and methods, experience and expertise, and already designed artifacts. The theories and methods in this paper's research project are the dashboard and UX design guidelines I found during the research. Experience and expertise, in this case, are the contained knowledge of experts on dashboard design. I gained knowledge from designing previous dashboards that I developed.

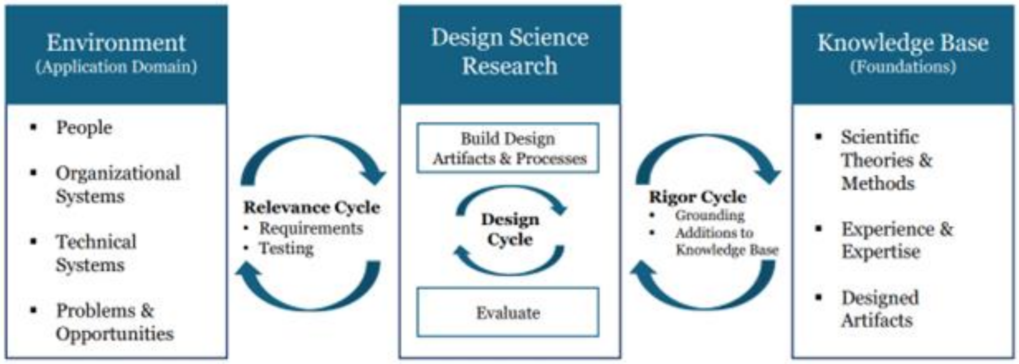


Figure 1 - Design Science Approach: Adopted from Hevner, 2007, p. 2

4 Artefact Development and Evaluation

Within this thesis, I developed a dashboard for the BPOS game and evaluated it with the game's instructor. This chapter first provides a general description of the BPOS game to describe how it is structured and played. Afterward, a detailed description of the dashboard's development and evaluation processes is provided to make the development process traceable.

4.1 BPOS Game

The BPOS game acts as a vehicle for developing and evaluating the dashboard. The dashboard supports a deeper analysis of the group's performances, compares them in general, and analyzes each group separately. The game is a learning simulation that teaches participants how real-world business processes work. It covers strategic development, finances, controlling, risk management, and more.

The game consists of a six-stage supply chain. The original equipment manufacturer (OEM) orders raw materials, and tier-1 delivers them to the OEM. Tier-1 orders its raw materials from tier-2, tier-2 orders from tier-3, and tier-3 orders from tier-4. Tier-4 orders his raw materials from an external supplier, which the game instructor indicates. The computer plays the OEM. Each tier buys raw materials and processes them further. Through further processing, the purchased raw materials become raw materials for the next tier, which also processes them further. The supply chain starts with raw materials such as screws, grills, and light-emitting diodes, which purchase tier-4. At the end of the supply chain, tier-1 sells bumpers to the OEM.

Additionally, each tier, except tier-4, has an alternative supplier in case the original tier cannot match the supply due to mismanagement or further problems. The simulation game concerns each tier's ability to match the demand and manage internal processes such as buying, producing, and selling the products. The instructor can control the whole game by indicating the percentage the alternative supplier can offer, the production error rate, the scope for price increases, and the ability to buy further warehouses or production machines. Each tier has one of each at the beginning of the whole game. The game can last up to 480 rounds. One round indicates one day and is 60 seconds long. Sixty rounds measure one-half of a year. The game depicts the profit and loss statement (P&L), which can give the instructor and each tier insights into their performance (Education 4 Success, n. d.).

4.2 Development

The development section involves three steps: (1) the chosen design guidelines that were applied to the dashboard, (2) the database structure and its implementation to the dashboard, (3) the development of the dashboard and its functionalities.

The dashboard is a comprehensive tool. Its first register provides an overview of all 18 KPIs that Tobias Engel, the game's instructor, chose. It also features 14 other registers that track the development of each KPI for each tier over the rounds, offering a detailed view of their progress.

4.2.1 Step 1: Chosen Design Guidelines

The dashboard consists of 17 registers. The overview register shows 18 KPIs in table format due to the need for a summarized and quick overview of the values. The dashboard holds two more registers displaying general information about the tiers, also in table format. 14 further registers prepare a more detailed visualization of the KPIs visualized as graphs. Therefore, following the chosen table design guidelines for the table registers listed in the order of arrangement, alignment, formatting, and presentation. Next, the selected graph guidelines are displayed, starting with basic graph guidelines, followed by guidelines specifically for line graphs, and ending with guidelines for legends, tick marks, and additional text. In the end, the overall UX guidelines follow in the order of basic UX guidelines, customization, interactive features, alert features, accessibility, and information grouping.

Table design guidelines:

- Data can be arranged alphabetically, hierarchically, numerically, time-based, or location-based. Still, the efficient way to arrange numbers, dates, or times is either ascending, descending or an order that the company usually uses. (Few, 2004, p. 146; Tidwell et al., 2020, p. 32 ff.).
- The alignment of subdivision categories is best readable on the very left side of the table and the related data on the right side (Few, 2004, pp. 144-147)
- If there are any relations between the data, they are best displayed hierarchically from the left to the right (Few, 2004, p. 144).
- Quantitative values are most readable right-aligned (Few, 2004, p. 147).
- Use commas every three digits to simplify the presentation and improve readability (Few, 2004, p. 149).
- Use parentheses or minus signs to indicate negative values, and place percentage signs directly to the right of the corresponding values (Few, 2004, p. 149).
- The font must be as easy to read as possible. Serif font styles are better for heavy texts because the small lines on each letter guide the reader's eye, while sans-serif

font styles are more legible when developers work with smaller font sizes (Few, 2004; Tidwell et al., 2020, p. 266 f.).

- The size should not be smaller than 10 points (Tidwell et al., 2020, p. 267).
- Further, developers should never use similar fonts in one dashboard, either sans serif or serif fonts, but in different styles, such as cursive or bold (Tidwell et al., 2020, p. 266 ff.).
- Enlarged white space between the columns makes the reader go through the columns, and enlarged white space between the rows gets the reader to read row for row (Few, 2004, p. 136).

Graph design guidelines:

- Graphs need to be displayed horizontally and be wider than high (Tufte, 2007, p. 186).
- When developers intend to display a large amount of information, it works best with a large data matrix and high data density. (Tufte, 2007, p. 168).
- The graph should represent a maximum of five to eight data sets (Few, 2004, p. 216).
- The lines must be easily distinguishable by different color hues, intensities, and line styles (Few, 2004, p. 191 f.).
- The index variable can only be displayed in order or by rank, depending on the user's needs (Few, 2004, p. 230).
- Legends work best with the information close to the graph to clarify where the legend belongs (Few, 2004, p. 216).
- Developers need to keep the attention on the actual information objects by using, for example, less intensive colors or omitting borders around the legends (Few, 2004, p. 216).

User Experience:

- Different sizes, positions, densities, background colors, line widths, or color intensities support information that needs to stand out (Few, 2006, p. 115 f.).
- For fast insights, it is good to involve general criteria through the dashboard that show something is either positive or negative or remains the same, for example, with the inclusion of icons. The most effective are the ones that show on/off and up/down (Few, 2013, pp. 74, 177).
- The larger the headline, the more significant it appears (Tidwell et al., 2020, p. 211).

- Customization possibilities, such as customizable KPIs, charts, layouts, and filters, might close the gap between new dashboard users and those already specialists (Allio, 2012, pp. 25-29; Tidwell et al., 2020, p. 34).
- *Interactive features* such as drill-downs, filters, or the function of high-level summarization into detailed view support data analysis (Froese & Tory, 2016, p. 87).
- In a well-designed dashboard, the most frequently used interactive features are positioned as visible as possible so that users do not have to search for them (Tidwell et al., 2020, p. 33).
- Alert features make issues or opportunities more visible by highlighting them (Bremser & Wagner, 2013, p. 67).
- Principle of proximity: elements near each other indicate that they belong together (Tidwell et al., 2020, p. 217).

4.2.2 Step 2: Database Structure and Implementation

Due to the high number of participants in the lectures where the BPOS game takes place, they are divided into several groups. These are named “Game 1“, “Game 2“ and further, depending on the group size of the lecture. These “Game 1“ and “Game 2, “ etc., play the game simultaneously and use several similarly structured databases. Each game consists of the six-staged supply chain mentioned in subchapter *4.1. BPOS Game*. To differentiate all the tiers, they are called, for example, “Game 1 – Tier-1“, depending on which game they belong to and which tier they are in.

Every database connection was created in MySQL Workbench. Figure 2 shows a database scheme in MySQL Workbench. In this example, the database used is “CNTPEYOA“. The table names and amounts are always the same.

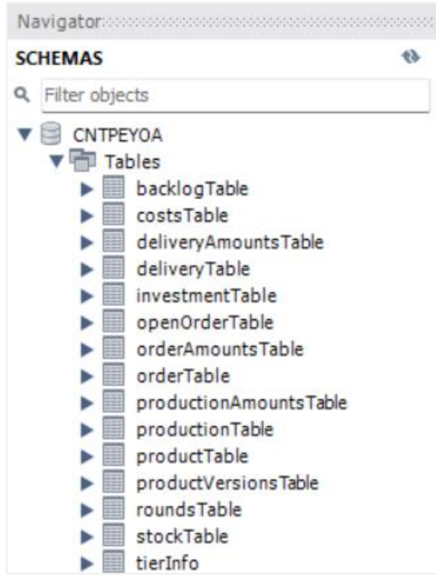


Figure 2 - Database Scheme in MySQL Workbench

After configuring the connection in MySQL Workbench, the next step was implementing the database connection into the Excel file. This occurs via an open database connectivity (ODBC) driver. The ODBC driver can be selected directly within the Excel file in the "Daten" register via “Daten abrufen“. This function offers many possibilities to import data into the Excel file; at this point, the option “Aus anderen Quellen“ contains the possibility to choose “Aus ODBC“. With selecting “Aus ODBC”, the connections from MySQL Workbench appear.

The database needed adjustments during development because some KPIs could not be taken directly from the tables. Therefore, after merging some of the existing tables to create new tables, the database in Excel expanded from 15 to 19 tables. These adjustments took place in the Excel Power Query Editor. The Power Query Editor can be used within Excel when working with data connections. Further adaptions can be made to the database by, for example, merging tables or adding columns from other tables or even columns with calculations (ptyx507x et al., 2024). The following figure shows an example of a merge conducted in the query dependency view that can be opened within the Power Query Editor (see Appendix A).

Figure 3 shows the merge for the Raw Material Costs KPI. For this KPI, an earlier-merged table, “MergedforDeliveryCosts“, and the “productTable“ table were merged. The column “product“ was used as the primary key, holding the product ID. A primary key is a unique attribute in a table that distinctively identifies each row and is therefore used to link tables (WilliamDAssafMSFT et al., 2024). In the last step, a calculated column was established, which estimates the raw material costs by multiplying the retail price from the “productTable“ table with the inbound amount from the “MergedforDeliveryCosts“ table.

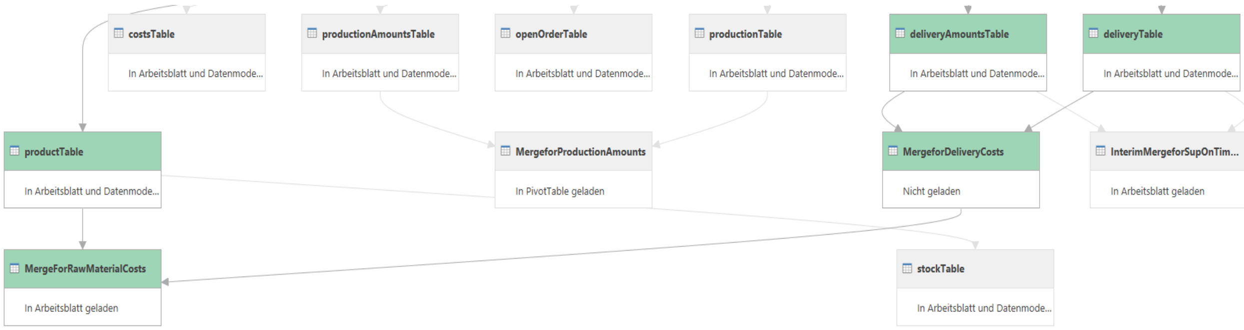


Figure 3 - Query Dependency of the Raw Material Costs KPI

The following table (Table 1) lists all KPIs used in the dashboard: First, the ones shown in the overview register, then the ones that appear in the other registers, and last, the base KPIs needed to calculate the dashboard KPIs. The table also provides a short description and the source of each KPI, which can be an existing table, a merged table, or a calculation (for the calculations see Appendix B, Figure A.4 till A.8).

KPI	**Description**	**Source**
Overview Register KPIs		
Total Revenue	Displays the total revenue earned by each tier per round.	Existing: deliveryTable
Production Costs	Displays the production costs caused by each tier per round.	Existing: productionTable
Backlog Costs	Displays the backlog costs caused by each tier per round.	Existing: costsTable
Gross Profit	Displays the gross profit earned by each tier per round.	Calculation performed in Excel
Operating Profit	Displays the operating profit earned by each tier per round.	Calculation performed in Excel

Warehousing Costs Raw Material	Displays the warehouse costs caused by the raw materials for each tier per round.	Existing: costsTable
Warehousing Costs Finished Goods	Displays the warehouse costs caused by the finished goods for each tier per round.	Existing: costsTable
Net Income	Displays the net income earned by each tier per round.	Calculation performed in Excel
Inventory Turnover	Shows the average inventory turnover over all rounds.	Merged productAmountTable columns to stockTable and added calculated column + Calculation in Excel
Delivery Distribution Index	Shows the share of the deliveries to the normal customer compared to the total deliveries made by the tier.	Calculation based on deliveryTable
Supplier Distribution Index	Shows the share of the fulfilled orders by the regular supplier to the tier, compared to the total orders purchased by the tier.	Calculation based on orderTable
Repeat Purchase Rate Alternative Customer vs. Normal Customer	Shows the share of repeated orders by the alternative customer compared to the full order volume that the tier gets.	Merged to new table: orderTable, orderAmountTable + Calculation in Excel
Capacity Utilization	Shows the percentage to which the tier is utilizing its full capacity, considering the tool change time and the number of machines available.	Existing: investmentTable + Calculation performed in Excel

On-Time Delivery Performance	Shows the percentage of deliveries that were delivered on time by the tier.	Merged to new table: orderTable, orderAmountTable
Supplier On-Time Delivery Performance	Shows the percentage of orders that were delivered on time by the supplier.	Merged to new table: deliveryTable, deliveryAmountTable
Production Costs vs. Total Revenue	Compares the production costs with the total revenue.	Calculation performed in Excel
Backlog Costs vs. Total Revenue	Compares the backlog costs with the total revenue.	Calculation performed in Excel
Warehouse Costs vs. Net Income	Compares the total warehouse costs from raw materials and finished goods to the net income.	Calculation performed in Excel
Additional KPIs for detailed registers		
Production Amounts	Displays the production amounts produced by each tier per round.	Merged to new table: productionTable, productionAmountsTable
Backlog Amounts	Displays the backlog amounts caused by each tier per round.	Existing: openOrderTable
KPIs needed for further calculations		
Raw Material Costs	Displays the raw material costs caused by each tier per round.	Merged to new table: MergedforDeliveryCosts, productTable and added calculated column
Order Costs	Displays the order costs, caused by each tier per round.	Existing: deliveryTable
Tool Change Costs	Displays the tool change costs, caused by each tier per round.	Existing: productionTable

Machine Costs	Shows the expenditure for purchased production machines.	Existing: investmentTable
Storage Facility Costs	Shows the expenditure for purchased warehouses.	Calculation based on information out of the BPOS game itself
Delivery Costs	Displays the delivery costs, paid by each tier per round.	Existing: deliveryTable
Warehouse Rent	Consists of costs that are incurred per product in the warehouse.	Calculation based on stockAmount table
Salaries	Displays the salaries paid by each tier per round.	Calculation based on information out of the BPOS game itself
Administrative Costs	Displays the administrative costs, paid by each tier per round.	Calculation based on information out of the BPOS game itself
Machine Depreciation	Displays the machine depreciation paid by each tier per round.	Calculation based on information out of the BPOS game itself
Buildings Depreciation	Displays the building depreciation paid by each tier per round.	Calculation based on information out of the BPOS game itself
Total Operating Expenses	Displays the total operating expenses paid by each tier per round.	Calculation performed in Excel
Cost of Goods Sold	Displays the cost of goods sold paid by each tier per round.	Calculation performed in Excel

Table 1: KPIs with Description and Source

As can be seen in the table, some KPIs are based on calculations consisting of other KPIs, and some are based on pivot tables. As an example, the excerpts of the Inventory Turnover KPI calculation follow (see Appendix B, Figure A.9 and A.10). This KPI is based on a pivot table sourced from the “stackable“. The first step was merging the retail price column from the “productTable“ to the “stockTable“. In the next step, I added a user-defined column that includes the multiplication of the retail price with the stock amount to get the inventory value. Out of this table, I created a pivot table that showed the inventory per round for each tier. A second table with the costs of goods sold (COGS) was needed for this KPI. I created this one manually using the same structure as the pivot table prepared. For the COGS KPI, I added up the before-calculated KPIs production costs, tool change costs, delivery costs, and raw material costs. For the inventory turnover, the COGS are divided by the average inventory.

Figure 4 shows the versions of the KPI provided to ensure the dashboard's functionality, which will be described in the following subchapter. Every KPI that is part of the overview register in the dashboard has a structure, as Figure 4 shows. Each KPI can be depicted in the overview in the four versions: round value of the chosen round (in this case 116), round value for the latest round (in this case 240), cumulated values of the round range selected (in this case 1-133) or cumulated values from the first to the actual last round (in this case 1-240).

CALCULATIONS FOR INVENTORY TURNOVER:					
ChosenRoundsBeginning:	1		Latest Round:	240	
ChosenRoundsEnd:	133				
ROUND VALUES			LATEST DATA PER ROUND		
1	Inventory Turnover	1,64	1	Inventory Turnover	-
2	Inventory Turnover	0,50	2	Inventory Turnover	-
3	Inventory Turnover	0,12	3	Inventory Turnover	-
4	Inventory Turnover	0,35	4	Inventory Turnover	-
CUMULATED VALUES			LATEST DATA CUMULATED		
1	Inventory Turnover	0,78	1	Inventory Turnover	0,95
2	Inventory Turnover	0,51	2	Inventory Turnover	0,50
3	Inventory Turnover	0,76	3	Inventory Turnover	0,78
4	Inventory Turnover	1,05	4	Inventory Turnover	1,50

Figure 4 - Calculation of the Inventory Turnover KPI

Figure 5 shows the preparation for the icons that appear in the overview; this is also done for every KPI that is part of the overview register in the dashboard. Furthermore, every KPI that is a part of the overview register has an icon to visualize the performance; as already mentioned, this will be described in the following subchapter. For the icons, the average of the last ten rounds is compared to the average of the previous ten rounds. If the first average value is higher than the second one, a green triangle appears; if reversed, an inverted red triangle appears. If both averages are the same, an orange rectangle appears.

		1. AVERAGE RANGE	2. AVERAGE RANGE	SYMBOL DEPENDING ON VALUES
RoundBeginning:		124	114	
ChosenRoundsEnd:	133	133	123	
1	Inventory Turnover	1,23	1,13	▲
2	Inventory Turnover	0,43	0,52	▼
3	Inventory Turnover	0,68	0,71	▼
4	Inventory Turnover	-	-	—

Figure 5 - Calculation for the Icon of the Inventory Turnover KPI

Figure 6 depicts the calculation enabling the KPI registers' tier selection function. This table is the base for the line graph. For this calculation, I linked the values from the pivot table and created an Excel formula that displays the values when the metric name appears and hides them when it does not appear. The appearance depends on the selection in the actual KPI register.

```
=WENNFEHLER(WENN($Z$2="TIER-1";$T3/$B5;" ");" ")
```

Y	Z	AA	AB	AC
CALC FOR TIER SELECTION				
	TIER-1	TIER-2	TIER-3	TIER-4
1	0,00	-	0,00	0,03
2	0,14	0,08	0,24	1,10
3	0,39	0,36	0,58	1,29
4	0,57	0,48	0,49	0,12
5	0,65	0,36	0,31	1,01
6	0,69	0,51	0,17	1,92
7	0,68	0,51	0,16	1,21
8	0,68	0,89	0,35	1,03
9	0,85	1,07	0,00	0,69
10	0,88	0,55	0,18	0,75
11	1,62	0,43	0,53	0,67
12	0,56	1,79	0,00	0,33

Figure 6 - Calculation for Tier Selection Function in KPI Registers

Figure 7 shows the calculation for the round appearance in the graph. Due to the additional table mentioned above, a second table was required to ensure that only the rounds that already contain values are shown in the graph and not all the maximum possible 480 rounds at once, which was a consequence of using the above mentioned formula. This Excel formula checks if the round number appears in the precious table. If so, it takes the values for the tiers; if not, the round is not transferred to the round appearance table.

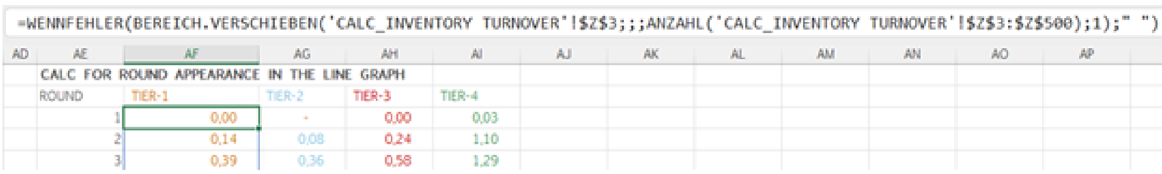


Figure 7 - Round Appearance Calculation for the Graph

4.2.3 Step 3: Dashboard development

The dashboard was developed using the Excel spreadsheet program as it is widely available and often used to create dashboards. The built-in Power Query tool provides several ways to connect Excel to databases from different sources, including the ODBC driver I used to integrate the MySQL Workbench connection. Power Query also makes it easier to adjust the database once it is implemented in the Excel file.

Before developing the dashboard, I discussed the structure of the dashboard and the KPIs to be included in the dashboard with Tobias Engel. Therefore, I collected the final reports from last semester's Information Management lecture to select the KPIs. The final reports had to be submitted at the end of the semester by each tier that played the BPOS game. The final reports contained all the submissions needed during the semester in an adapted and revised form. I took the KPIs I found in the strategy maps from these final reports. Afterward, I structured the collected KPIs according to their relevance, i.e. the ones that appeared more than once were placed higher on the list. In the subsequent meeting with Tobias Engel, we reviewed the KPIs and selected 15, which can be found in the table in subchapter 4.2.2. In terms of structure, we also opted for an overview tab showing the 15 selected KPIs and a tab per KPI for a more detailed presentation.

The dashboard was evaluated regularly every one to two weeks. The evaluation took about an hour and was conducted via Zoom. It consisted of three rounds: the first on June 3rd, the second on June 17th, and the last on July 5th. During the evaluations, the dashboard database was updated to verify that the connection to the database was working. Furthermore, the updates and additional features were discussed (see Appendix C).

4.3 Evaluation

The dashboard was evaluated with Tobias Engel, the instructor for the BPOS game giving the lectures “Information Management“ and “Supply Chain Management“. Unfortunately, I could not identify more instructors, which limited the results.

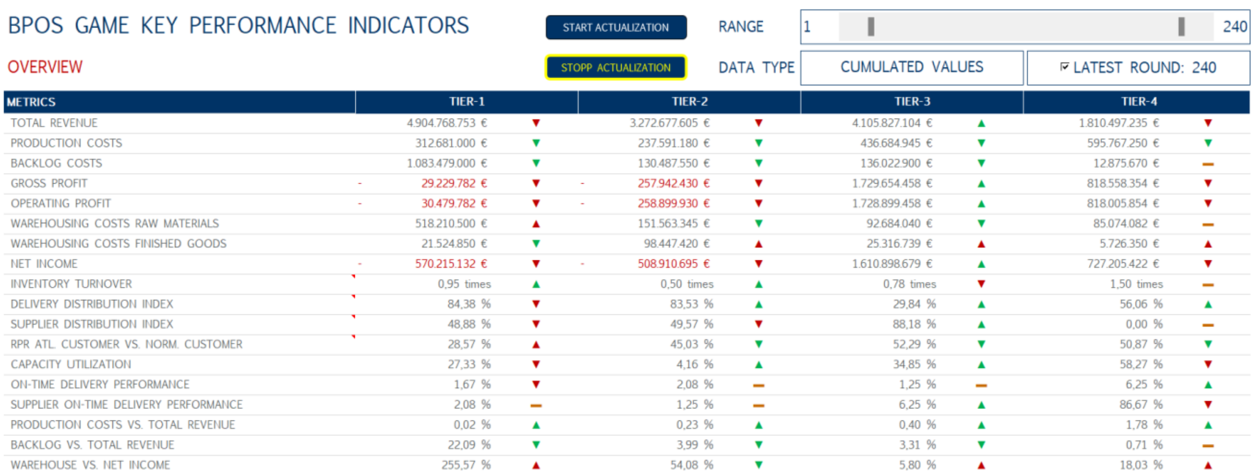
Table 2 lists the evaluation outcomes from each round and describes the usability improvements that came with the adapted changes. No more changes were needed in the third round of the evaluation, so the process was finished after this round. I wrote down all comments during the review with Tobias Engel to subsequently analyze them and get the outcomes.

Discussed Changes	**Usability improvement**
Evaluation Round 1:	
▪ The possibility for choosing round ranges needs to be added to the existing element that enables the selection of the rounds from the fixed start variable 1 to what the instructor wants	The instructor can analyze the data flexibly and go into more detail by the possibility of choosing the round ranges.
▪ Three more KPIs that show relations	Relation KPIs give a more detailed view of the financial performance of the tiers.
▪ Additional Icons to each KPI in the overview that compare the last ten rounds to the ten rounds before	The instructor sees the development of each KPI at a glance.
▪ Additional graph in the detailed registers that depict not only the costs but also the amounts where possible, e.g., production costs and production amounts	Seeing the costs and the amount enables more profound analysis and evaluation of the tiers' performance.
▪ Additional function to choose whether the round range or the latest data should be shown.	The instructor can do a deeper analysis or see the latest data, which can be helpful when the game is being played, and new data is added every time the dashboard is updated. Without this feature, the instructor must look for the latest data by moving the slider to the last round, where the data stops changing.

Evaluation Round 2:	
▪ Additional function to the detailed registers of choosing the tier that the graph has to depict.	If only a few or only one tier is displayed in the graph, the axes change so that the development of the selected tier is more straightforward to recognize.
▪ Additional function that lets the dashboard actualize automatically every five minutes once the function is activated.	This function does not require the instrucor to actualize the dashboard manually. However, each actualization takes time. The later the dashboard is actualized, the more data it needs to load, so actualizations would take longer than with this function.
▪ Additional function that automizes the implementation of new databases to the dashboard.	This function enables easy database changes by automating the process of deleting the old database and connecting to the new database.
▪ Additional visual effect of negative values turning red.	This enables the instructor to see which KPIs of which tier are negative because they stand out.
▪ Additional function that enables to get to the detailed register of the KPI by clicking on the KPI name in the overview table and getting back to the overview register by clicking on the button that returns to the overview.	With this function, the instructor can quickly access the detailed register of the KPI and return to the overview. The dashboard consists of 15 registers that are not depicted in the register bar at a glance. Therefore, the instructor has to click through the bar to find the detailed register, which is time-consuming.

Table 2: Evaluation Outcomes

Figure 8 shows the main register of the dashboard with all of the added functionality listed in the table above (see Appendix D). The dashboard automatically switches to the detailed registers when the instructor clicks on the metric names. Some KPIs need further explanation, which was realized by having a note that opens with a short description when the cursor moves over it. Negative KPIs are highlighted in red. The icons show the development of each KPI at a glance. The "Start Actualization" button starts the automatic actualization, and the "Stopp Actualization" button stops the actualization; if the instructor forgets to click the stop button before closing the dashboard, the actualization will stop automatically. The button that is activated lights up. The slider allows the instructor to choose round ranges. The instructor can select the data type from a drop-down list that contains the selection between cumulated or round values. It is also possible to see the most recent values by checking the "Lates Round" box. The function that automates the implementation of new databases to the dashboard could not be implemented. Therefore, the game instructor has to do that manually (see attachment Detailed Instruction Database Exchange).



METRICS	TIER-1		TIER-2		TIER-3		TIER-4	
TOTAL REVENUE	4.904.768.753 €	▼	3.272.677.605 €	▼	4.105.827.104 €	▲	1.810.497.235 €	▼
PRODUCTION COSTS	312.681.000 €	▼	237.591.180 €	▼	436.684.945 €	▼	595.767.250 €	▼
BACKLOG COSTS	1.083.479.000 €	▼	130.487.550 €	▼	136.022.900 €	▼	12.875.670 €	—
GROSS PROFIT	- 29.229.782 €	▼	- 257.942.430 €	▼	1.729.654.458 €	▲	818.558.354 €	▼
OPERATING PROFIT	- 30.479.782 €	▼	- 258.899.930 €	▼	1.728.899.458 €	▲	818.005.854 €	▼
WAREHOUSING COSTS RAW MATERIALS	518.210.500 €	▲	151.563.345 €	▼	92.684.040 €	▼	85.074.082 €	—
WAREHOUSING COSTS FINISHED GOODS	21.524.850 €	▼	98.447.420 €	▲	25.316.739 €	▲	5.726.350 €	▲
NET INCOME	- 570.215.132 €	▼	- 508.910.695 €	▼	1.610.898.679 €	▲	727.205.422 €	▼
INVENTORY TURNOVER	0,95 times	▲	0,50 times	▲	0,78 times	▼	1,50 times	—
DELIVERY DISTRIBUTION INDEX	84,38 %	▼	83,53 %	▲	29,84 %	▲	56,06 %	▲
SUPPLIER DISTRIBUTION INDEX	48,88 %	▼	49,57 %	▼	88,18 %	▲	0,00 %	—
RPR ATL. CUSTOMER VS. NORM. CUSTOMER	28,57 %	▲	45,03 %	▼	52,29 %	▼	50,87 %	▼
CAPACITY UTILIZATION	27,33 %	▼	4,16 %	▲	34,85 %	▲	58,27 %	▼
ON-TIME DELIVERY PERFORMANCE	1,67 %	▼	2,08 %	—	1,25 %	—	6,25 %	▲
SUPPLIER ON-TIME DELIVERY PERFORMANCE	2,08 %	—	1,25 %	—	6,25 %	▲	86,67 %	▼
PRODUCTION COSTS VS. TOTAL REVENUE	0,02 %	▲	0,23 %	▲	0,40 %	▲	1,78 %	▲
BACKLOG VS. TOTAL REVENUE	22,09 %	▼	3,99 %	▼	3,31 %	▼	0,71 %	—
WAREHOUSE VS. NET INCOME	255,57 %	▲	54,08 %	▼	5,80 %	▲	18,03 %	▲

Figure 8 - Overview Register

Figure 9 shows the first sub-register that displays the Total Revenue KPI. All KPI registers are structured in the same way. A button on the top left of each register leads directly to the overview register. To the right of this button is a tier selector, allowing the instructor to choose which tiers to see in the graph. The tiers always have the same color: Tier-1 is orange, Tier-2 is light blue, Tier-3 is red, and Tier-4 is green. The X and Y axes adjust automatically.

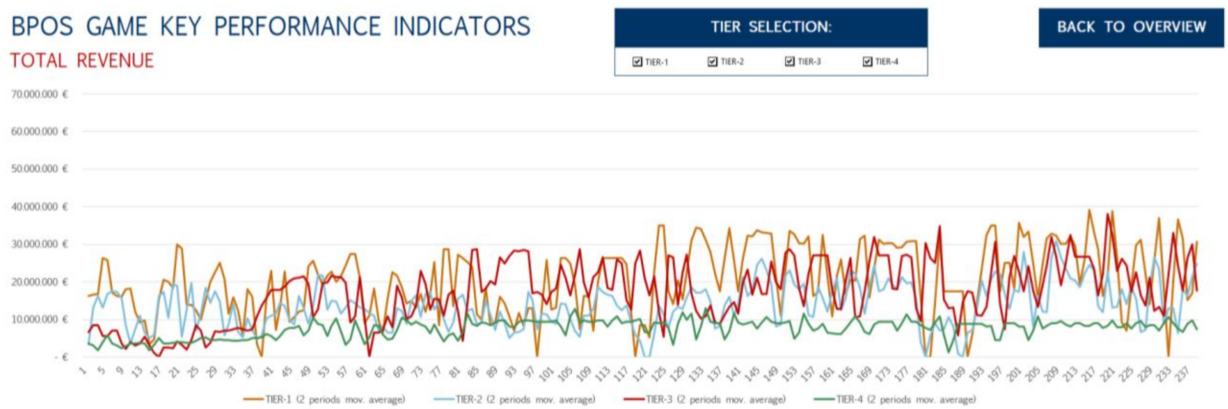


Figure 9 - Total Revenue Register

5 Discussion

Within this bachelor's thesis, a dashboard for the BPOS game was developed using several design guidelines. The dashboard's purpose is to enable the game instructor to analyze the performance of each tier participating in the BPOS game. The results are discussed in table format for a better understanding. Table 3 holds the design guidelines I applied from Chapter 2 and contrasts them with the findings I collected during development.

Design Guideline	**Findings**
Data can be arranged either alphabetically, hierarchically, numerically, time-based, or location-based, but the efficient way to arrange numbers, dates, or times is either ascending, descending, or an order that the company usually uses. (Few, 2004, p. 146; Tidwell et al., 2020, p. 32 ff.).	I arranged the dashboard's data hierarchically based on the P&L because no other arrangement would make sense, and the instructor is used to it. Therefore, this guideline can be *confirmed*.
The alignment of subdivision categories is best readable on the very left side of the table and the related data on the right side (Few, 2004, pp. 144-147).	I applied this guideline to the presentation of the overview table. It enables a clear understanding and readability. Therefore, this guideline can be *confirmed*.
If there are any relations between the data, they are best displayed hierarchically from the left to the right (Few, 2004, p. 144).	I applied this guideline in the Production Time register. By arranging the data from left to right, depending on their relationship, the delivery hierarchy becomes visible in the table. Therefore, this guideline can be *confirmed*.
Quantitative values are most readable right-aligned (Few, 2004, p. 147).	The overview register contains many different number formats. All these number formats or quantitative values are left-aligned and very easy to read. Therefore, this guideline can be *confirmed*.
Using commas every three digits simplifies the presentation and improves readability (Few, 2004, p. 149).	I applied this guideline to the entire dashboard. The dots improve readability. Therefore, this guideline can be confirmed.

To indicate negative values, developers can choose between using parentheses or minus signs, and to indicate percent values, developers must use percentage signs placed directly to the right of the value (Few, 2004, p. 149)	This guideline is only partially implemented. I placed the percentage signs not directly next to the number. Since 2020, depending on the Duden, a space must be placed between the number and the percent sign (Cornelsen Verlag GmbH, n. d.). Therefore, this guideline can be only partially confirmed and needs an update.
The font must be as easy to read as possible. Serif font styles are better for heavy texts because the small lines on each letter guide the reader's eye, while sans-serif font styles are more legible when developers work with smaller font sizes (Few, 2004; Tidwell et al., 2020, p. 266 f.).	The font used in the dashboard is sans serif because I needed the font to be legible at a very small size in the graphs, and the font is legible at a very small size. Therefore, this guideline can be *confirmed*.
The size should not be smaller than 10 points (Tidwell et al., 2020, p. 267).	This guideline was not adopted in the dashboard. All axis labels are nine points in the detailed registers and readable anyway. Therefore, this guideline *cannot* be *confirmed*.
Further, developers should never use similar fonts in one dashboard, either sans serif or serif fonts, but in different styles, such as cursive or bold (Tidwell et al., 2020, p. 266 ff.).	This guideline was fully adopted for the dashboard. I used the same font but integrated font styles to highlight values where needed. Otherwise, it would not be as legible as it is now. Therefore, this guideline can be *confirmed*.
Enlarged white space between the columns makes the reader go through the columns, and enlarged white space between the rows gets the reader to read row for row (Few, 2004, p. 136).	I applied this guideline in every table to indicate the reading direction of each column, which is column by column. Therefore, this guideline can be *confirmed*.

Graphs need to be displayed horizontally and be wider than high (Tufte, 2007, p. 186).	This guideline was applied in every detailed register; the other way around was too confusing because users are used to this way of visualizing graphs. Therefore, this guideline can be *confirmed*.
When developers intend to display a large amount of information, it works best with a large data matrix and high data density. (Tufte, 2007, p. 168).	I applied this guideline in every detailed register. The database consists of large data matrixes and depicts a high data density in each graph. Therefore, this guideline can be *confirmed*.
The graph should represent a maximum of five to eight data sets (Few, 2004, p. 216).	In every graph in the detailed registers, four data sets are displayed. Depending on the development's fluctuation, four are also very difficult to differentiate. Therefore, this guideline cannot be confirmed. It is too generalizing. The number of maximum data sets should depend on the development that the data sets depict. When the data sets are similar or fluctuating, less than five data sets per graph are better.
The lines must be easily distinguishable by different color hues, intensities, and line styles (Few, 2004, p. 191 f.).	I applied this guideline to every graph to distinguish the lines. Every line has different color hues, and the line width is enhanced to ensure the lines are distinguishable. Therefore, this guideline can be *confirmed*.

The index variable can only be displayed in order or by rank, depending on the user's needs (Few, 2004, p. 230).	The index variable in every graph is the round number; hence, it is displayed in order; otherwise, it would make no sense and confuse the user. Therefore, this guideline can be *confirmed*.
Legends work best with the information close to the graph to clarify where the legend belongs (Few, 2004, p. 216).	I used this guideline on every graph; placing the legend near the graph makes the assignment clear. Therefore, this guideline can be *confirmed*.
Developers need to keep the attention on the actual information objects by using, for example, less intensive colors or omitting borders around the legends (Few, 2004, p. 216).	I kept the legends as simple as possible. They are the same color as the whole graph, which indicates that they do not draw too much attention. Therefore, this guideline can be *confirmed*.
Different sizes, positions, densities, background colors, line widths or color intensities support information that must stand out (Few, 2006, p. 115 f.).	In the dashboard, I used sizes to indicate headlines, background color to make the buttons stand out, and color intensities to indicate negative or positive development. Therefore, this guideline can be *confirmed*.
For fast insights, it is good to involve general criteria through the dashboard that show something is either positive or negative or remains the same, for example, with the inclusion of icons. The most effective are the ones that show on/off and up/down (Few, 2013, pp. 74, 177).	I applied this guideline in the overview register. The colored icons that show up and down or no change and the red color that appears when a negative value indicate fast insight about each value. Therefore, this guideline can be *confirmed*.

The larger the headline, the more important it appears (Tidwell et al., 2020, p. 211).	I used this guideline on every dashboard register. To indicate the relevance of each headline and make it stand out. Therefore, this guideline can be *confirmed*.
Customization possibilities, such as customizable KPIs, charts, layouts, and filters, might close the gap between new dashboard users and those already specialists (Allio, 2012, pp. 25-29; Tidwell et al., 2020, p. 34).	I applied this guideline to every register. The KPIs in the overview register are customizable by allowing the instructor to choose the data type and round range, and the detailed registers enable the instructor to select the data set that should be shown in the graph. This allows the instructor to adapt the dashboard to personal analyzing skills. Therefore, this guideline can be *confirmed*.
Interactive features such as drill-downs, filters, or the function of high-level summarization into detailed view support data analysis (Froese & Tory, 2016, p. 87).	The interactive features remain related to customization. For example, the instructor can choose the data by drilling down. This feature supports the analysis because the instructor can customize the interface, enhancing data exploration and insights. Transforming a summarized view into a detailed view enhances data exploration. This option is also applied to the overview register. Therefore, this guideline can be *confirmed*.
In a well-designed dashboard, the most frequently used interactive features are positioned as visible as possible so that users do not have to search for them (Tidwell et al., 2020, p. 33).	I used this guideline on every register. All the interactive features mentioned are positioned in the upper left so the instructor does not need to search for them. Therefore, this guideline can be *confirmed*.

Alert features make issues or opportunities more visible by highlighting them (Bremser & Wagner, 2013, p. 67).	I applied this guideline to the overview register. Negative values are visualized in red to catch the user's attention. Therefore, this guideline can be *confirmed*.
Principle of proximity: elements near each other indicate that they belong together (Tidwell et al., 2020, p. 217).	I applied this guideline in connection with the white space guideline mentioned before. In every dashboard table, proximity and white space separate each tier's values and indicate which values belong to the same tier as they are placed very near each other. Therefore, this guideline can be *confirmed*.

Table 3: Discussion of the Findings

6 Limitations and Future Research

The within this thesis developed dashboard aims to enhance the possibility of performance analysis for each tier participating in the BPOS game. Therefore, the dashboard should be looked at in the context of limitations. The dashboard was only developed for this specific use case, so it does not apply to every simulation game. Further, as mentioned in Chapter 4.3, the dashboard was evaluated by only one person. This can limit the outcomes due to several factors: subjectivity and bias, lack of diversity in perspectives, lack of validation, and reduced transparency and credibility. These factors can negatively impact the evaluation when only one person participates in the evaluation process; hence, using the dashboard cannot be generalized.

Accordingly, future research should be conducted by evaluating the dashboard with a target audience or through a survey to get a more objective, valid, and reliable assessment. Different perspectives and expertise contribute to a more comprehensive analysis, while the possibility of verification and validation by others increases the credibility and acceptance of the results. Future research could also be used to enhance the dashboard by integrating AI. As mentioned in chapter 2.3.1, an AI-driven chatbot has already been integrated into some dashboards. Such a chatbot could also improve the overall work that will be done with the BPOS dashboard.

7 Conclusion

This bachelor thesis outlines the essential steps in developing a dashboard for managing performance outcomes using the design science approach. The development of a dashboard can be separated into three steps: the application of design principles of different dashboard elements as well as UX, the engagement with the database, and the evaluation cycles that ensure the creation of a user-centered and insights-bringing tool. The use of principles and the performance of regular evaluation cycles are elementary. Applying both in the dashboard development process for the business process operations simulation game enables the instructors to analyze and manage the performance outcomes of each tier that participates in the game. With further evaluation by more game instructors, the dashboard's functionality could be enhanced.

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Appendix

Appendix A Remaining Query Dependencies

Figure A.1 shows the merge for the On-Time Delivery Performance and Order Amounts KPIs. The “orderID“ was used as the primary key. This merge was needed to match the order amounts, depicted in the table “orderAmountsTable“, with the ordering tier and round they were made, shown in the table “orderTable“.

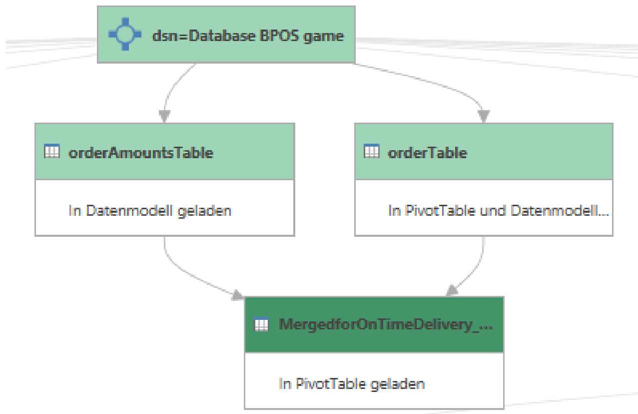


Figure A.1 - Query Dependency of the On-Time Delivery Performance and Order Amounts KPIs

Figure A.2 depicts the merge for the Supplier On-Time Delivery Performance KPI. In this merge, the “deliveryID“ was the primary key to match the delivery amount with the round and tier information.

Figure A.2 - Query Dependency of the Supplier On-Time Delivery Performance KPI

Figure A.3 shows the merge for the Production Amount KPI. In this case, the "productionId" was the primary key. Through this merge, the production amounts were matched with the producing tier and round in which the amounts were produced.

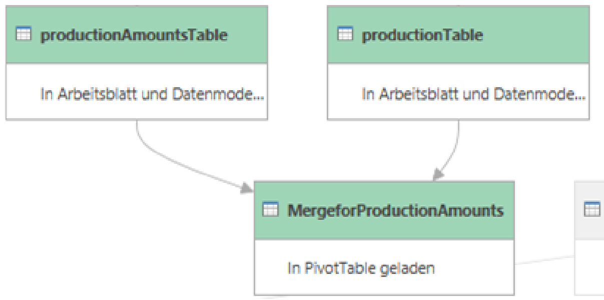
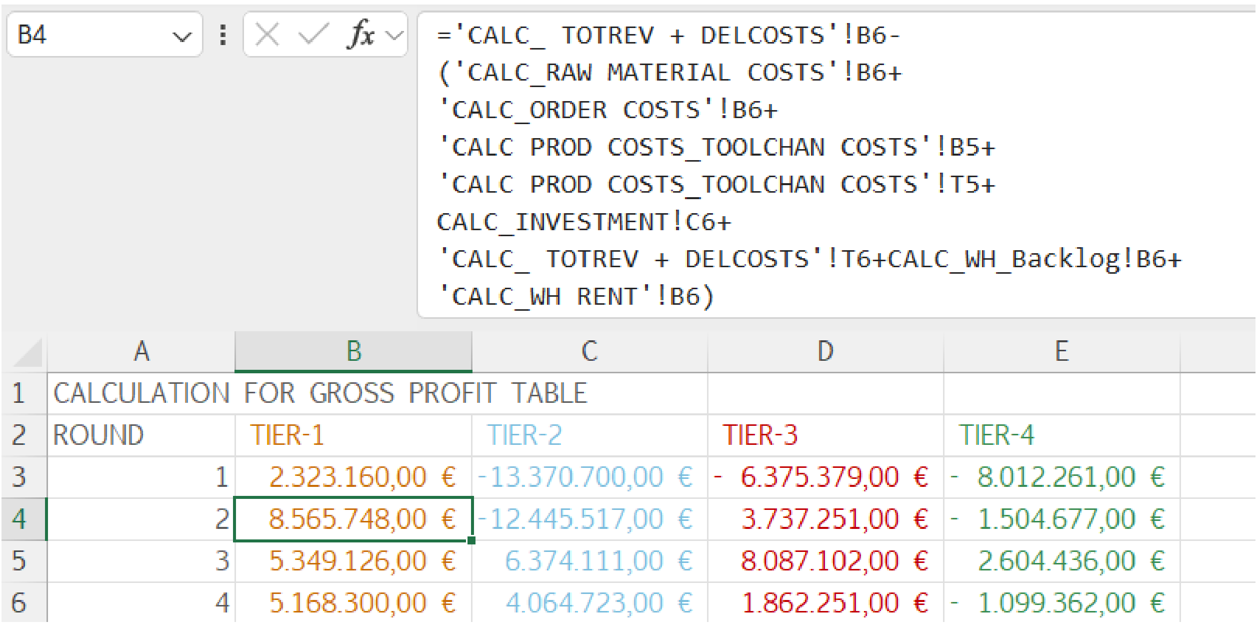


Figure A.3 - Query Dependency of the Production Amount KPI

Appendix B Calculations

The following figures show some of the calculations mentioned in the subchapter 4.2.2; in most cases, they work through linkages with other KPIs in the entire dashboard.

Figure A.4 shows the calculation of the Gross Profit KPI. To calculate the gross profit, the raw material costs, order costs, production costs, tool change costs, machine costs, storage costs, delivery costs, backorder costs, and warehouse rent were deducted from the total revenue.



B4

```
='CALC_ TOTREV + DELCOSTS'!B6-
('CALC_RAW MATERIAL COSTS'!B6+
'CALC_ORDER COSTS'!B6+
'CALC PROD COSTS_TOOLCHAN COSTS'!B5+
'CALC PROD COSTS_TOOLCHAN COSTS'!T5+
CALC_INVESTMENT!C6+
'CALC_ TOTREV + DELCOSTS'!T6+CALC_WH_Backlog!B6+
'CALC_WH RENT'!B6)
```

	A	B	C	D	E
1	CALCULATION FOR GROSS PROFIT TABLE				
2	ROUND	TIER-1	TIER-2	TIER-3	TIER-4
3	1	2.323.160,00 €	-13.370.700,00 €	- 6.375.379,00 €	- 8.012.261,00 €
4	2	8.565.748,00 €	-12.445.517,00 €	3.737.251,00 €	- 1.504.677,00 €
5	3	5.349.126,00 €	6.374.111,00 €	8.087.102,00 €	2.604.436,00 €
6	4	5.168.300,00 €	4.064.723,00 €	1.862.251,00 €	- 1.099.362,00 €

Figure A.4 - Calculation of the Gross Profit KPI

Figure A.5 shows the calculation of the Operating Profit KPI. To calculate the operating profit, salaries, administrative costs, machine depreciation, and building depreciation were deducted from the gross profit. These KPIs are calculated manually using the information from the tier info register, which can be seen in Appendix D.

B4

```
=CALC_GROSSPROFIT!B4-
('CALC_INTERIM for OVERVIEW CALC'!$D$7*'CALC_OPERATING PROFIT'!$A4)+
('CALC_INTERIM for OVERVIEW CALC'!$D$25*$A4)+
('CALC_INTERIM for OVERVIEW CALC'!$K$7*$A4)+
('CALC_INTERIM for OVERVIEW CALC'!$K$25*$A4)
```

	A	B	C	D	E	F	G
1	CALCULATION FOR OPERATING PROFIT TABLE						
2	ROUND	TIER-1	TIER-2	TIER-3	TIER-4		
3	1	2.325.451,67 €	-13.368.408,33 €	- 6.373.087,33 €	- 8.009.969,33 €		
4	2	8.570.331,33 €	-12.440.933,67 €	3.741.834,33 €	- 1.500.093,67 €		
5	3	5.356.001,00 €	6.380.986,00 €	8.093.977,00 €	2.611.311,00 €		
6	4	5.177.466,67 €	4.073.889,67 €	1.871.417,67 €	- 1.090.195,33 €		
7	5	24.099.458,33 €	3.594.827,33 €	3.694.109,33 €	5.595.004,33 €		

Figure A.5 - Calculation of the Operating Profit KPI

Figure A.6 depicts the calculation of the Net Income KPI. To calculate this KPI, the warehouse costs of finished goods and raw materials are deducted from the operating profit.

B3

```
='CALC_OPERATING PROFIT'!B3-
(CALC_WH_Backlog!H5+CALC_WH_Backlog!N5)
```

	A	B	C	D	E
1	CALCULATION FOR NET INCOME				
2	ROUND	TIER-1	TIER-2	TIER-3	TIER-4
3	1	1.275.451,67 €	-14.750.408,33 €	- 6.832.837,33 €	- 8.019.969,33 €
4	2	6.941.681,33 €	-14.345.433,67 €	3.418.584,33 €	- 1.650.688,67 €
5	3	4.028.101,00 €	4.608.986,00 €	7.838.977,00 €	2.142.912,00 €

Figure A.6 - Calculation of the Net Income KPI

Figure A.7 depicts the relation calculations. In this register, the KPIs are linked to the base registers and compared using a simple calculation, e.g., backlog / total revenue.

CUMULATIONS FOR RALATIONS

CALCULATIONS BACKLOG VS. TOTAL REVENUE:							CALCULATIONS FOR ARROWS IN OVERVIEW TABLE			
ChosenRoundsBeginning	1	0						1. AVERAGE RANGE	2. AVERAGE RANGE	SYMBOL DEPENDING ON VALUES
ChosenRoundsEnd:	240	238					RoundBeginning:	231	221	
ROUND VALUES			LATEST DATA PER ROUND				ChosenRoundsEnd: 240	240	230	
1	BACKLOG VS. TOTAL REVENUE	0,00%	1	BACKLOG VS. TOTAL REVENUE	0,00%	1	BACKLOG VS. TOTAL REVENUE	0,15%	0,16%	▼
2	BACKLOG VS. TOTAL REVENUE	0,00%	2	BACKLOG VS. TOTAL REVENUE	0,00%	2	BACKLOG VS. TOTAL REVENUE	0,30%	0,88%	▼
3	BACKLOG VS. TOTAL REVENUE	0,00%	3	BACKLOG VS. TOTAL REVENUE	0,00%	3	BACKLOG VS. TOTAL REVENUE	0,08%	0,54%	▼
4	BACKLOG VS. TOTAL REVENUE	0,00%	4	BACKLOG VS. TOTAL REVENUE	0,00%	4	BACKLOG VS. TOTAL REVENUE	0,00%	0,00%	–
CUMULATED VALUES			LATEST DATA CUMULATED							
1	BACKLOG VS. TOTAL REVENUE	22,03%	1	BACKLOG VS. TOTAL REVENUE	22,03%					
2	BACKLOG VS. TOTAL REVENUE	3,93%	2	BACKLOG VS. TOTAL REVENUE	3,93%					
3	BACKLOG VS. TOTAL REVENUE	3,31%	3	BACKLOG VS. TOTAL REVENUE	3,31%					
4	BACKLOG VS. TOTAL REVENUE	0,71%	4	BACKLOG VS. TOTAL REVENUE	0,71%					

PRODUCTION COSTS VS. TOTAL REVENUE							CALCULATIONS FOR ARROWS IN OVERVIEW TABLE			
ChosenRoundsBeginning	1							1. AVERAGE RANGE	2. AVERAGE RANGE	SYMBOL DEPENDING ON VALUES
ChosenRoundsEnd:	240						RoundBeginning:	231	221	
PER ROUND VALUES			LATEST DATA PER ROUND				ChosenRoundsEnd: 240	240	230	
1	PRODUCTION COSTS VS. TOTAL REVENUE	0,02%	1	PRODUCTION COSTS VS. TOTAL REVENUE	0,02%	1	PRODUCTION COSTS VS. TOTAL REVENUE	0,00%	0,00%	▲
2	PRODUCTION COSTS VS. TOTAL REVENUE	0,32%	2	PRODUCTION COSTS VS. TOTAL REVENUE	0,32%	2	PRODUCTION COSTS VS. TOTAL REVENUE	0,03%	0,03%	▲
3	PRODUCTION COSTS VS. TOTAL REVENUE	0,63%	3	PRODUCTION COSTS VS. TOTAL REVENUE	0,63%	3	PRODUCTION COSTS VS. TOTAL REVENUE	0,05%	0,04%	▲
4	PRODUCTION COSTS VS. TOTAL REVENUE	2,81%	4	PRODUCTION COSTS VS. TOTAL REVENUE	2,81%	4	PRODUCTION COSTS VS. TOTAL REVENUE	0,19%	0,17%	▲
CUMULATED VALUES			LATEST DATA CUMULATED							
1	PRODUCTION COSTS VS. TOTAL REVENUE	0,02%	1	PRODUCTION COSTS VS. TOTAL REVENUE	0,02%					
2	PRODUCTION COSTS VS. TOTAL REVENUE	0,23%	2	PRODUCTION COSTS VS. TOTAL REVENUE	0,23%					
3	PRODUCTION COSTS VS. TOTAL REVENUE	0,40%	3	PRODUCTION COSTS VS. TOTAL REVENUE	0,40%					
4	PRODUCTION COSTS VS. TOTAL REVENUE	1,78%	4	PRODUCTION COSTS VS. TOTAL REVENUE	1,78%					

WAREHOUSE VS. NET INCOME							CALCULATIONS FOR ARROWS IN OVERVIEW TABLE			
ChosenRoundsBeginning	1							1. AVERAGE RANGE	2. AVERAGE RANGE	SYMBOL DEPENDING ON VALUES
ChosenRoundsEnd:	240						RoundBeginning:	231	221	
PER ROUND VALUES			LATEST DATA PER ROUND				ChosenRoundsEnd: 240	240	230	
1	WAREHOUSE VS. NET INCOME	0,00%	1	WAREHOUSE VS. NET INCOME	0,00%	1	WAREHOUSE VS. NET INCOME	7,15%	2,75%	▲
2	WAREHOUSE VS. NET INCOME	0,00%	2	WAREHOUSE VS. NET INCOME	0,00%	2	WAREHOUSE VS. NET INCOME	-7,38%	26,64%	▼
3	WAREHOUSE VS. NET INCOME	0,00%	3	WAREHOUSE VS. NET INCOME	0,00%	3	WAREHOUSE VS. NET INCOME	0,55%	0,54%	▲
4	WAREHOUSE VS. NET INCOME	0,00%	4	WAREHOUSE VS. NET INCOME	0,00%	4	WAREHOUSE VS. NET INCOME	0,08%	0,04%	▲
CUMULATED VALUES			LATEST DATA CUMULATED							
1	WAREHOUSE VS. NET INCOME	255,57%	1	WAREHOUSE VS. NET INCOME	255,57%					
2	WAREHOUSE VS. NET INCOME	14,06%	2	WAREHOUSE VS. NET INCOME	14,06%					
3	WAREHOUSE VS. NET INCOME	5,80%	3	WAREHOUSE VS. NET INCOME	5,80%					
4	WAREHOUSE VS. NET INCOME	18,03%	4	WAREHOUSE VS. NET INCOME	18,03%					

Figure A.7 - Calculation of Relation KPIs

Figure A.8 shows the interim calculation for the overview cumulation, which uses the information from the tier info register and the chosen round range to calculate the KPIs needed to calculate the operating profit: salaries, machine depreciation, administrative costs, and building depreciation.

CALCULATIONS FOR SALARIES:					
ChosenRoundsBeginnin	1			LATEST ROUND:	240
ChosenRoundsEnd:	240				
ROUND VALUES			LATEST DATA PER ROUND		
TIER-1	Salaries	1.458,33	TIER-1	Salaries	1.458,33
TIER-2	Salaries	1.250,00	TIER-2	Salaries	1.250,00
TIER-3	Salaries	1.041,67	TIER-3	Salaries	1.041,67
TIER-4	Salaries	833,33	TIER-4	Salaries	833,33
CUMULATED VALUES			LATEST DATA CUMULATED		
TIER-1	Salaries	350.000,00	TIER-1	Salaries	350.000,00
TIER-2	Salaries	300.000,00	TIER-2	Salaries	300.000,00
TIER-3	Salaries	250.000,00	TIER-3	Salaries	250.000,00
TIER-4	Salaries	200.000,00	TIER-4	Salaries	200.000,00

CALCULATIONS FOR MACHINE DEPRECIATION:					
ChosenRoundsBeginnin	1			LATEST ROUND:	2
ChosenRoundsEnd:	240				
ROUND VALUES			LATEST DATA PER ROUND		
TIER-1	Machine depreciation	1.666,67	TIER-1	Machine depreciation	1.666,6
TIER-2	Machine Depreciation	1.250,00	TIER-2	Machine Depreciation	1.250,0
TIER-3	Machine Depreciation	833,33	TIER-3	Machine Depreciation	833,3
TIER-4	Machine Depreciation	416,67	TIER-4	Machine Depreciation	416,6
CUMULATED VALUES			LATEST DATA CUMULATED		
TIER-1	Machine depreciation	400.000,00	TIER-1	Machine depreciation	400.000,0
TIER-2	Machine Depreciation	300.000,00	TIER-2	Machine Depreciation	300.000,0
TIER-3	Machine Depreciation	200.000,00	TIER-3	Machine Depreciation	200.000,0
TIER-4	Machine Depreciation	100.000,00	TIER-4	Machine Depreciation	100.000,0

CALCULATIONS FOR ADMINCOSTS:					
ChosenRoundsBeginnin	1			LATEST ROUND:	240
ChosenRoundsEnd:	240				
ROUND VALUES			LATEST DATA PER ROUND		
TIER-1	Administration Costs	416,67	TIER-1	Administration Costs	416,67
TIER-2	Administration Costs	31,25	TIER-2	Administration Costs	31,25
TIER-3	Administration Costs	20,83	TIER-3	Administration Costs	20,83
TIER-4	Administration Costs	10,42	TIER-4	Administration Costs	10,42
CUMULATED VALUES			LATEST DATA CUMULATED		
TIER-1	Administration Costs	100.000,00	TIER-1	Administration Costs	100.000,00
TIER-2	Administration Costs	7.500,00	TIER-2	Administration Costs	7.500,00
TIER-3	Administration Costs	5.000,00	TIER-3	Administration Costs	5.000,00
TIER-4	Administration Costs	2.500,00	TIER-4	Administration Costs	2.500,00

CALCULATIONS FOR BUILDING DEPRECIATION:					
ChosenRoundsBeginnin	1			LATEST ROUND:	2
ChosenRoundsEnd:	240				
ROUND VALUES			LATEST DATA PER ROUND		
TIER-1	Building depreciation	1.666,67	TIER-1	Building depreciation	1.666,6
TIER-2	Building Depreciation	1.458,33	TIER-2	Building Depreciation	1.458,3
TIER-3	Building Depreciation	1.250,00	TIER-3	Building Depreciation	1.250,0
TIER-4	Building Depreciation	1.041,67	TIER-4	Building Depreciation	1.041,6
CUMULATED VALUES			LATEST DATA CUMULATED		
TIER-1	Building depreciation	400.000,00	TIER-1	Building depreciation	400.000,0
TIER-2	Building Depreciation	350.000,00	TIER-2	Building Depreciation	350.000,0
TIER-3	Building Depreciation	300.000,00	TIER-3	Building Depreciation	300.000,0
TIER-4	Building Depreciation	250.000,00	TIER-4	Building Depreciation	250.000,0

Figure A.8 – Interim Calculation for Overview Calculation

Figures A.9 and A.10 show the entire calculation, explained in Chapter 4.2.2.

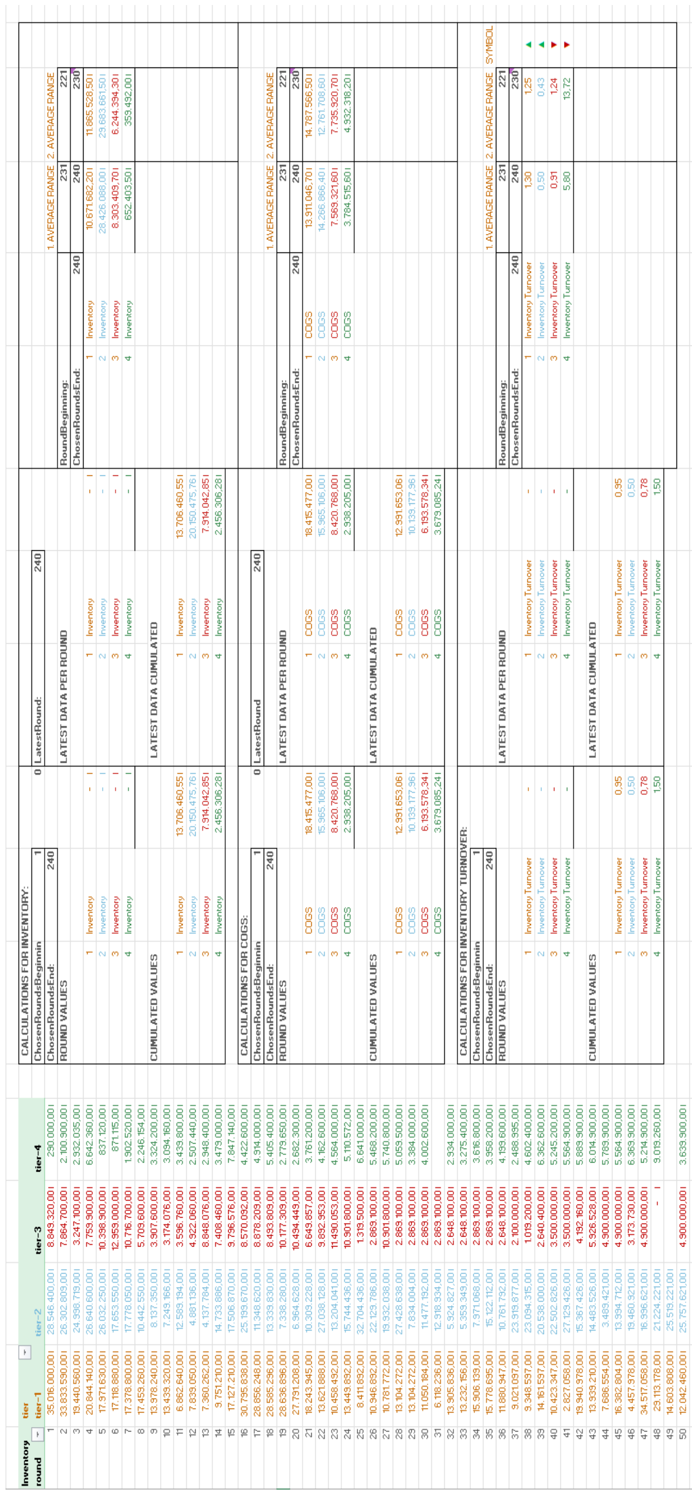


Figure A-.9 - Entire Inventory Turnover Calculation Part I

CALC FOR TIER SELECTION

	TIER-1	TIER-2	TIER-3	TIER-4
1	0,00	-	0,00	0,03
2	0,14	0,08	0,24	1,10
3	0,39	0,36	0,58	1,29
4	0,57	0,48	0,49	0,12
5	0,65	0,36	0,31	1,01
6	0,69	0,51	0,17	1,92
7	0,68	0,51	0,16	1,21
8	0,68	0,89	0,35	1,03
9	0,85	1,07	0,00	0,69
10	0,88	0,55	0,18	0,75
11	1,62	0,43	0,53	0,67
12	0,56	1,79	0,00	0,33
13	0,69	0,78	0,37	0,78
14	0,90	0,78	0,35	0,66
15	0,35	0,32	0,20	0,29
16	0,22	0,42	0,02	0,52
17	0,40	0,80	0,13	0,47
18	0,40	0,67	0,17	0,43
19	0,40	1,23	-	0,30
20	0,43	1,35	0,22	0,35
21	1,18	0,91	0,28	0,65
22	0,86	0,40	0,07	0,59
23	0,03	0,83	0,24	0,21
24	0,85	0,69	0,07	0,50
25	1,40	0,35	2,36	0,60
26	0,14	0,50	0,20	0,20
27	0,89	0,55	0,34	0,46
28	0,90	0,40	1,00	0,21
29	1,13	1,22	0,28	0,32
30	1,34	1,01	1,28	0,60
31	2,00	0,07	1,28	
32	0,19	1,86	1,39	0,32
33	1,12	2,05	1,33	0,73
34	0,83	0,34	1,23	0,66
35	0,05	0,73	1,28	0,61
36	0,99	1,14	1,39	0,58
37	1,23	0,46	1,68	1,14
38	0,04	0,44	5,91	0,53

CALC FOR ROUND APPEARANCE IN THE LINE GRAPH

ROUND	TIER-1	TIER-2	TIER-3	TIER-4
1	0,00	-	0,00	0,03
2	0,14	0,08	0,24	1,10
3	0,39	0,36	0,58	1,29
4	0,57	0,48	0,49	0,12
5	0,65	0,36	0,31	1,01
6	0,69	0,51	0,17	1,92
7	0,68	0,51	0,16	1,21
8	0,68	0,89	0,35	1,03
9	0,85	1,07	0,00	0,69
10	0,88	0,55	0,18	0,75
11	1,62	0,43	0,53	0,67
12	0,56	1,79	0,00	0,33
13	0,69	0,78	0,37	0,78
14	0,90	0,78	0,35	0,66
15	0,35	0,32	0,20	0,29
16	0,22	0,42	0,02	0,52
17	0,40	0,80	0,13	0,47
18	0,40	0,67	0,17	0,43
19	0,40	1,23	-	0,30
20	0,43	1,35	0,22	0,35
21	1,18	0,91	0,28	0,65
22	0,86	0,40	0,07	0,59
23	0,03	0,83	0,24	0,21
24	0,85	0,69	0,07	0,50
25	1,40	0,35	2,36	0,60
26	0,14	0,50	0,20	0,20
27	0,89	0,55	0,34	0,46
28	0,90	0,40	1,00	0,21
29	1,13	1,22	0,28	0,32
30	1,34	1,01	1,28	0,60
31	2,00	0,07	1,28	
32	0,19	1,86	1,39	0,32
33	1,12	2,05	1,33	0,73
34	0,83	0,34	1,23	0,66
35	0,05	0,73	1,28	0,61
36	0,99	1,14	1,39	0,58
37	1,23	0,46	1,68	1,14
38	0,04	0,44	5,91	0,53

Figure A.10 – Entire Inventory Turnover Calculation Part II

Appendix C Dashboard Versions during Feedback Loops

Figure A.11 shows the dashboard version evaluated in the first evaluation.

BPOS GAME KEY PERFORMANCE INDICATORS

ROUNDS: 88

OVERVIEW

DATA TYPE: CUMULATED VALUES

METRICS	TIER 1	TIER 2	TIER 3	TIER 4
TOTAL REVENUE				
PRODUCTION COSTS	89.463.520,00 €	69.186.070,00 €	102.166.500,00 €	156.329.015,00 €
BACKLOG COSTS	479.495.000,00 €	49.546.950,00 €	32.140.900,00 €	4.523.043,00 €
GROSS PROFIT				
OPERATING PROFIT				
WAREHOUSING COSTS RAW MATERIALS	161.877.500,00 €	42.924.180,00 €	21.692.415,00 €	53.888.917,00 €
WAREHOUSING COSTS FINISHED GOODS	15.953.550,00 €	42.011.220,00 €	9.873.576,00 €	2.015.998,00 €
NET INCOME				
INVENTORY TURNOVER				
COMPARISON ALTERNATIVE VS. NORMAL DELIVERY COSTS				
COMPARISON ALTERNATIVE. VS. NORMAL SUPPLIER COSTS				
ON-TIME DELIVERY PERFORMANCE				
CUSTOMER LOYALTY (REPEAT PURCHASE RATE)				
CAPACITY UTILIZATION				
SUPPLIER ON-TIME DELIVERY PERFORMANCE				

Figure A.11 - Dashboard Version on First Evaluation

Figure A.12 shows the dashboard version evaluated in the second evaluation.

BPOS GAME KEY PERFORMANCE INDICATORS

RANGE: 1 60

OVERVIEW

DATA TYPE: CUMULATED VALUES ☑ LATEST ROUND: 187

METRICS	TIER-1		TIER-2		TIER-3		TIER-4	
TOTAL REVENUE	3.624.264.779,00 €	▲	2.389.321.979,00 €	▲	2.999.639.594,00 €	▲	1.366.884.243,00 €	▼
PRODUCTION COSTS	227.133.600,00 €	▲	163.119.680,00 €	▼	318.384.315,00 €	▼	449.539.450,00 €	▼
BACKLOG COSTS	1.018.860.750,00 €	▼	91.001.250,00 €	▼	100.217.500,00 €	▲	9.866.032,00 €	▲
GROSS PROFIT	- 460.505.498,00 €		- 80.042.193,00 €		1.543.512.255,00 €		642.311.208,00 €	
OPERATING PROFIT	- 460.505.498,00 €		- 80.042.193,00 €		1.543.512.255,00 €		642.311.208,00 €	
WAREHOUSING COSTS RAW MATERIALS	389.207.900,00 €	▲	108.397.905,00 €	▲	67.491.520,00 €	▼	81.311.287,00 €	▼
WAREHOUSING COSTS FINISHED GOODS	17.956.950,00 €	▼	68.040.480,00 €	▼	21.896.450,00 €	▼	5.063.450,00 €	▲
NET INCOME	- 867.670.348,00 €		- 256.480.578,00 €		1.454.124.285,00 €		555.936.471,00 €	
INVENTORY TURNOVER	271,26		210,84		266,12		1.039,56	
COMPARISON DELIVERY / ALT-DEL COSTS								
COMPARISON SUPPLIER / ALT-SUP COSTS								
ON-TIME DELIVERY PERFORMANCE								
CUSTOMER LOYALTY (REPEAT PURCHASE RAT	4277,14%	▲	2670,65%	▲	381,84%	▲	-220,50%	▲
CAPACITY UTILIZATION								
SUPPLIER ON-TIME DELIVERY PERFORMANCE								
TOTAL REVENUE VS. BACKLOG	3,56 €	▲	22,04 €	▲	44,09 €	▼	15,02 €	▼
PRODUCTION COSTS VS. TOTAL REVENUE	6,27 %	▼	6,83 %	▼	10,61 %	▼	32,89 %	▼
WAREHOUSE VS. NET INCOME								

Figure A.12 - Dashboard Version on Second Evaluation

Appendix D Remaining Dashboard Registers

The following figures, A.13 to A.27, show the remaining dashboard registers. They are listed in the order that they appear in the Excel file after the overview and the total revenue register.

Figure A.13 shows the Production register, which contains graphs of the production costs and amounts.

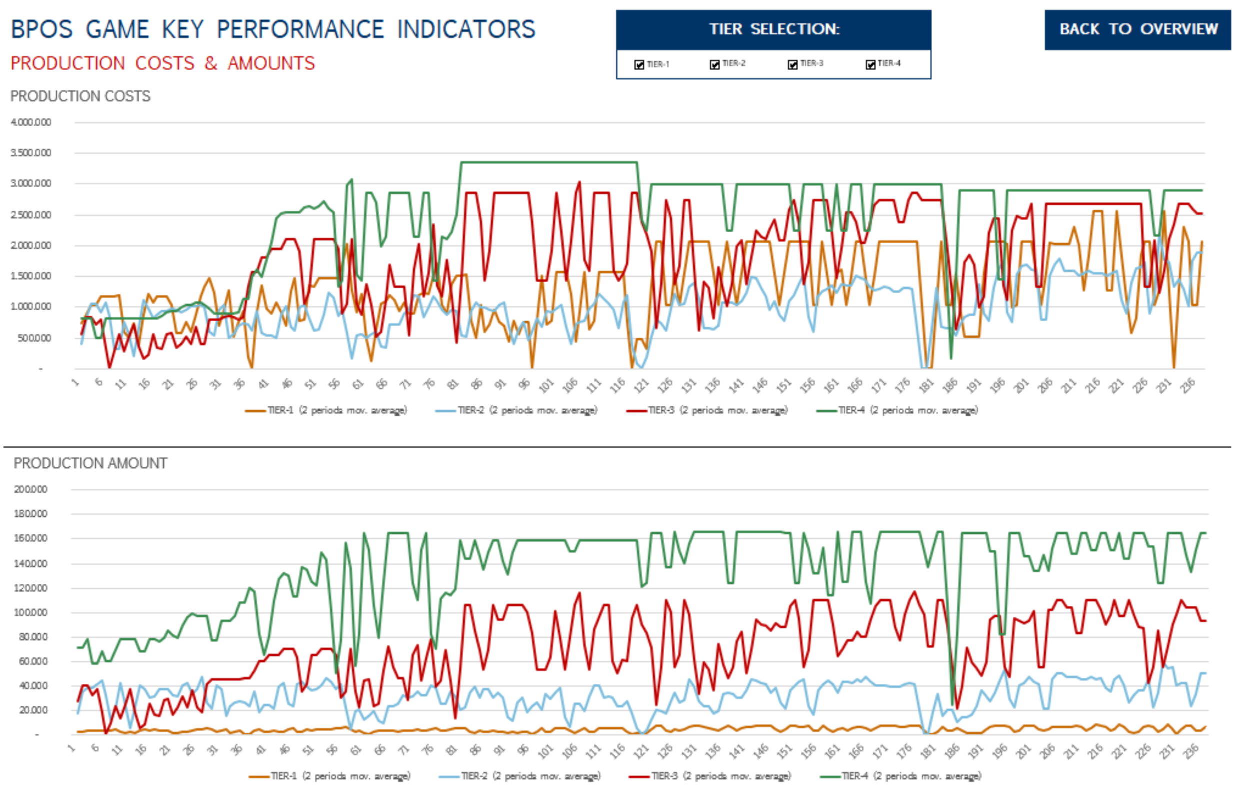


Figure A.13 - Production Register

Figure A.14 shows the Backlog register. It contains a graph of the backlog costs and the backlog amounts.

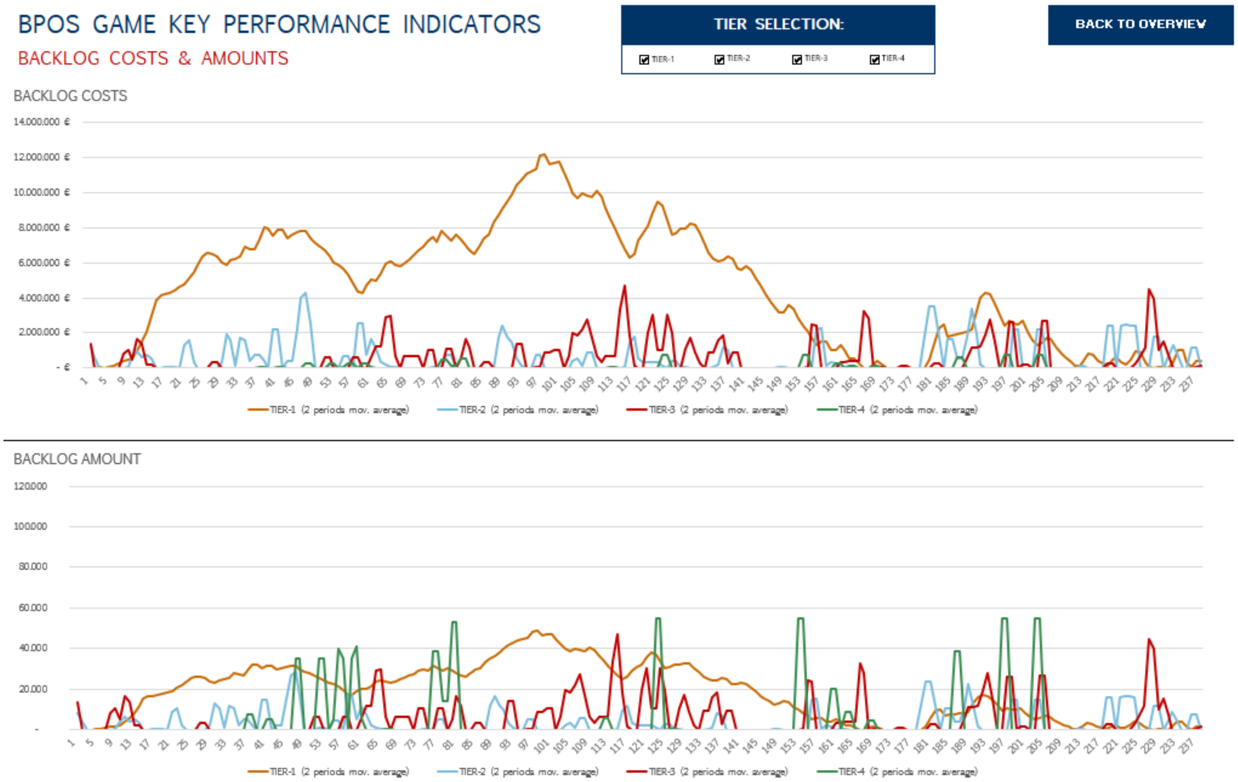


Figure A.14 - Backlog Register

Figure A.15 shows the Gross Profit register.

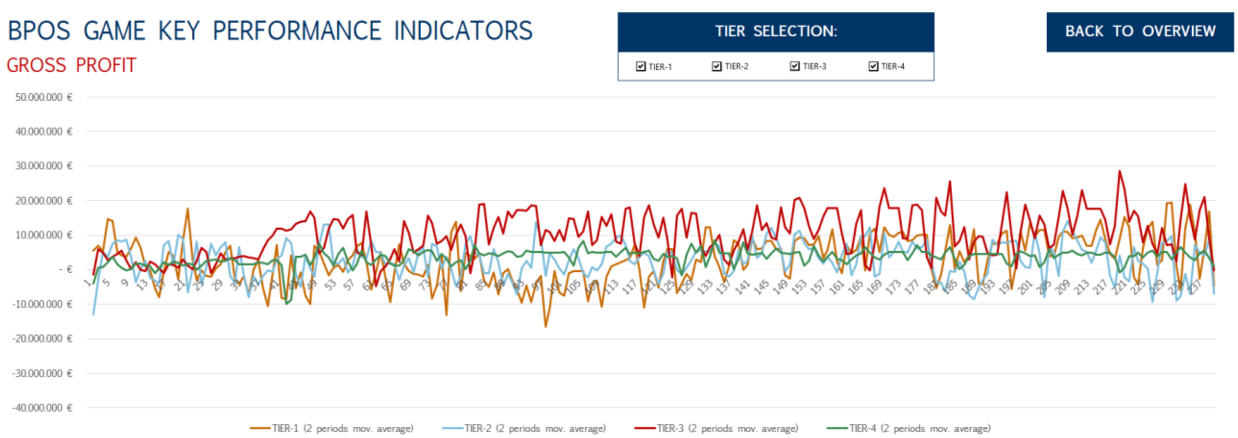


Figure A.15 - Gross Profit Register

Figure A.16 shows the Operating Profit register.

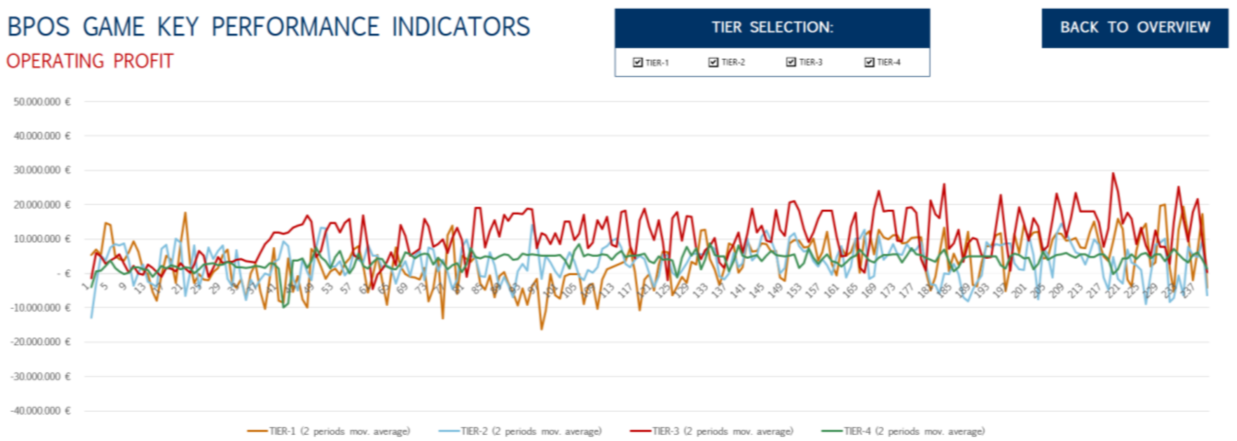


Figure A.16 - Operating Profit Register

Figure A.17 shows the Warehousing Costs Raw Materials register.

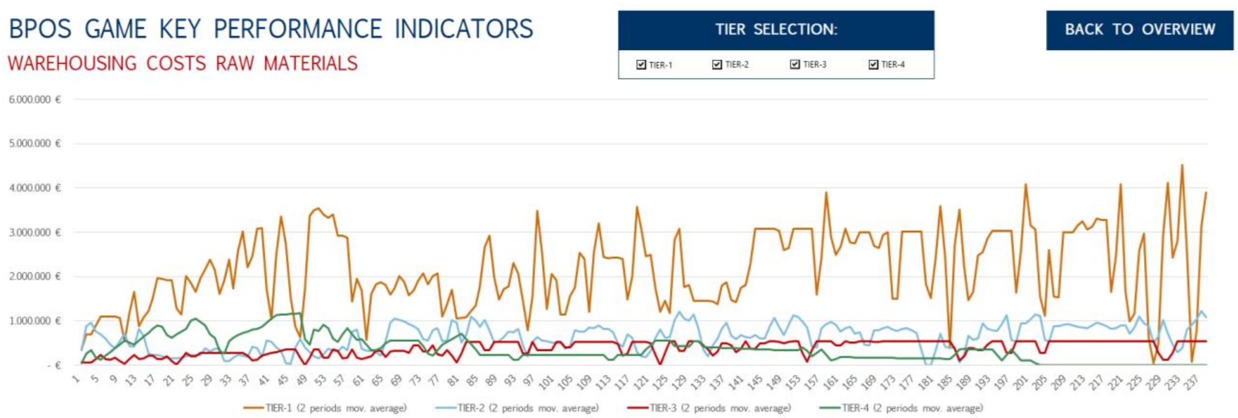


Figure A.17 - Warehousing Costs Raw Materials Register

Figure A.18 shows the Warehousing Costs Finished Goods register.

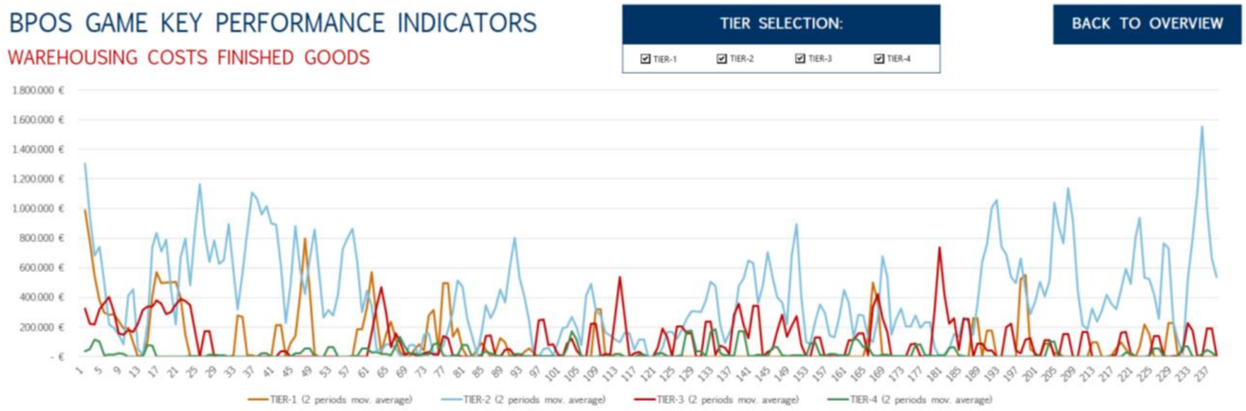


Figure A.18 - Warehousing Costs Finished Goods Register

Figure A.19 shows the Net Income register.

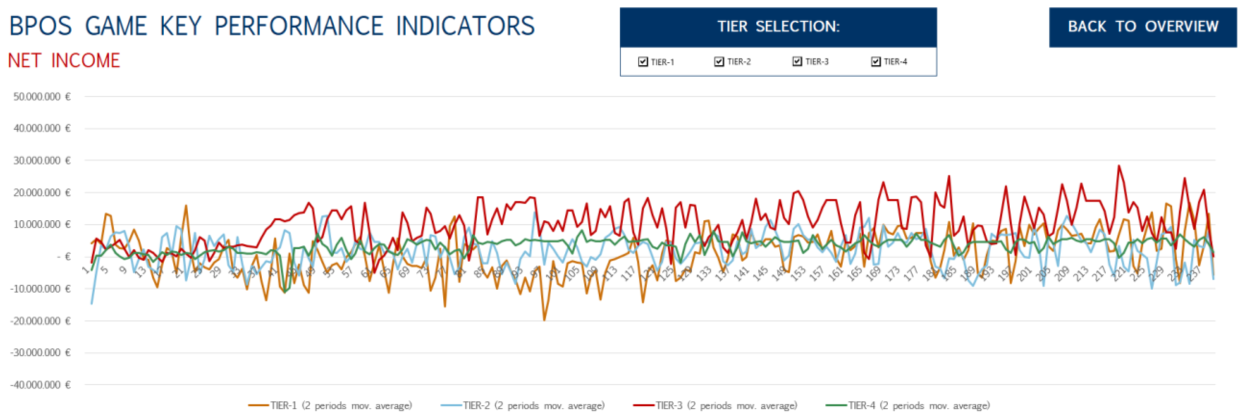


Figure A.19 - Net Income Register

Figure A.20 shows the Inventory Turnover register.

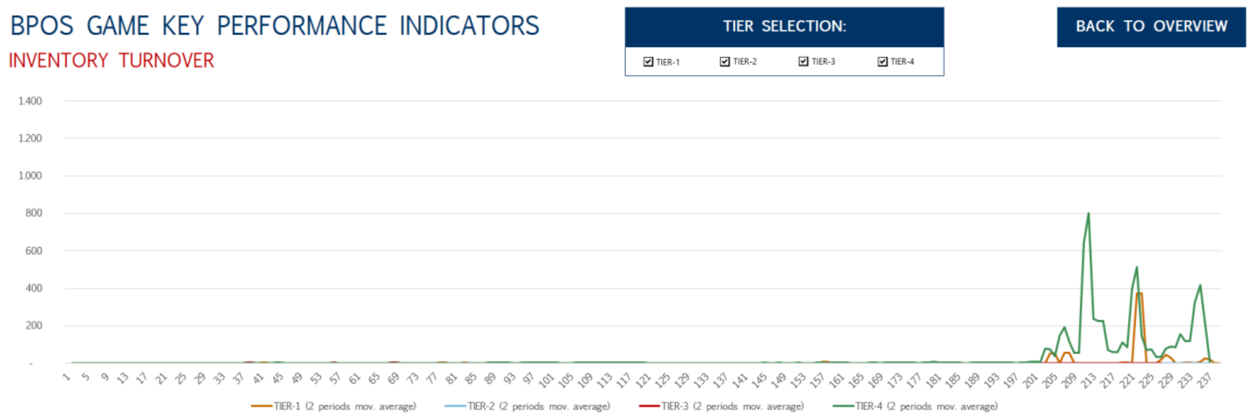


Figure A.20 - Inventory Turnover Register

Figure A.21 shows the Delivery Distribution Index register.

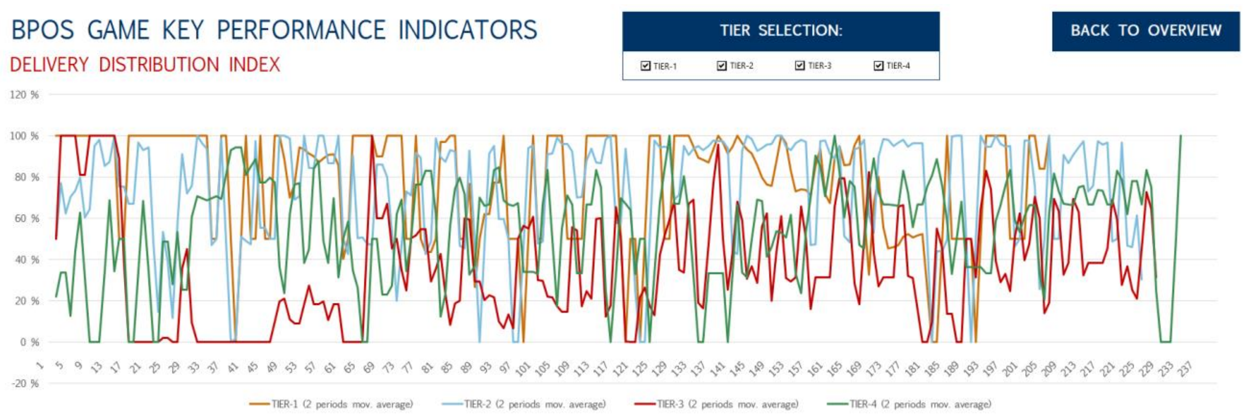


Figure A.21 - Delivery Distribution Index Register

Figure A.22 shows the Supplier Distribution Index register.

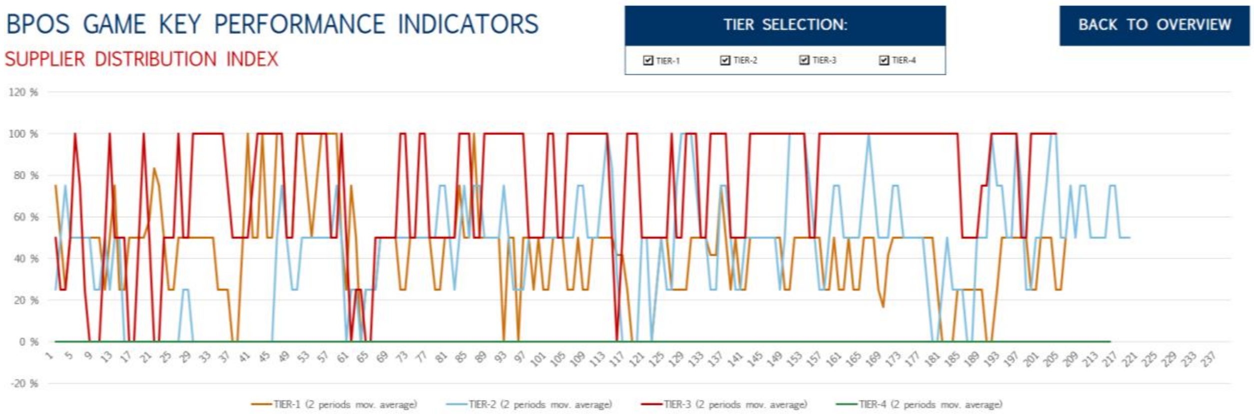


Figure A.22 - Supplier Distribution Index Register

Figure A.23 shows the Repeat Purchase Rate register.

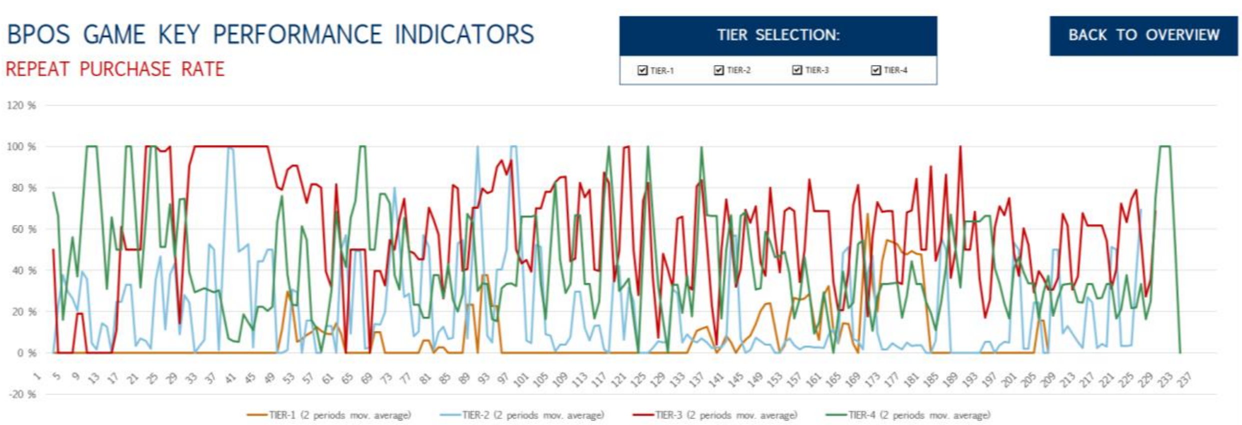


Figure A.23 - Repeat Purchase Rate Register

Figure A.24 shows the Capacity Utilization Register.

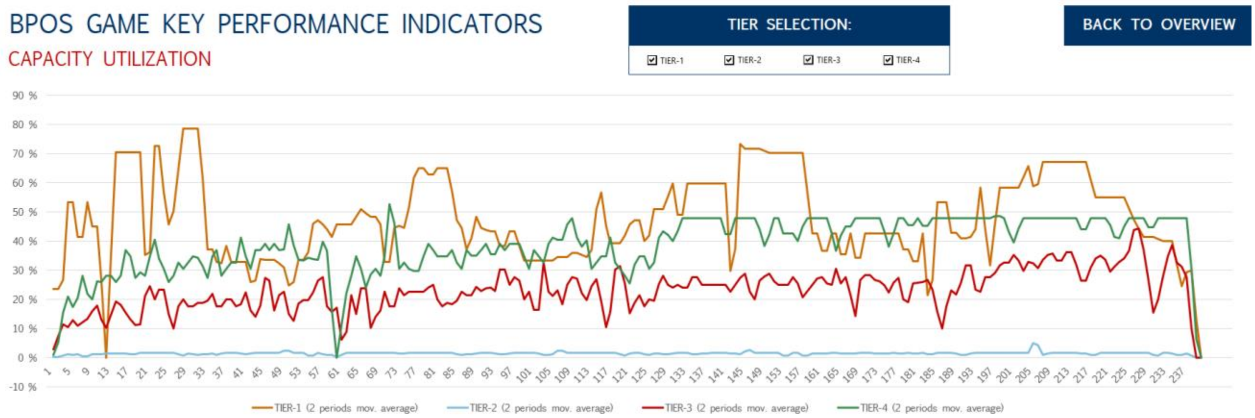


Figure A.24 - Capacity Utilization Register

Figure A.25 shows the On-Time Delivery Performance register. It shows the on-time deliveries. The green squares indicate an on-time delivery, and the red squares indicate a failed on-time delivery.

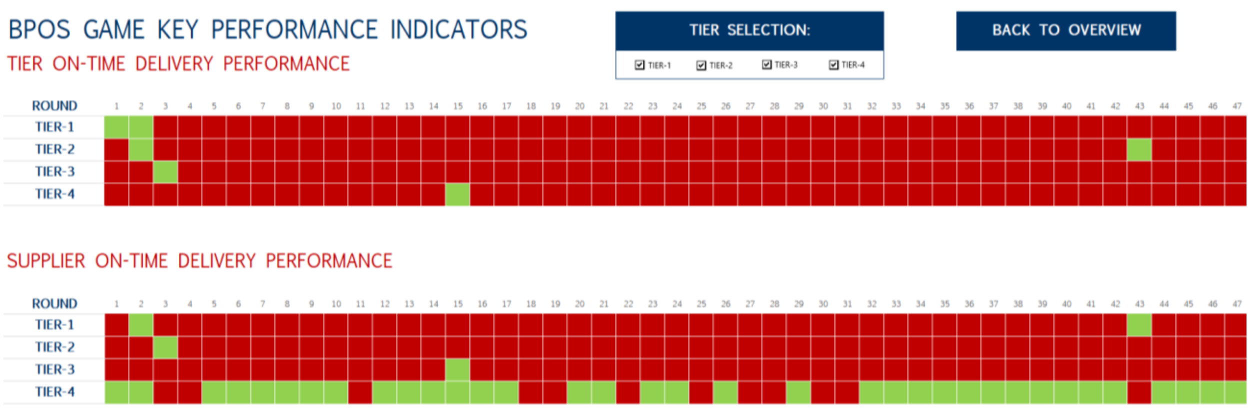


Figure A.25 – On-Time Delivery Performance Register

Figure A.26 shows the Relations register. It displays the Backlog Costs vs. Total Revenue, Production Costs vs. Total Revenue, and Warehouse Costs vs. Total Revenue KPIs.

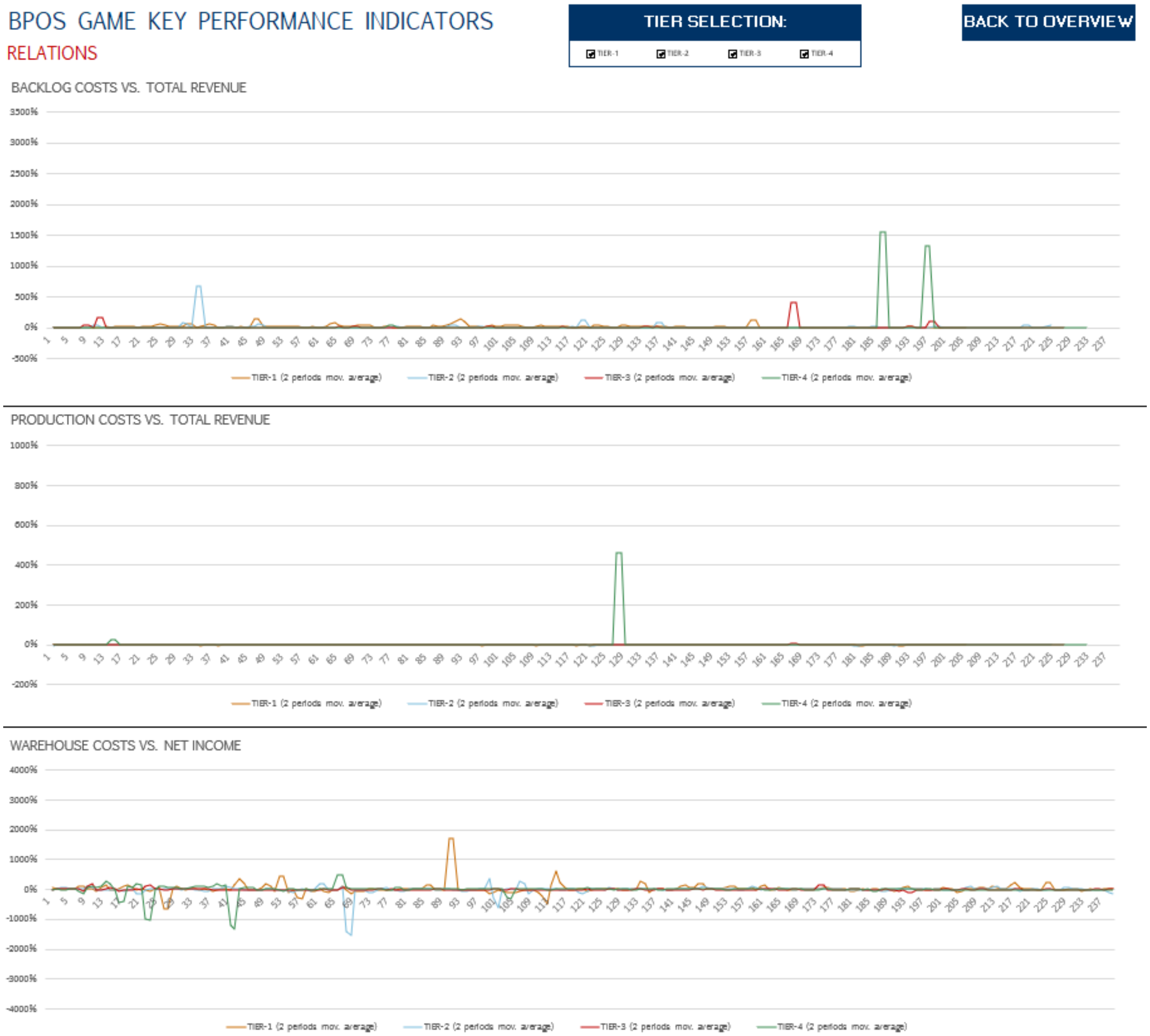


Figure A.26 - Relations Register

Figure A.27 shows the Production Time register. It lists general production information for the products manufactured by the tiers and is used to calculate the Capacity Utilization KPI.

BPOS GAME

PRODUCTION TIME

BACK TO OVERVIEW

TOTAL ROUNDS: 240

PRODUCT ID	PRODUCT	TIER-1		TIER-2		TIER-3		TIER-4	
prod05	Cover							0,0005	seconds
prod06	Screw							0,0005	seconds
prod07	LED							0,0005	seconds
prod08	Grill							0,0005	seconds
prod09	Frame					0,0005	seconds		
prod10	Fog lamp socket					0,0007	seconds		
prod11	Bubble					0,0005	seconds		
prod12	Customized grill					0,00095	seconds		
prod13	Bumper			0,005	seconds				
prod14	Fog lamp			0,0001	seconds				
prod15	LED set			0,00035	seconds				
prod16	Painted customized grill			0,001	seconds				
prod17	Bumper BMW	0,009	seconds						
prod18	Bumper Audi	0,008	seconds						
prod19	Bumper Benz	0,007	seconds						
prod20	Bumper VW	0,009	seconds						
TOOL CHANGE TIME		5	seconds	5	seconds	5	seconds	5	seconds
MACHINES		2		2		2		2	

Figure A.27 - Production Time Register

Figure A.28 shows the Tier Information register. It contains general information about the tiers that are, in some cases, used for further calculations. The yellow field on the upper left needs to be filled in with the planned years played during the lecture. The yellow fields in the bottom table need to be filled in by the game's instructor with the round that the warehouses were purchased and the red ones with the number of purchased warehouses. This information is needed to calculate the Storage Facility Costs KPI.

BPOS GAME

TIER INFO: GENERAL COSTS PER YEAR

TOTAL ROUNDS: 479

Planned Years:

METRICS	TIER-1		TIER-2		TIER-3		TIER-4	
WAREHOUSING COSTS	100,00 €	per Product	15,00 €	per Product	5,00 €	per Product	1,50 €	per Product
WAREHOUSING CAPACITY	10.000		10.000		10.000		10.000	
ORDER COSTS	4.000,00 €		3.000,00 €		2.000,00 €		1.000,00 €	
MACHINE VALUE	4.000.000,00 €		3.000.000,00 €		2.000.000,00 €		1.000.000,00 €	
MACHINE DEPRECIATION RATE	10 %		10 %		10 %		10 %	
MACHINE DEPRECIATION PERIOD	10	years	10	years	10	years	10	years
BUILDING VALUE	8.000.000,00 €		7.000.000,00 €		6.000.000,00 €		5.000.000,00 €	
BUILDING DEPRECIATION RATE	5 %		5 %		5 %		5 %	
BUILDING DEPRECIATION PERIOD	20	years	20	years	20	years	20	years
SALARIES	350.000,00 €		300.000,00 €		250.000,00 €		200.000,00 €	
ADMINISTRATION COSTS	100.000,00 €		7.500,00 €		5.000,00 €		2.500,00 €	
NEW WAREHOUSE COST	250.000,00 €		200.000,00 €		150.000,00 €		100.000,00 €	
RENT PER PRODUCT	150,00 €		15,00 €		5,00 €		2,50 €	

METRICS	TIER-1		TIER-2		TIER-3		TIER-4	
	ROUND	AMOUNT	ROUND	AMOUNT	ROUND	AMOUNT	ROUND	AMOUNT
AMOUNT OF BOUGHT WAREHOUSES								
AMOUNT OF BOUGHT WAREHOUSES								
AMOUNT OF BOUGHT WAREHOUSES								

Figure A.28 - Tier Information Register

Declaration

I declare that I have written this thesis independently, that I have not otherwise submitted it for examination purposes, that I have not used any sources or aids other than those sources and aids other than those stated, and that I have marked literal and analogous quotations as such, and that I tolerate the verification through anti-plagiarism software.

Nördlingen, 2nd of September 2024	Katharina Hammer
Place, Date	Signature