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Faculty of Business Economics

Master of Management

Master's thesis

The Contribution of Data Visualization Dashboards to Managerial Decision-Making

Fatemeh Ehteshamifar

Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Business Process Management

SUPERVISOR :
Prof. dr. Koenraad VANHOOF

MENTOR :
Maarten VANHOOF

2023
2024

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www.uhasselt.be
Universiteit Hasselt
Campus Hasselt:
Martelarenlaan 42 | 3500 Hasselt
Campus Diepenbeek:
Agoralaan Gebouw D | 3590 Diepenbeek

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Preface

It has been a long journey for me to this season of writing my master's dissertation in management.

I want to express my deepest gratitude to my family.

I adore my mother and father's consistent and unconditional love and support for teaching me to be a lifelong learner and seeker of wisdom and beauty. I appreciate their encouragement and assistance my whole way and during my educational years.

I am deeply grateful, especially to my brother, for all his help and support during every step of my educational journey, and I appreciate my sister for all her encouragement.

I appreciate my supervisor, Prof. Dr. Koenraad Vanhoof, for his valuable support and being part of this academic process.

I sincerely thank my promoter, Dr. Maarten Vanhoof, for his valuable comments and guidance while writing this dissertation. His constructive suggestions, understanding, and support helped me improve my work noticeably.

Last but not least, I am thankful for all the moments, thoughts, and insights that led me to write this research and gave me this unique opportunity to think, search, and write.

Fatemeh Ehteshamifar

Hasselt, Spring 2024

Summary

With the huge growth of data and the increasing need to analyze it, it is important to apply methods and tools to use the data more efficiently.

In recent years, many companies have applied data visualization dashboards to their businesses, and managers use them to make decisions. Although there are some studies about their functions and effects, one important question is how they can affect an organization's business, especially when making decisions by managers, what kind of decisions are affected in this way, and if there are factors influencing the effects of using them for decision-making.

A qualitative study was conducted to answer the above research questions. The research was conducted through judgment sampling. The sample included five managers with experience working with visualization and dashboards for at least 2 years. Four participants are working in Iran, and one is working in Belgium, but he has experience related to this research in Iran and Belgium. The method used to analyze the interview's contents was thematic analysis with deductive and inductive coding.

This study shows that dashboards are mainly used for monitoring, decision-making, analysis, planning, and data visualization. Managers mostly use data visualization dashboards for mid-term and tactical decisions. Using data visualization dashboards for short-term and operational decisions is the least common compared to their use for tactical and strategic decisions. Using dashboards can help managers make strategic and long-term decisions as well. However, since making these decisions requires considering many factors and parameters, all the parameters involved in long-term decision-making might not be presentable and monitorable in dashboards during strategic decision-making.

The study shows that visualization dashboards enhance decisions speed, accuracy, clarity, and validity. Additionally, using dashboards positively affects risk understanding by showing the trends and increasing the predictability of probable outcomes.

The research also reveals that experience working with data visualization and dashboards, dashboard design, task characteristics, and organization type can influence using data and visualization dashboards for managerial decision-making.

This study explores the effects of data visualization dashboards in an organization's operational, tactical, and strategic decision-making by managers and the factors influencing this effect. Further, it contributes to managers who want to improve decisions using decision support tools like data visualization dashboards.

It is worth mentioning that there were limitations to this study. The research literature search was mainly done through Google Scholar for articles between 2017 and 2024.

Another limitation is related to the number of managers interviewed for this research. Considering the time limitation for conducting this study, the interview participants were limited to five

managers. A bigger and more diverse sample could increase its generalizability. Also, the results might differ if the sampling design becomes arranged differently or the questions are designed differently.

The interviews were transcribed from Persian to English by the researcher. Although there were few applications for this purpose, they were not designed to transcribe all the details and points from the main language to English, like the proverbs and expressions used when answering the questions by the participants.

In addition, the apps were not tailored to the context of business and management. As a result, the interviews were transcribed manually so the reader could get the most out of the language. It is impossible to translate from one language to another 100% perfectly. However, the aim has been to convey the content honestly, with minimal errors.

Another potential limitation could be that the questions asked from the participants were broader than the research questions, and they included some questions about participants' experiences and limitations of using the dashboards and visualization in their role for decision-making.

Furthermore, since it was an explorative study with semi-structured interviews, the interviews were, to some extent, adjusted following the participant flow. This caused the emergence of terms and contents that have the potential to be defined more precisely. these words were used in the research in the same way the participants mentioned them. Considering the interview time limit and research topic constraint, this study does not focus on their academic and precise definitions.

An opportunity for future research could be the role of artificial intelligence (AI) in using visualization dashboards for business decision-making. The effect of the organization and business types on the application of data tools and visualization techniques could be another research opportunity. Furthermore, the effects of an organization’s life cycle and culture on applying dashboards, visualization tools, and techniques are worth studying and investigating in future research.

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Chapter 1: Introduction

Data visualization is one of the words we hear a lot these days since data has become trendy for businesses. At first, it might seem a very technical or academic term. The fact is that although it is frequently used in the mentioned domains, the concept is not limited to papers and theories.

As we might have heard or read in books, We can face data visualization in our everyday lives, from when we want to check a location on Google Maps or when we are waiting for our train at the station in the visual signs and icons on the station boards. It is a concept we live with daily.

Data visualization is not all about techniques; It can be applied to simple tasks like drawing a flow chart or using an Excel file. The main purpose of it is to facilitate communication and perception.

With the growth of data, the need to visualize data has grown. Businesses face massive amounts of data that can be analyzed and benefitted from. Here, the need for visualization appears, and with the increasing need for it, organizations and businesses try to use it in their activities more than before.

Data visualization transforms abstract data into interpretable visual representations, minimizing the time needed to access, analyze, and report data.(Khatri & Gupta, 2022).

At the start of this research, the researcher intended to search for a tangible, practical aspect of data visualization that makes sense in business. With this in mind, it was found that many companies apply data visualization through dashboards for different roles in their business.

Dashboards are being used extensively in many businesses as a tool for making better performance and decisions. This creates a growing need to study their design and functionality.(Sarikaya et al., 2019)

Dashboards can be useful tools by selecting proper information and suitable visualization techniques. (Abduldaem & Gravell, 2019)

The use of dashboards can be searched from different approaches; However, one of their applications is to help managers make decisions.

At the beginning of this research, it was noticed that although there are studies about dashboards in academic literature, there is a lack of studies about dashboards in the business domain from some perspectives, which will be discussed in the following sections.

In a systematic literature review about the effects of visualization on judgment, based on 133 peer-reviewed original empirical articles published between 1990 and 2020, limited to information and social science domains (and excluding medicine and natural science), a noteworthy part of the works originates from the information science literature and the second biggest part is for cognitive psychology research. (Eberhard, 2023)

In management, despite some articles about the benefits or deficiencies of using data visualization and dashboards for judgment and decision-making, it is unclear which decisions might be affected this way and for what type of decisions are used in the organizations.

Further, little to no research has been done about the effect of dashboards and data visualization in strategic and operational decision-making areas. (Eberhard, 2023).

As Frazao et al.(2021) state, there is a lack of studies about dashboards in the business domain at the functional level.(Frazao et al., 2021)

In addition, in the literature, it is unclear how the organization's type and culture might affect the use of dashboards and data visualization in decision-making; I was wondering if it could work the same in different companies or if there might be differences between various corporate settings.

This study focuses on this perspective of visualization through dashboards and their applications in different roles in business, emphasizing their contribution to decision-making.

The researcher aims to find an answer to the research questions by collecting unexplored parts in this regard and asking questions related to less or non-explored parts after reading the research literature in five semi-structured interviews with managers with experience working with data visualization and dashboards.

The research questions are as follows:

R1 What are the roles of dashboards in a company?

R2 For what kinds of decisions do managers use dashboards in a company?

R3 How do data visualization dashboards contribute to managerial decision-making?

R4 Are there factors influencing managers' use of visualization and dashboards for decision-making?

The procedure for choosing the research topic and research questions is shown below:

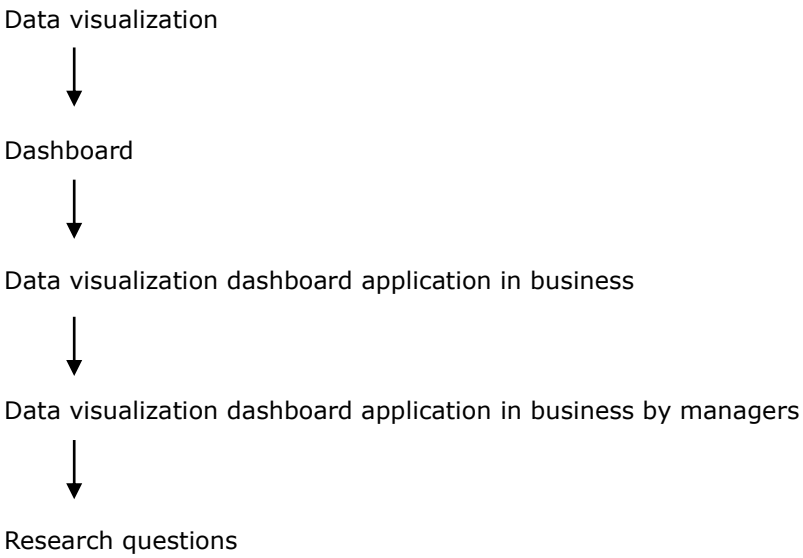

Figure 1: The procedure for choosing the research topic

The first part of this study will include an overview of the research literature. The methodology will be discussed in the second part, in which the research method, sampling, and content analysis will be discussed. The next chapter focuses on the results, followed by a discussion chapter. The last chapter will be for the conclusion, limitations, and suggestions for future research.

Chapter 2: Literature Review

2.1 Data Visualization

As Schneiderman (2003) says:" A picture is often cited to be worth a thousand words." (Schneiderman,2003)

Data visualization represents the data and information in a graphical and visual form. It could be a set of points in a scatterplot or statistical summaries in a histogram. (Unwin, 2020)

Data, information, and knowledge are three terms frequently used in connection with one another in the data visualization field. To clarify their difference, While data is raw facts or numbers, information is data that has given meaning through rational connections. Information visualization mainly focuses on data mining and knowledge discovery, whereas data visualization's main objective is to gain insight into an information space. Finally, Knowledge is the proper collection of information aimed to be beneficial and creates a reliable basis for making decisions. (Toasa et al., 2018)

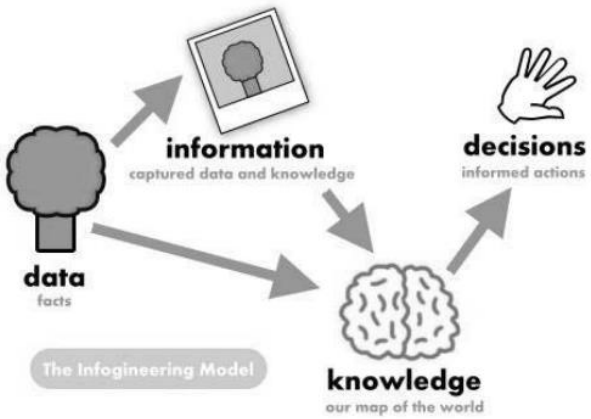

Figure 2: Data, information, knowledge, and decision (Toasa et al.,2018)

2.2 Dashboards

In their article, Abduldaem and Gravell (2019) mentioned that dashboards have no uniform comprehensive definition. Still, it might clarify that they refer to Few's (2006) definition of dashboards as a single screen representing the most significant information at one glance. (Few, 2006).

They mention that one of the important reasons for using dashboards is information overload management to use data more efficiently. Hence, dashboards are a business intelligence tool that helps users achieve better performance by merging metrics like key performance indicators (KPIs) and scorecards. (Abduldaem & Gravell, 2019).

Dashboards can facilitate the need to represent data visually in a business and make it possible to track and analyze business activities through metrics. (Toasa et al., 2018).

For many people in an organization, dashboards are the first encounter with data. At first glance, they may seem like an integration of charts and visuals, but as a visualization tool, they work more than to integrate each part. (Sarikaya et al., 2019).

Dashboards can integrate multiple sources and information types, enabling users to interact with the data. Based on a survey, companies mainly use dashboards for three activities: snapshot reporting, active monitoring, and visual data analysis. Many companies apply dashboards to view basic reports. These reports are usually stored in a database for users. This makes it possible to observe the changes over time. Displaying key performance indicators and metrics in dashboards helps users measure and control the progress toward goals over time. (Khatri & Gupta, 2022).

Dashboards allow users to combine visual representations and data analyses into one page. (Islam & Jin, 2019)

Zingde and Shroff (2020) study the effects of BI dashboards in business decision-making and performance management. Based on their studies, BI dashboards facilitate transforming huge, complicated data into actionable information. This dependable integrated data enables managers to respond to customers faster. (Zingde & Shroff, 2020)

2.3 The effects of data visualization on decision-making

Why can visualization be helpful and effective in decision-making? There are different perspectives on answering this question. One of these perspectives comes from cognitive psychology.

From the cognitive psychology perspective, cognitive ability includes capacities like perceptual speed (the quickness with which perceptual tasks are completed), visual working memory, and verbal working memory. This cognitive ability can influence an individual's data visualization consumption. (Moore, 2017)

The working memory is limited. Data visualization can reduce this cognitive load and accelerate cognitive processing by allowing the user to focus on the most relevant information in a more efficient, faster, and simpler gazing pattern as a measure of cognitive effort (Smerecnik et al., 2010). This way, more time can be spent on highly related information, and less working memory is required. The cognitive load a person experiences can affect the person’s performance during a task. The high cognitive load can negatively impact performance. Good data visualization can enhance the users' perception of the problem and performance. (Eberhard, 2023).

Other articles like Tukey’s (1977) and Friedman’s (2008) articles confirmed that it is easier for the human brain to recognize graphics than texts, as visual data is easier to decode, and decision-making could be faster by analyzing the patterns. (Islam & Jin, 2019)

It is discussed in the above paragraphs that there are improvements in the decision-making process by visualization, but which parameters are affected in this process?

To answer this question, studies suggest that data visualization can influence executives to use the required information considering consumption, speed, and confidence. “Consumption” refers to how well the representation aligns with the decision’s goal. “Speed” measures how quickly important aspects can be identified in the visualization by applying colors, for instance, to highlight the critical details. The “confidence” depends on the executive knowledge of the decision, the accuracy and integrity of the data, the familiarity with the technology used, and the presenter’s comprehension of the decision-making process. (Moore, 2017).

In her systematic literature study, Eberhard (2023) states that Dong and Hayes (2012) experimented and found that visualizing uncertainty through a decision support system enhances understanding of the problem and recognition of vague decision situations. Moreover, visualization enhances the accuracy of decisions (Pfaff et al., 2013) and conclusions drawn from data. (Sato et al.,2019) (Eberhard, 2023)

Considering that decision-making speed and quality can be affected by data visualization, using the right visuals and their section is important in dashboard design; for example, the key information design on the top of the dashboard screen and the related details at the bottom are suggested. (Zingde & Shroff , 2020)

The parameters moderating the effect of data visualization on decision-making have been discussed in several studies. The importance of mentioning them in this study comes from the fact that the decision-making process will not be affected similarly for different decision-makers and datasets.

Lurie and Mason (2007) suggest that the characteristics of decision-makers are one of these moderating parameters. However, they clarify that this parameter includes the decision-maker's experience and involvement with visualization tools. The User's expertise refers to the user's understanding of important factors and ability to alter the visual representation to modify the important factors.(Lurie & Mason, 2007)

According to Kakkar (1977) and Slovic (1972), decision-makers use information as it is presented. It might make less-experienced decision-makers assume that the presented visualization and the used variables are the most proper, but that is not always true.
Unlike experts, visualized information is more likely to be overweighted by novices. Further, changing reference points is likely to have a greater impact on the riskiness of decisions made by novices than experts, and beginners are more subject to framing effects.(Lurie & Mason, 2007)

The framing effect, or the way the information is presented, is a concept worth defining in this study because it can affect the decision-making process and cause biases by executives and managers during this procedure.

Lurie and Mason (2007) argue that visual representations may irritate biases by altering how decision-makers absorb and process information. To be more clear, different ways of showing the same information visually can affect how people frame and judge this information. For example, if people associate green color with healthy and red color with unhealthy, a mostly green pie chart will look healthier than one with mostly red. This can be the effect of framing. (Lurie & Mason, 2007)

Framing could result from changing the reference point against which data are compared and, for example, considering the framed data as a loss or gain.
Daily presentations are more likely to indicate losses than long-term presentations, as daily losses seem more noticeable and frequent than losses over longer periods.
It can impact risk-taking by managers because decision-makers prefer to prevent losses more than earn gains in their risk-taking behaviors. When they observe losses on daily presentations, they might become more focused on preventing them, leading them to make riskier decisions to recover those causes more quickly. (Lurie & Mason, 2007)

After mentioning some of the benefits of using visualization for decision-making, this question might arise: Is data visualization always a better choice than using texts or tables in tasks, and which kind of visualization is beneficial for which kinds of tasks?
It might seem logical that there should be a fit between the task type and the format used. Some findings in the literature support this.

About what was discussed in the previous paragraph, Eberhard(2023) points out in Vessey's (1991) studies that graphs do not necessarily work better than tables, as more working memory is needed when there is not a good fit between data, task, and format. She notes that cognitive fit theory can be extended to match task and format complexity. It means that charts and graphs work efficiently when they present the required data for a task and do not create more complexity, as confirmed in studies by others like Pieters et al.(2010) and Geryk (2017). It is worth noting that there should be a fit between task complexity and the user's ability to obtain positive visualization effects in judgment. However, there is not much research in management in this regard. (Eberhard, 2023)

This might lead to the question of how a user chooses a visualization format.

Luo's (2019) findings indicate that task difficulty, cognitive style, and visualization format affect a user's choice of visualization format. These parameters also influence decision accuracy and confidence. Users prefer to use tables for easier tasks and graphic visualization format for harder tasks, indicating that task characteristics are taken into account by users when choosing a visualization format. (Luo,2019)

For users to benefit from the visualization while making decisions, the visualization format must match the mental model that the task's characteristic requires. Research on the cognitive fit theory has demonstrated that the symbolic (table) information representation is limited when supporting complicated tasks, and decision-makers will change for the perceptual process rather than the symbolic process for more complicated tasks. Users' cognitive styles are important in the visualization format they select. For example, people with visualizer cognitive styles are more likely to select the graphic format. In contrast, verbalizer cognitive style users are more likely to choose the tabular format. (Luo,2019)

Graphic data representation can speed up the recognition of patterns and trends compared to text-based data like tabular data presentations. However, it is less accurate, especially in small datasets, because the variables could be biased or perceived with a higher correlation.
(Lurie & Mason,2007)

As mentioned in the article by Eberhard (2023), despite all the positive effects of visualization on decision-making, some studies show that visualization may not always have positive effects due to misguiding attention and increasing overconfidence. Misguiding attention can result from irrelevant visual elements that distract attention, referring to studies by (Zacks et al., 1998; Fischer, 2000)

showing that adding unnecessary three-dimensional cues to quantitative graphs decreases the accuracy in interpreting the graphs. (Eberhard,2023)

This study mentions that overconfidence in decisions is another probable negative effect of visualization as a cognitive bias. Overconfidence could be defined as increasing confidence in decisions without increasing decision quality to the same degree. The perception that visualization presents more information at once makes decision-makers believe no extra search is needed to look for more information and simplify a problem. However, unless uncertainty is explicitly highlighted, visual aids usually boost decision confidence, especially in financial reporting and management control. Still, it is almost unexplored in the context of strategic decision-making. (Eberhard,2023)

Chapter 3: Methodology

3.1 Research Design

Five in-depth semi-structured interviews with open-ended exploratory research questions were conducted for this research, so the respondents were more flexible in replying to the questions.

The questionnaire has been designed to cover the main research questions, and it has been attempted to cover the gaps found in the research literature in questions.

The questions from all five participants were similar, except for some questions in between the interviews in accordance with the flow of the interviews or to better understand the participant's replies and have more flexibility.

At the end of the questions, there was a last question that asked the interviewees about anything they would like to mention or add to their replies about the main topic.

Each online interview by Google Meet took around 60 minutes. All five participants have experience working with data visualization dashboards and are company managers. Furthermore, as all the interview participants are Iranian, interviews were conducted in Persian.

Choosing the mother tongue for the interview made it possible for the researcher and interviewees to communicate better and not miss any concept point because of language barriers or limitations.

The interviews were conducted between April 7 to April 30. All the interviews were recorded to the participants' satisfaction and then transcribed from Persian to English.

The researcher manually transcribed the interviews for about three weeks from Persian to English. The main reason for transcribing them manually and not by transcription application was that there are few applications for transcription from English to Persian. There were many casual words or sometimes proverbs in the interviewee's sentences, which needed to be edited after transcription by the application, even with the assumption that the transcription application would do all the transcription perfectly.

Regarding familiarity with the Persian language and the context of the interview and business, the researcher decided to transcribe the interviews manually for better quality and avoid spending separate time editing the transcription by the application.

All the recorded interviews and transcriptions are available for reference.

The researcher tried to have a minimal interference extent of researcher interference during the interviews to let the participants express their ideas and experiences freely.

The sampling design of the research was judgment sampling, which, according to Sekaran and Bougie (2016), involves selecting the most appropriate people to achieve the required information.

The sample included five managers with experience working with visualization and dashboards in their tasks and positions. Four participants are working in Iran, and one is working in Belgium, but he also has experience related to this research in Iran and Belgium.

In choosing the interviewees for the sample, some factors have been considered by the researcher:

First, all of them are professionals with the possibility and capability to make decisions in their roles; They are all managers in different fields.

They all have a good insight into data visualization and have had the experience of working with dashboards and visuals to talk about their experience and the perceived contribution.

The sample was selected from professionals in Iran. The main reason was the social and professional network of the researcher, which was richer there and made it possible to arrange the interviews more easily. The participants' general information is as follows:

Participant ID	**Industry**	**Age**	**Education**	**Job Position**	**Gender**	**Experience Working with Dashboards &Visualization**	**Location**
P1	Digital Freight Forwarding	35	Computer Science	Vice President	Male	5 (years)	Iran
P2	Fintech Industry	31	Electronic Eng.	Data solution Manager	Male	4	Iran
P3	Ride-Hailing Services	28	Electronic Eng.& Physics	Engineering Manager	Male	2.5	Iran
P4	Printing	36	Industrial Eng.& Marketing Mgmt.	Insight & Reporting Manager	Male	7	Iran & Belgium
P5	Digital Freight Forwarding	33	MBA	Marketing & Business Development Manager	Male	3	Iran

Table 1: The participants' general information

3.2 Data Analysis

The method used to analyze the interview's contents was thematic analysis with deductive and inductive coding.

Since there was a list of interview questions, the first set of coding was deductive based on themes related to questions. At first, for each interview, the whole interview was analyzed based on the deductive codes (as main codes) related to themes in the questions, and it was applied for all 5 interviews under the same main codes.

Then, the interviews were coded inductively based on the replies (subcodes).

In the next step, each interview was coded inductively if there were codes that added to the insight reached from the content, and these codes were added to the first set of codes derived from the replies.

The coding was done iteratively to merge the common themes and find new themes, if any.

Inductive coding was inevitable, especially for the last part of the interviews that relates to the interviewee's comments about the topic, considering that they talked about their own experiences and concerns outside the research questions.

For coding, NVivo software was applied for faster and more precise analysis.

The process is shown below:

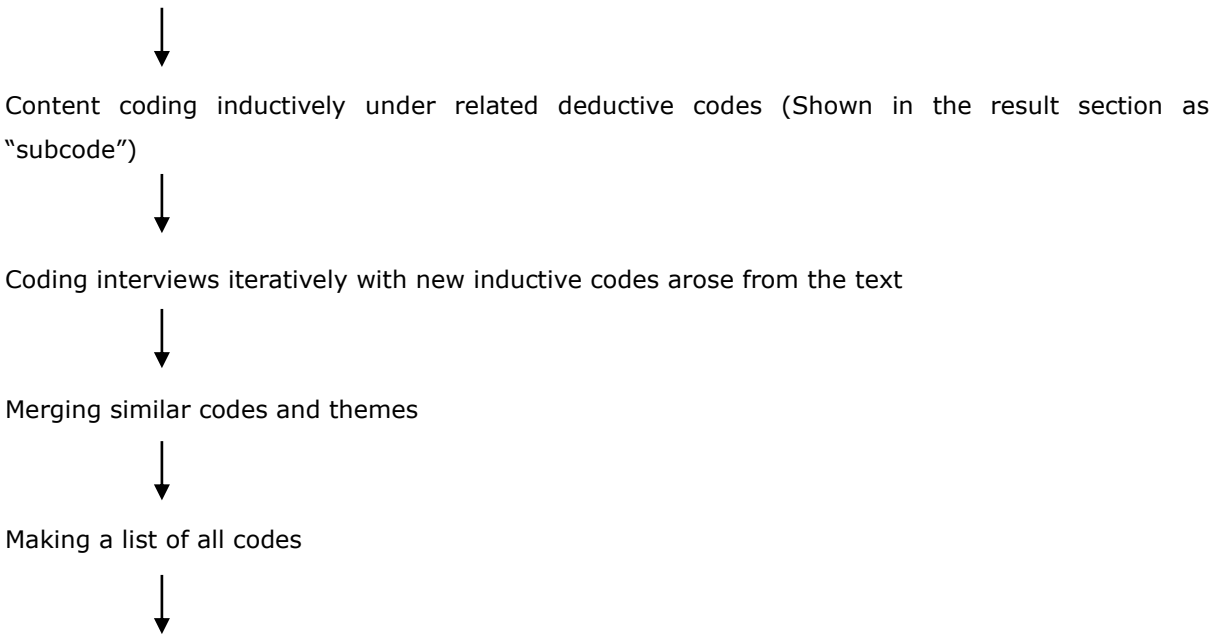

Figure 3: The process for content analysis

Chapter 4: Results

In this section, the result of the analysis of the interviews under the selected codes is written under each research question (regarding the associated codes) as below:

R1 What are the roles of dashboards in a company?

Main Code: Purpose

According to the interviews, dashboards are mainly used for monitoring, decision-making, analysis, planning, and visualization. The examples are shown in the following:

Subcode: Monitoring (of business KPIs and metrics or technical aspects)

P2: "Business dashboards, which we use to ensure our business services are working properly."
P4: "We monitor repetitive parameters, like yesterday's sale or yesterday's delay, So they are a set of KPIs that need to be monitored daily."

Subcode: Decision-making

P2:" There are also dashboards used for decision-making, specifically in product development and business."

P3:" We also have a set of scoring dashboards, and based on which the teams follow standards in software engineering, we score the teams. We also use these dashboards for long-term decisions."

Subcode: Analysis

P1: "The first dashboards we created were for market analysis (by collecting general data)(market analysis)[...],(Also for) making a series of tables for user analysis that are not necessarily visual but are live tables for what happens in the application."(users' performance analysis)

Subcode: Planning

P3: "We use different dashboards: a series for resource planning to define how many resources we are using already, how much space we have, and what the resource trend is to be prepared to purchase hardware for the future years because it takes time." (resource planning dashboards)

P5: "We use dashboards, in many cases, for budgeting."

Subcode: Visualization

P3: "Another set of dashboards is our panels of diagrams, which show the organization and the team architecture, and software architecture, which shows software components."

Main Code: Visualization techniques

Subcodes: Line charts, Bar charts, Pie charts

The most commonly used charts are line charts, bar charts, and, after them, pie charts. Other charts, like Sankey diagrams (as Participant 2 mentioned), are also used for decision-making but are not commonly used.

Line charts and bar charts are mainly used to see the changes over time and the trends, while pie charts and sometimes bar charts are used to observe the portions. Another reply was based on the function, and in this approach, bar charts are for monitoring the business over time, especially for operation functions, and pie charts are used for the time they need to see the reason for causes' breakdown like in IT functions for ticketing.

P1:" We mainly use timelines, both **line charts** and **bar charts**, and the X-axis is time, and there are a few **pie charts**. Most charts are timelines, and they are in two dimensions."

P2:" We use bar charts and line charts to pie diagrams or even Sankey diagrams for flow, but mainly for decision making, more than 75% to 80% of our diagrams are **bar charts, line charts**, and **pie charts**."

P3:" We mainly use time series charts, which indicate changes in some parameters in time; around 70% of our diagrams are **line charts** like that, and around 20% of the rest are **pie charts** showing each business's resource portions."

P5:" We mainly use **line charts** because they show trends more easily."

P4:" It depends. For sure, for monitoring the business over time, you need **bar charts**, and for the time you need to see the reasons or causes' break down or something category, you need a **pie chart**,[...], The charts differ based on functions; for example, **bar charts** are always important for operation functions. For IT functions, a **pie chart** is important."

P5:" We mainly use **line charts** because they show trends more easily, [...], we use **bar charts** sometimes to understand what the change in composition looks like and to see the difference in composition percentages."

Main Code: Metrics

Subcodes: KPIs, Scorecards

Different KPIs and Scorecards are used for monitoring the business over time, and to see the trends. Scorecards are mainly used when the value of some parameters is important and does not change much over time.

P1:" We use mainly **KPIs**, and in many cases, the outputs are displayed as rolling averages; we calculate the rolling average of different **KPIs** and asses them over the time axis, so the X axis is time, and the Y axis shows the rolling average of different **KPIs**."

P2:" **Scorecards** are so helpful. Especially where some trends are not that important, or the liveness of some parameters is important, using scorecards is very assisting, or where in a

comparative space, there are lots of charts and diagrams and items, having a scorecard can bold what we are searching for. Each product has its metrics."

P3:"10% are status panels which only show a number. Those are for values that do not change much during the time and do not have any category. Our panels show numbers relating to scorecards and **KPIs**; we see time series diagrams for **KPIs**, and our **scorecard** dashboards show just figures."

Main Code: Same tasks without the use of dashboards

Without using dashboards, participants explained that they had to work with raw data manually, through Excel sheets and tables, visualize raw data manually, and make estimations based on outdated data, so it might not be precise and efficient.

P2:" I had the same role somewhere, but as far as I did not have any developer or any software like Power BI at the enterprise level, I had to work with raw materials, but I converted these raw data to diagrams and analyzed them by different tools like Excel."

P3:" Before, we tracked these numbers through sheets and tables manually, and this caused us some issues. First, there was a large volume of manual work, and the data was outdated, but it was not that reliable, so we had to make new tables with new data every time we wanted to decide about something based on new data,[..], we did not have data based on time, so we made such mistakes sometimes."

Main Code: Change in the tasks with the use of dashboards

Subcodes: Making new possibilities, Facilitating tasks

The main changes in interviewees' tasks using dashboards can be classified into two categories: Making new possibilities and facilitating tasks in different aspects.
Using dashboards for doing the same tasks, create the following possibilities for the managers:

1. Possibility to work with historical data and to analyze the market for new possibilities (P1)
2. Possibility to work with broader data with more accuracy (P2 and P3)
3. Possibility to have evidence for data (P5)

The dashboards also facilitate some functions for managers:

1. Facilitating to work with big data (P2)
2. Facilitating to make decisions faster (P4)
3. Facilitating for the organization managers to be less dependent on the people's reports(P4)
4. Facilitating access to different data sources (P3)

P1: "Initially, we did visualization for our data, and later, we extended our application to see our possibilities. As our market was new, we could not do benchmarking, so we could not see what

others do in such a market, maybe for one year, we just analyzed the data in the market (which we visualized), and then we thought about product development."
P2: "They facilitate it somehow, plus traditional tools do not work for big data."

P3:" We tried to convert (data tables) to dynamic dashboards that their related data are being read from some resources. We have access to them easily, and following the trends becomes much easier...Dashboards help us in these two ways: they cover broader frequency with more accuracy for historical data and are automated."

P4:" It makes decision-making much faster. It is always available, and you do not need people to prepare and send reports to you because, with just one click, you go to a page and have access to the data you are searching for. The dependency of the organization on people will decrease."

P5:" They helped me a lot. You can see the effects of one parameter in dashboards and then talk about it with the evidence of data; otherwise, you have to talk about it with limited evidence."

Main Code: Method for data visualization on dashboards

Subcodes: Method, software

Participant 1 and Participant 5 use Metabase as a data visualization tool, while Participants 2 and 4 use Power BI, and Participant 3 uses Grafana.

Both participants 1 and 5 work in a company with a data team; data entry is automated (except for exceptions), and different roles have different access to the data tables based on what they need to do to make their visual reports. There are pre-built dashboards for less-skilled people.

Similarly, participant 2 works in a company with automated data gathering and a team responsible for data to make the data ready for use, and then the dashboards are queried. According to him, people who need to make decisions in a company need analysis based on visualized data, so their access is to dashboards, not the data. They also have access management.

About Participant 3, the dashboards for showing system status at the moment are built based on the requirements, and he makes the dashboards needed for decision-making for more long-term decisions like for 3 to 6-month dashboards.

P1:" Most of our dashboards are only on Metabase,[...], Different roles with different access levels can make visual reports from the tables; everyone has access to a specific part of the tables. For people in the company who have less skill to work with these tools, there are pre-built dashboards for their daily tasks."

P2:" We use Power BI. Usually, data gathering is automated, and the databases are queried. A team is responsible(for preparing data) to reach the step in which these data can make dashboards together as a base for data diagrams...People who need decision-making need analyses based on visualized data, and they do not need pure data, so their access is to the dashboards, not the data. We have considered access management somehow."

P3: "With Grafana. We usually announce which data are required, and a set of panels(dashboards) become built, but these panels usually show the system status at the moment, and they show moment troubles in the system. For more long-term dashboards, like 3 to 6-month dashboards or those that show the system's overall status, I have made them till now using data from other sources and made some general overview dashboards."

P4: "With Power BI, I do them myself. For each service with a database, you can connect to the database and run queries, and then you prepare data by merging or joining tables. By connecting it to the dashboard, you make visualizations."

P5:" We have a data part in the company who is responsible for data. We use Metabase, which is connected to a copy of the database. We run queries on it and create charts. Sometimes, we enter data manually for specific cases, such as when entering the campaigns' costs. Sometimes, you do not need to query; the Metabase dashboard does the job."

R2 For what kinds of decisions do managers use dashboards in a company?

Main Code: Kind of managerial decisions by the use of dashboards

Subcodes: Short, mid, long term decisions; Operational, tactical, and strategic decisions

All the managers replied that they use data visualization dashboards for tactical and mid-term decisions.

The application of data visualization dashboards for operational and short-term decisions has the least portion compared to their use for tactical and strategic decisions.

Participants 1, 2, and 5 use dashboards for strategic and long-term decisions, while participants 3 and 4 do not use them because they believe that long-term decisions have more items that should be considered while decision-making, and it is not possible to have all these parameters on a visualization dashboard. In the following there are more details:

Participant 1 uses dashboards for tactical and strategic decisions, but not operational ones, because they are detailed and small, and simple dashboards showing just figures and tables are enough for such decisions without the need to use the data visualization dashboards.

P1: "We use them for both **tactical** and **strategic decisions.**

Operational decisions are very detailed and daily, and we do not use dashboards for operational decisions that much. I emphasize that from dashboards here, I mean data visualization dashboards, but we use them in operational decisions for those that just show a table or figures.

Tactical decisions, like the amount of discount we are going to offer to our different users' packages, are not strategic decisions, but they are more long-term, and we need to see charts and visualizations for our users' purchases in the last month or last three months."

Participant 2 stated that they use data visualization dashboards for long, mid, and short-term decisions in a proportion of 50, 35, and 15 percent, and these portions can be different in different organizations according to the organization's maturity level. Dashboards can be helpful for their decision-making by providing a general overview and showing the hidden layers of data through visualization to observe data behavior and business behavior.

P2:" Mainly **long-term decisions**, with an approximate proportion of 50, 35, and 15 percent respectively for **long, medium, and short-term decisions**."

They use dashboards for operational decisions, to facilitate smooth technical operations (because they need live data in daily frames for some of their systems), and for marketing purposes.

P2: "Dashboards and visualization could be helpful in two dimensions: First, in **technical operation**, the system must operate in technical parts without any problem.

Second, in **operational decision-making** at the marketing level, for example, when there is the necessity for tracking to provide a service to the customer that needs to be tracked and to receive feedback from customers in **the short term**."

Participant 3 noted they use dashboards mainly for mid-term decisions in 2,3 to a maximum of 6 months; In this duration, decision-making based on the data trend makes sense. For decisions longer than this period, many factors can affect decision-making, and strategic decisions need to consider the company's vision and competitors. They use dashboards in operational decision-making to find and fix the problems with the system at the moment or on the same day, just as trouble-shooting when they receive an alert or see an anomaly in one of the diagrams, which is 10% of the cases.

P3:" (For **operational level**) it is mainly for trouble-shooting to find the problems with the system to fix them, so we do not check these dashboards every day except in cases we receive an alert or we detect an anomaly in one of these diagrams.

(For decision-making, we use dashboards) mainly **mid-term** because our view dashboards are not helpful for short-term decisions. The dashboards that show the in-moment system status help fix sudden problems with the system at the same moment or day, which is about 10% of our situation. Still, for mid-term decisions in 2,3 to a maximum of 6 months, we use them mainly because, in this way, decisions based on our data trend make sense. More than 6 months is not that reliable in our case(because many factors can affect more than 6 months of decision-making), and the data trend is unreliable. The long-term decisions are made by considering company visions, and we consider many other factors, such as our competitors."

Similarly, participant 4 noted that they use data visualization dashboards in short and mid-term decisions by providing the related data. They are not helpful for long-term decisions because many items are involved in long-term decisions, but the capacity for data entry in dashboards is limited, and it is not possible to show trends per category per product per customer for decision-making for sales, for example.

P4:" **Short-term** and **mid-term**, but not long-term. For long-term decisions, you need more details, and these details might not fit in the dashboard because there is a limited capacity for data entry in dashboards, and many parameters are involved in long-term decision-making.
(For **operational decisions**) it depends on the function...For operation function, some KPIs like delay in order delivery, volume per produced category, or a machine business are important decisions that must be considered. "
Participant 5 mentioned that they use dashboards for all kinds of decisions, especially for activities that require seeing the trends for making mid and long-term decisions, like budgeting, or activities that require monitoring, especially for short-term decisions.

P5:" All kinds of decisions, especially for budgeting, because you want to predict the future, and you need to see the past trends and, based on that, predict the future budget...Our short-term use of dashboards is mainly for monitoring to ensure nothing has gone wrong. For mid-term and long-term decisions, trends are important, and what causes a change in the trends to check which actions are required."

R3 How do data visualization dashboards contribute to managerial decision-making?

Main Code: Contribution of dashboards and visualization to managerial decision-making

Subcodes: overall contribution, causing overconfidence, facilitating collaborative decision-making, framing effect, facilitating finding the actionable steps, impact on risk-taking

In response to the question of how data visualization dashboards contribute to managerial decision-making, the impact is asked in several aspects, including the description of overall and general contribution from the managers' perspectives and its influence on other aspects related to decision-making, like the effect of dashboards' application in causing overconfidence or uncertainty, facilitating collaborative decision-making and defining actionable steps to meet goals of a decision, framing effect for presenting the information related in decision-making, and the impact on taking risks. In continuation, the results for each of the above factors are mentioned under subcodes separately, and at the end, the overall result will be mentioned.

Subcodes: overall contribution

The reply to the question of how data visualization dashboards contribute to decision-making in their task, participants replied differently; Some with more examples and illustrations, and some of them just described the effect with adjectives, but overall, 4 parameters were affected according to their answers, and those are speed, accuracy, clarity and validity of decisions respectively.

Participant 1 pointed out that by visualization, repetitive patterns and trends become clear, and recognizing differences and challenges becomes possible (which affects clarity).

P1: "If we cannot decide on the plan model, we test it in 4 different cases for 4 different users. We visualize these users' performance over time, and then we can decide or define a KPI like purchase amount. We see if it is ascending or descending, or we can see repetitive patterns and trends and predict based on them. We can see and recognize differences and changes by overlapping charts for different applications, like for user categories or similar time durations."
Participant 2 mentioned that data visualization affects(decision-making) speed, accuracy, and simplicity in his task.

P2:" It affects decision-making procedure speed, accuracy, and simplicity."

Additionally, by making a general overview, they make it possible to observe and check if the strategic goal-setting is proper and if the organization's path to its goals is correct and proper. In this regard, data can make all these observable and trackable.

P2:" Dashboards provide a general overview. Data can be helpful for the organization in two dimensions: first, in primary decision-making for checking the trueness of its path,[...], and in continuation, as the business is advancing, it is trackable to check how the made assumptions have been true and how much it is on the path, and to some extent its goal-setting has been correct...The visualization can make it observable; for example, by visualizing two line charts, some abnormalities can probably be observed, or the data trend on charts can help, whereas with raw data, there is not such a possibility... It is a subset of accuracy somehow, meaning that when you can see abnormality vividly in your chart, it is helpful for a better analysis because just by looking at data, it could not be recognized easily."

Participant 3 noted that data visualization dashboards make decisions more valid and precise, affecting speed as well.

P3: "Using them makes decisions more valid and precise because sometimes we think based on some personal sense, which could not be that precise, and these diagrams can help to make decisions more precise by showing(the data). It affects decision speed for sure."

Participant 4 referred to the improvement in timing for problem-solving due to data monitoring.

P4:" Timing improves for problem-solving even if you cannot solve the problem, I think. Timing is important because you monitor data on dashboards instantly, and you like to act and see the result."

Participant 5 stated they speed up the problem-cause recognition, control, and analysis of the data, and future challenges become clear by monitoring the dashboards, and by running a query, the result can be seen instantly. Further, it provides evidence of influencing parameters for decisions (that is not observable in tables) and clarifies cause and effect relationships.

P5: "For example, when you make a price change, the one who calls customer support is the one who is complaining. If you want to decide based on that, you might think it was wrong to increase

the price, but when you check the dashboards, you see that it is normal, and there has not been a problem."

One of the points in his words was that data visualization dashboards make it possible to find the proper parameters for decision-making because it is easier to test the cause and effect with visualization and drawing charts. Data visualization shows the evidence that is not observable in tables.

P5: "It increases the speed; you quickly determine what is wrong. I can say this use with an example: Last year, I made our budgeting based on the app per freight parameter, but after 4 to 5 months, I understood that one of the reasons that I could not predict the company's income correctly was because of defining an irrelevant parameter for my prediction. From the drawing app per freight chart, I noticed that the factors affecting the chart had nothing to do with us, and many factors are market-related, so we changed the parameter."

Subcodes: Causing overconfidence

About causing overconfidence in decision-making and other probable negative effects of using visualization for managers, this question was asked to participants 2, 3, and 4 in accordance with the flow of the interviews. Participant 4 mentioned he did not have the experience required to reply to this question, but the other two managers noted that visualization can cause overconfidence in some cases, although it is still more helpful for making decisions.

Participant 2 noted the situations where a manager's intuition for a solution or decision becomes confirmed with data and makes this assumption that the manager knew this without any need for data visualization beforehand, but it is still an achievement for the organization to move forward in its maturity path to attract the manager's attention to the data and makes him trust more in the data. Still, a sub-optimal balance point exists for a manager to use data and intuition to decide.

Participant 3 pointed out that, in most cases, data visualization results in more confidence in decision-making, but there are cases where confidence can be decreased. This happens in the steps where the data is not valid and reliable yet, like at the beginning of launching a new product or feature, and at this step, negative feedback or news can decrease confidence in making decisions about that feature, for example. Another noticeable point was that since they do not have any feature on the dashboards to recognize the relationship between charts, having many dashboards misleads them sometimes.

P3:" As we do not have features to recognize the relationship between charts, having many dashboards misleads us sometimes. For example, something increases, which is not a cause, but is the effect of something else, and it is not obvious from data what has caused this, so having many charts and visuals sometimes is misleading."

P2:" It is a double-edged sword. There is a probability that if the data confirms the decision-maker's intuition and ideas, he says that he knew that beforehand, and you (as the visual

provider) attempted a lot to present what he has known from the first. It may not seem like a good situation at first look. Still, it is a kind of success in the organization's maturity path because, in this case, you have successfully attracted the manager's attention to data. When it happens, the decision maker tries to use his intuition less than before because then he assumes that the data is working and reliable. Of course, there are balance sub-optimal points in which the experience of decision-makers and the situations can show where this balance can be achieved by using intuition and data together in decision-making."

P3:" Yes, the confidence in decision-making increased based on data,[...], On the other hand, there are cases in which the confidence of a decision can be decreased. For example, imagine that a new feature is being launched, and maybe if there is not enough data, you may feel that people are using it happily without any problem. Later, based on the data, you recognize that just a few percent of people use that feature, which decreases their confidence in doing that. It can be bad because if you decide soon about that feature and do not give enough time for that, it seems that before that data becomes valid and reaches a step that could be usable statistically, every day by negative data about that feature your confidence for using that feature decreases or even you disregard to use it."

Subcodes: facilitating collaborative decision-making

In reply to the impact of visualization on collaborative decision-making, all participants 1, 2, and 4 noted that it is effective in converging people to a common agreement faster in the company. They explained a similar concept with different words like common agreement(P1), reference point(P2), and common ground (P4). Further, participant 2 referred to the term SSOT and explained that visualization and data on dashboards could be a source of truth that people in the company can refer to for making conversations and decisions in the organization. Participant 4 has the same reasoning but with a different expression.

P1:" It helps people converge on a common agreement faster in the company. It may be hard to discuss, but it is easy to see on visuals and KPIs."

P2:" I name it a "reference point". In data, there are terms like SSOT. When you have a dashboard from data provision to all defined metrics and KPIs agreed upon by people in the organization, and you visualize them, that dashboard and visualization could be a source of truth. Based on that reference point, people in the organization can make dialogues and decisions and collaborate between different entities of the organization so that the dashboards can be the point for decision-making and dialogue in the organization."

P4:" When there is a dashboard, and people see data a lot, they have common ground on a basic level, and this makes them all see one thing, like when people see the clock showing 10 pm, which is a time monitoring, and they know that it is dinner time; The monitoring is the same. People have a common ground, so it makes people come to the same ground to make decisions."

Subcodes: framing effect

In response to whether participants have had any experience with the framing effect because of

data visualization, although none of them were familiar with the concept, after asking about its definition (referred to in the research literature section), they stated that they had experienced it.

All respondents confirmed that the way data is presented and the reference point against which data are compared can represent the same information by visualization in different ways.

Participant 2 named it a kind of storytelling in which the dashboard design or UI can change the story and make it different. He stated for more clarification that if it is needed to make people sensitive to a parameter drop in the company, the negative side of it can be bolded. Similarly, if it is required to bold the positive side of a parameter, the charts can be designed to show that positive side.

Participant 3 makes the decision-making dashboards himself to reduce this bias. He gave an example of defining a KPI on a dashboard for system error rate in their company, which was changed from an error rate KPI presenting a 2% error to a success rate KPI presenting a 98% success rate instead to attract the managers' satisfaction.

He mentioned the importance of different colors for making people sensitive to a parameter like total capacity for a system in their company, which can be interpreted differently if the colors were correctly selected, like orange color for almost full or red color for a very high percentage full, around 95%.

According to his experience, this mainly happens in data presentation from one management layer to another management layer. When one is making dashboards for use himself, this bias is much less because he is setting it for display himself, but for presenting, it is different, and it is one of the reasons that he makes dashboards himself.

Both participants 2 and 3 mention a similar concept.

Participant 4 mentioned the importance of the data validation process in dashboarding because, in his previous experience as a manager in a ride-hailing company, he was resistant to accepting the data easily. In his current role as reporting and insight manager, he also tries to do data validation several times to decrease the bias because people in a company are sensitive about monitoring, which reflects back on dashboards that present the people's performance in front of the eyes.

In reply to the question about framing bias, he mentioned that it matters whom it is presenting for. As for a product manager, for instance, volume is more important than sales, and for a sales manager, sales is more important than volume, so the way of presenting data is different accordingly.

Participant 5 replied to this question similarly; He mentioned he presented the data based on the person he was presenting.

P3:" For the thresholds, previously, we defined 70% full system capacity to be changed from green to yellow, and we defined orange color for 90% full system capacity, and 95% full system capacity, it changes color to red; Before that, when the system was full, even on 74%, the managers thought that everything was okay, and we changed the colors to display the system

status better. There are considerations like that for the dashboard and visualization provided for the first time. I make the dashboards used for decision-making myself as much as possible to decrease this bias."

Subcodes: facilitating finding the actionable steps

The effect of the dashboards and visualization for facilitating actionable steps was clearly explained by Respondent 4, who was previously the manager of a ride-hailing company.

The dashboards helped them monitor the system continuously, as in their business, fast responsiveness to the customer was so important, and they monitored the number of rides as an important KPI through their dashboard, which was updated at a high rate of every 5 minutes. This way, they could check for any sudden change, like a decrease in ride requests or the number of rides accepted by a driver, to define the proper action to solve the problem immediately.

Participant 1 confirmed this, and Participant 2 approved that planning and dashboards can help define the required steps for achieving a goal or defined target. Still, it is not 100% limited to dashboards, and the planner's approach is also important to define actionable steps. Dashboards can be useful after planning to define the necessary steps.

P4:" In my previous company, for our business KPI related to the number of rides was very important. We defined a KPI, and based on that, if the number of our rides descended or the drivers' ride acceptance rate decreased, we were required to take action as it affected our customer satisfaction since we were a ride-hailing company. If we were not fast, responsive enough, and unavailable, the customer would remove the company application. Referring to this, our monitoring dashboards, which became updated every five minutes (and it was a high rate), helped us make decisions daily, instead of a duration like 2 weeks, because we were all on the same ground by this monitoring, and we defined actions for the problem, like this decrease in rides acceptance, by giving more bonus for example. We could see the action's result five hours later."

Subcodes: impact on risk-taking

The interviewees were asked whether the data visualization affected their understanding of risk and risk-taking. The responses were positive except for Participant 4, who had no experience in this regard. However, they did not have a predefined definition of risk, and they replied to this question according to what they knew as risk.

Particularly considering the effect of visualization, participant 2 replied that monitoring parameter trends in charts makes the prediction possible, and this prediction can be helpful in risk management.

Participant 3 also referred to trends and the effect of visualization in monitoring slow, dangerous trends whose change is not noticeable in 2 or 3 months. Still, for a long-term duration like one year or more, by monitoring and recognizing such trends, a list could be made of such trends to find necessary actions related to them before it becomes too late or the system becomes interrupted.

Participant 5 referred to monitoring dashboards also, like monitoring and checking if a business activity like an increase in the price could be the right action, or if it needs to do make-up activities like giving discounts, and it could be for any case, to monitor the change feedback on dashboards and evaluate if a change is working, or better to do another change.

Participant 1 from the same company believes that as any decision-making is a risk, visualization can affect decision-making and risk-taking, too.

P3: "We have had some dangerous slow trends, and these trends increasing or decreasing are not noticeable in a 2 or 3-month duration. These trends are noticed, and in the critical area, maybe it could be too late for any action, and to fix the problem, the system may be interrupted. For these kinds of trends, visualization is so helpful to have long-term data and observe the system trend and data in one year or even more, and based on that, we make some lists of these kind of trends which seem that they are not changing, but they are changing in fact according to visualizations. We can organize risks in this way and define actions for them."

P5:" Yes, for example, we increased the prices recently, and I checked dashboards daily to see if we needed some activity to make up for this price increase if needed, like giving discounts. There were cases in which we made a change, and then we saw that it did not work, and we made another change."

R4 Are there factors influencing managers' use of visualization and dashboards for decision-making?

Main code: influencing factors

Subcodes: experience, related training, visual memory, mathematical ability, dashboard design, company culture, task characteristics

Subcode: experience

All the managers mentioned that their experience working with data visualization has positively affected their decision accuracy.

Participant 1, with 5 years of experience as the vice president of their company, tried to apply the visualization tools in the company from the beginning, pointing out that these tools are much stronger now compared to 10 years ago when they had to develop them themselves which causes spending less time reaching the results.

For Participant 2, the effect of this experience reflected in providing credible data for decision-making more accurately, while in the beginning, he could not trust the data.

Participant 5 mentioned that sometimes he uses his intuition and experience to make a decision, and then he checks it with the data, as data helps to test and check if a decision is practical on a smaller scale.

P3: "It affects the decision to become more precise."

P4:" I learned about it a lot in business. One of the tools that helped us make the right decisions was the dashboard, which is valuable for the organization."

P2: "Yes, from the point where I could not trust the data that I provided, I have reached the point where first I try to provide credible and accurate data and then make my decisions more precise based on that data."

Subcode: related training

Participants 1 and 3 did not have any training. Participant 5 did not have direct training about dashboards and visualization tools, but he passed a dynamic analysis training course to understand trends and charts better. Participants 2 and 4 have passed training related to visualization. Participant 2, as data product manager, noted that both dashboard development and utilizing dashboards have training courses that he participated in.

Participant 4 pointed out the importance of familiarity with data in a dashboard when someone is senior in management, so he noted he needed to have training as a service provider to managers to provide better dashboard services to them.

P2:" I made it separate to dashboard development and utilizing the dashboard, and both have training courses and were very helpful,[...], For decisions like activating or deactivating this button or whether it is on the right placement, you can use visualization tools to make the correct decision and gradually track the correctness of that decision by testing and visualization."

P4:" Yes, because I am a service provider here, and if you want to have seniority in management, you need to know what is happening in data when you see a dashboard. You need to be able to analyze sales dashboards. I do not make dashboards for junior employees; I make them for C levels and managers who need to make decisions with dashboards."

Subcode: visual memory

Participants 1 and 2 had good visual memory, whereas it was normal for participants 3 and 5. Participant 4 noted that he forgets details, but trends are important to him.

Subcode: Mathematical ability

All five participants have had a good understanding and mathematical ability.

Subcode: Dashboard design

All the respondents approved that dashboard design is important for them, including dashboard layout, shape, and color of the charts.

Participant 3 mentioned color is essential, especially for overview dashboards that are full of charts and figures, because it makes the possibility to find and focus on what you want without necessarily having a sense of the statistics; Participant 1 related this importance to his personality, and Participant 5 noted that it increases the speed of reading various charts.

Participant 2 especially emphasized the importance of the frequency of using dashboards in their design, as in continuous and regular use, UI and UX design is more important. He also mentioned that the layout, shape, and color of charts and the liveness of dashboards are important for decision-making.

Participant 4 noted that he is not a good person to ask this question because he designed the dashboards according to what he found important for the final user and service receiver, so he tried to put the most important numbers in front of eyes, evolution, and the details. Also, about the colors, he applies them more nicely, and it conveys the message more easily, like using green and red colors in addition to just one color like blue.

P3: "Yes, it is very important, especially the color. The layout can also be important, but the color is more important because, with just one look, especially in overview dashboards that display many diagrams and figures, you can have a look at colors that you define differently on the dashboard and focus on that, without having the sense to figures."

P4: "For colors, I try to add red (to my design) to make it more beautiful. We work with Power BI, which, by default, has light blue and dark blue, but Tableau gives nicer charts. I try not to use just light and dark blue; to emphasize, I try to put goals. in my tables, I try to use figures that show gross amounts in green and red colors."

Subcode: company culture

The participants believed that even if the organization's culture is not data-driven, data visualization still can be effective in decision-making, except Participant 2, who believes that in this case, people do not tend to use dashboards and visualization and developing dashboards would be without added value, and makes costs for the company.

Participant 4 replied differently, believing that data can change the company culture slowly. He had evidence of his recent work experience as an insight and reporting manager in the printing industry. He started this role for the first time in the company. He said that there was resistance at the beginning to his role because people do not like to be monitored continuously. Still, dashboarding reflects numbers and trends and attracts attention to the numbers and performances. Then it stimulates curiosity in people about the numbers, to search for the reasons behind them, and it can disrupt the organization routine.

When the organization is old-fashioned, people do their routine tasks without daily or monthly monitoring, and the decisions are made yearly. No one focuses on reasons and details, but continuous monitoring based on data makes the errors and deficiencies become exposed, so the organization starts to change little by little in this way.

One of the interesting points he mentioned was the comparison he made between his previous company in the ride-hailing industry as a start-up and his recent company as a factory in the printing industry.

He mentioned that in his previous company, as it was a start-up and it was young, like 3 to 4 years ago, the culture of working with data existed from the beginning, and the infrastructure, like

clouds and databases, was designed properly for that. In such a company, data and dashboarding presentation is easier. In his current company, the business is 50 years old. The database is 30 years old, so it does not have the day standards, and whenever he learns something and wants to test it on the company's databases, it takes a long time for him because our databases are old.

Another difference between these two experiences in previous and current organizations goes back to the fact that in his previous company, as an IT-based start-up, data and IT were the main tools to make income, the solutions were new, and people were creative in the organization; but here, they have a factory in the printing industry, so they are two different businesses.

Participant 3 believed that he works in a not data-driven company, in which, based on the engineer manager of each team, working with data is different from team to team. He assumed that many wrong decisions were made in the company due to this. Still, one factor that makes the company culture is alignment from higher management layers.

He noted that if the managers do their tasks using dashboards and visualization, and the teams are asked to do the assigned tasks this way, this data-driven culture can be spread from higher to lower layers in practice. Contrary to that, If the lower organization layers were not requested to present their tasks through visuals and dashboards, they would not feel the necessity to do so.

Participant 5 believed that because the company he works for spends a lot on dashboards and visualization, data has value in practice in such an organization, and the value that an organization considers for data is reflected in the amount the company spends on it. He argued that convincing a manager with data from his experience is easier, even if a manager does not care about data.

P4: "Data visualization can change the organization and make it data-driven. When I first came to this company, it was not data-driven. When data visualization comes to a company, people become curious about the numbers and figures, that is why a number is increasing, for example, and then you need to know why you are seeing such a big number,[...], Now the fact that there is a mirror in the organization (to reflect the performance in different areas) impacts their performance."

P5: "The value the organization considers for data is related to how much it spends on data. Our organization spends a lot on dashboards and visualization to track our users in different parts. Ultimately, it is easier to convince a manager with data, even though that manager is not data-driven. I have had this experience."

Subcode: task characteristics

In some cases, the managers mentioned that they prefer tables to data visualization and charts for decision-making. When the numbers have more significance compared to trends, changes over time, and composition percentages, using tables might be easier for them.

Participant 1 prefers to use tables when the table is small and needs to focus on numbers. He also mentioned that making a chart and seeing the trend is easier when the table is big.

Participant 2 pointed out the fact that some people's eyes might get used to searching and tracking figures easily, like the people working in the finance and accountancy department, so for these people, it might be preferable to track the trends by eyes in the tables, so it can be a matter of habit and behavior. Still, even these people during time can change to use visualization for their decision-making.
Participant 5, as the marketing manager, uses tables instead of charts sometimes to see the breakdown of the campaign's costs because, in such cases, only numbers matter to him, not the composition percentage, which changes over time.

P2:" In a practical situation, a person whose eyes get used to raw data for decision-making might believe that the visualized data could even decrease his accuracy for decision-making. Still, after some time, even those people prefer using visualization. For example, in my organization, some people whose work is in finance and accountancy can recognize and track figures easily because their eyes get used to figures, and they prefer to find trends by eyes on tables compared to visualized data, so it is somehow a matter of behavior and habit which is hard to change it fast."

Main code: comments about the topic by participants

At the end of questions designed for interviewees, they were asked if there was anything they wanted to add to the discussed questions about the topic.
They talked about different aspects of the topic that were insightful. They are as mentioned below:
There were two considerations about the topic that were mentioned by 2 participants in the interviews:

One is about the importance of a company's life cycle in using data visualization and data analysis tools. Participant 1, the vice president of the freight marketplace active in digital freight forwarding, and Participant 2, the product manager of a stock exchange company active in the fintech industry, talked about this point.

In reply to the question about using data visualization dashboards for short-term, mid-, and long-term decisions, Participant 2 noted that this is dependent on the organization's maturity level and referred to Gartner's analytics maturity model, which says organizations evolve from retrospective and predictive levels to prescriptive levels(according to what he explained) and the usage percentage of data and visuals in decisions depends on this. As far as the organization evolves from a non-data-driven decision-making organization to an organization that cares about data, the data usage can change accordingly.
An organization may have all the necessary structures for using data but does not have enough trust in data yet, or the manager might prefer using his intuition rather than trusting data at a point in an organization's maturity path.

In this regard, Participant 1 mentioned this point, as a comment, that data visualization and data analysis methods differ in a company's life cycle steps, and if something is prescribed to a

company at a specific point of its life cycle, 5 or 10 years later, it could not be prescribed the same again from the perspective of using a tool or data policy. There is an example for more clarification in his quote:

P1: "For example, when a company is small, maybe its policy is that everyone in the company knows everything, and later, while growing up, this policy could be different, or a company uses a tool in some steps internally. Still, later, it is required to use other visualization tools to present the data to its customers, for instance."

Another point that at least two participants noted during interviews was the optimal limit of using data, dashboards, and data-related tools in an organization. Both participants 1 and 5 work in a similar company, which is a freight marketplace, in different roles, as vice president and business development manager, and they both referred to the risk of dependency on data and data tools in the organization in their replies to other questions.

Participant 1 mentioned that "there is a trap that working with data makes people somehow so dependent on the data, but it has a balance limit. Some issues should be solved by considering users and product-based, and not data-based, and some people spend much time on data analysis because they have found the data visualization tool. At the same time, it might not be required, and they should explain their request to the company data team. With the help of visualization tools, the data team can deliver the report and the result.
Still, as they think it is data-driven decisions, they believe it is true, while maybe the problem is something else. For example, you need to do a data analysis to decide which products should be shown on the top list of your products in the online shop for sale or how people should sort them, while its solution is to put a sort option in your online shop, and people would sort themselves."

Participant 5, as the marketing manager, believed that too much dependency on data prevents risk-taking in the company and slows down doing new things because the company gets used to making all the decisions based on data, but sometimes it is needed to apply other strategies rather than data analysis, like experiencing or making decisions based on daily events and exploring what happens next without any data history.

He stated there should be a space in the company for new activities, such as separating routine and new activities, so the idea that not everything should be measured with numbers must be established within the organization.

P5: "We wanted to create a feature for our branding and to make a radio for drivers. We decided in December, and we started it in July. Why? Because we did not have data, we had to do interviews with drivers, then play it for 2 months in a run test for drivers, and we did all these steps to check the idea with data to decide whether to do it or not. This happens a lot, especially for new activities in which we do not have data. "

Furthermore, the organization type can also mentioned as a factor that affects the use of dashboards and visualization in decision-making for managers in an organization. It was mentioned in Participant 2 and Participant 4's discussions.
The comparison between Participant 4 's previous and current company can be insightful about this effect.

There are three main differences between the previous and current companies :

The first difference is that, referring to what he mentioned, the former company was a start-up, young, and data-based from the beginning. In contrast, the latter printing company is old-fashioned and not IT-based. While the first company had the necessary infrastructure with current solutions, in the current company, the infrastructure and company culture are different;
People are more resistant to accepting data, and it takes more time to use data than a start-up company.

Secondly, referring to his statements, in the previous company, data and IT were the main tools to make income, the solutions were new, and people were creative in the organization; it is different in a factory active in the printing business, according to his experience.

The third difference is that according to what he explained, the business type was B2C in the previous company, and it is B2B in the current organization.
He added that the B2B business activities are mainly mid-term, while long-term and short-term acts are related to the operation, not the sales department, where he works as a report and insight manager.
He explained that their dashboards for sales are mainly for mid-term actions because they need to have mid-term solutions for their organization clients as their problems are not immediate.
In summary, as they have a B2B business, they are not at risk of losing a customer immediately, and their dashboards, monitoring, and decision-making are for the mid-term.
On the other hand, in his previous company, they had a B2C business. It was probable in that kind of business to lose a customer immediately, and this caused them to make immediate decisions sometimes.

In support of Participant 4’s remarks, Participant 2 emphasized the importance of the organization type and structure and the types of team configurations for developing dashboards in business process management.

From Participant 2’s point of view as a data product manager, in a practical and realistic overview, some dashboard developers probably make the dashboards for the use of other people, and this is a very serious issue.
In a small start-up with limited data, if someone gets the data to a point where it becomes ready for use, a person who aims to use it can carry out any desired exploitation from that data, visualize it, and decide based on it.

Additionally, he mentioned that when talking about an at-scale company, the data's complexity and nature are so overwhelming that people cannot, even if they want to, put that much energy into data because they do not have the time and technical ability.

He added that a team is needed in such companies to capture people's analytical requirements, visualize them, and develop dashboards as a service. This team implements a Decision Support System in the organization so people can make decisions based on it.

In such a company, as he explained, the results can depend on the organization's selection for this team formation and the positioning of these teams at different levels.
To clarify, if a central team decides which dashboards should be developed for which requirements, this team may turn into a silo and have no connection with different business layers.

He noted that this disconnection between the central data team and dashboard developers could be risky for the organization because, on one side, people need to see visualized data, but on the other side, they have no control over the choice of chart type or the way data is presented in practice. He also emphasized the importance of an organization's maturity in accepting and using dashboards.

P2:" In previous parts, I mentioned that if you develop a dashboard but the organization does not have enough maturity in practice, people in the organization will not use that dashboard. The biggest risk is when you have a central team that develops dashboards, and people in the organization not only do not use those dashboards but are also unaware of those risks. It may seem a trivial and obvious issue, but it is a common mistake in many organizations."

He stated that if an organization's structure is designed based on the data use case and the decision-making requirements based on that data, this risk might be reduced.
He added that in a decentral structure where dashboard developers are in different business layers, they act as data analysis arms for someone who wants to perform business analysis, regardless of whether he knows the different charts or their differences (pointing out the way dashboards are developed and where their data come from).
He might request this arm to show him the trend correctly. In this way, a professional with a business mindset can provide the decision-maker with the proper data visualization, which results in more accurate and faster decision-making.

P2: "Suppose we want to look at the end-to-end business process decision-making process, excluding that dashboard development part. In practice, before and after this process becomes facilitated in this way. In that case, this communication affects the dashboard development process."

In the comments section of the interview, Participant 3 emphasized the significance of AI applications in data visualization and data analysis tools in the future. He added that some dashboard providers like Grafana have gone towards that, but it is at the level of suggesting the name for charts or the name for x and y axes plots.

He suggested that AI could present new visualizations based on the data it provides. For example, the tool may suggest to the user how to visualize three dashboards based on the data presented, or it can offer a set of new data for use on dashboards. He thinks that this place is empty.

Chapter 5: Discussion

This section mentions and discusses the replies to the research questions.

R1 What are the roles of dashboards in a company?

According to the interviews, dashboards are mainly used for monitoring, decision-making, analysis, planning, and visualization.

The most commonly used visualizations and charts in dashboards for participants are line charts, bar charts, and, after them, pie charts. Other charts are also used that participants mentioned, like Sankey diagrams for decision-making.

Line charts and bar charts are mainly used to see the changes over time and the trends, while pie charts and sometimes bar charts are used to observe the portions. Another classification could be based on the charts' function, and in this approach, bar charts are mainly used for monitoring the business over time, especially for operation functions, and pie charts are used for the time it is required to see the reason for causes' breakdown like in IT functions for ticketing.

Additionally, different KPIs and scorecards are used to monitor the business over time and to see trends. Scorecards are used primarily when the value of some parameters is important and does not change much over time.

Without using dashboards, participants explained that they had to work with raw data manually or through Excel sheets and tables or visualize raw data manually and make estimations based on outdated data, so it might not be precise.

The main changes in interviewees' tasks using dashboards can be classified into two categories: making new possibilities and facilitating tasks in different aspects.

Using dashboards creates the following possibilities for managers:

1. Possibility to work with historical data and to analyze the market for new possibilities (P1)

2. Possibility to work with broader data with more accuracy (P2 and P3)

3. Possibility to have evidence for data (P5)

The dashboards also facilitate some functions for managers:

1. Facilitating to work with big data (P2)

2. Facilitating to make decisions faster (P4)

3. Facilitating for the organization managers to be less dependent on the people's reports (P4)

4. Facilitating access to different data sources (P3)

These findings align with the literature. Dashboards can integrate multiple sources and information types, enabling users to interact with the data. Many companies apply dashboards for active monitoring and visual data analysis. Following key performance indicators (KPIs) and metrics in

dashboards help users measure and control their progress in their goal-setting over time. (Khatri& Gupta, 2022).

R2 For what kinds of decisions do managers use dashboards in a company?

All the managers replied that they use data visualization dashboards for tactical and mid-term decisions. The use of data visualization dashboards for operational and short-term decisions is the least compared to their use for tactical and strategic decisions.

To summarize the usage of data visualization dashboards for different kinds of decision-making, it can be concluded that the main use is for tactical and mid-term decisions, and all the participants mentioned that they use dashboards to see the trends.

As many parameters are involved in long-term and strategic decision-making, using dashboards for such decisions could be helpful. Still, other factors and variables might not necessarily be presented on dashboards when managers want to make strategic decisions.

When reviewing the research literature, there was scarce to no research about the impact of dashboards on operational decision-making. (Eberhard, 2023).

As this research shows, one of the reasons could be that dashboards are used less for decision-making at short-term and operational levels. In this case, the usage is mainly for monitoring and fixing sudden problems with the system.

The participants' replies are discussed in more detail accordingly.

Participants 1, 2, and 5 use dashboards for strategic and long-term decisions. In contrast, participants 3 and 4 do not use them because they believe long-term decisions have more items that

Participant 1 uses dashboards for tactical and strategic decisions, but not operational ones, because, as he stated, they are detailed and small, and simple dashboards showing just figures and tables are enough for such decisions without data visualization dashboards.

Participant 2 stated that they use data visualization dashboards for long, mid, and short-term decisions in a proportion of 50, 35, and 15 percent, and these portions could be different in different organizations according to the organization’s maturity level; Dashboards can be useful for their decision-making by providing a general overview and showing the hidden layers of data through visualization to observe data and business behavior.

They use dashboards for operational decisions, a smooth technical operation (because they need live data in daily frames for some of their systems), and marketing purposes.

Participant 3 noted they use dashboards mainly for mid-term decisions in 2,3 to a maximum of 6 months; in this duration, decision-making based on the data trend makes sense. For decisions longer than this period, many factors can affect decision-making, and for strategic decision-making, it is necessary to consider the company's vision and competitors.

They use dashboards in operational decision-making to find and fix the problems with the system at the moment or on the same day, just as trouble-shooting when they receive an alert or see an anomaly in one of the diagrams, which is 10% of the cases.

Similarly, Participant 4 noted that they use data visualization dashboards in short- and mid-term decisions by providing the related data. They are not helpful for long-term decisions because many items are involved in long-term decisions. Still, the capacity for data entry in dashboards is limited, and it is impossible to show trends per category per product per customer for decision-making for sales, for example.

Participant 5 mentioned that they use dashboards for all kinds of decisions, especially for activities that require seeing the trends for making mid and long-term decisions, like budgeting, or activities that require monitoring, especially for short-term decisions.

It might be considered that Participants 1 and 5 work in the same company in different roles as vice president and business development manager, respectively, and Participant 2 works as data solution manager in a financial group of a stock exchange company. When talking about using dashboards for decision-making in the long term or strategic decision-making, both Participants 3 and 4 stated that decision-making in the long term requires more factors. Both participants worked in a ride-hailing company, though Participant 4 had this experience in his previous work experience.

R3 How do data visualization dashboards contribute to managerial decision-making?

The overall contribution of data visualization dashboards to decision-making

The effects of data visualization dashboards on managerial decision-making are mentioned from two perspectives.

The first perspective is an overall evaluation of data visualization dashboards' contribution to the managers' decision-making. The second perspective includes the effects of using data visualization and dashboards on some important factors related to managerial decision-making, like the effects on causing overconfidence, facilitating collaborative decision-making, finding actionable steps to meet goals of a decision, framing effect (for presenting the information related to decision-making), and finally, the impact on taking risks. These effects were selected with an eye on the literature, like the framing effect and causing overconfidence.

The participants answered this question in different ways; Some had more examples and illustrations, and some just described the effect with adjectives, but overall, 4 parameters were affected according to their answers. Those are speed, accuracy, clarity, and validity of decisions.

The above findings align with the research literature. Decision-making could be made faster by analyzing patterns when data visualization is applied. (Islam& Jin, 2019).

Moreover, good data visualization can enhance the users' perception of the problem and their performance. (Eberhard, 2023)

Participant 1 pointed out that data visualization makes repetitive patterns and trends clear, and recognizing differences and challenges becomes possible (which affects clarity).

Participant 2 mentioned that data visualization affects (decision-making) speed, accuracy, and simplicity in his task. Additionally, data visualization dashboards, by providing a general overview, make it possible to observe and check if the strategic goal-setting is proper and if the organization's path to its goals is correct and proper. In this regard, data can make all these observable and trackable.

Participant 3 noted that visualization dashboards make decisions more valid and precise, affecting speed as well.

Participant 4 referred to the improvement in timing for problem-solving due to data monitoring.

Participant 5 stated they speed up the problem-cause recognition, control, and analysis of the data, and future challenges become clear by monitoring the dashboards, and by running a query, the result can be seen instantly. Further, it provides evidence of influencing decision parameters (not observable in tables) and clarifies cause and effect relationships.

One of the points in his words was that data visualization dashboards make it possible to find the proper parameters for decision-making because it is easier to test the cause and effect with visualization and drawing charts. Data visualization shows the evidence that is not observable in tables.

The Contribution of data visualization in creating overconfidence in decision-making

About causing overconfidence in decision-making and other probable negative effects of using data visualization for managers, this question was asked to participants 2, 3, and 4 in accordance with the flow of the interviews.

Participant 4 mentioned he did not have the experience required to reply to this question, but the other two managers noted that data visualization can cause overconfidence in some cases, although it is still more helpful for making decisions;

Participant 2 noted the situations where a manager's intuition for a solution or decision becomes confirmed with data and makes the assumption that the manager knew this without any need for data visualization beforehand. However, it is still an achievement for the organization to move forward in its maturity path to attract the manager's attention to the data and make him trust more in the data. Still, a sub-optimal balance point exists for managers to use data and intuition to decide.

Participant 3 pointed out that, in most cases, data visualization results in more confidence in decision-making, but there are cases where confidence is decreased. This happens in the steps where the data is not valid and reliable yet, like at the beginning of launching a new product or feature. At this step, negative feedback or news can decrease confidence in making decisions about that feature, for example. Another noticeable point was that since they do not have any feature on the dashboards to recognize the relationship between charts, having many dashboards misleads them sometimes.

Referring to the research literature, data visualization may not always have positive effects due to misleading attention and increasing overconfidence. Overconfidence could be defined as increasing confidence in decisions without increasing decision quality to the same degree. This might happen when decision-makers believe that no extra search is needed to look for more information, and they simplify the problem. This effect is unexplored in the context of strategic decision-making (Eberhard,2023)

However, The two replies of the participants above are not enough to make an overall conclusion about the effects of data visualization in creating overconfidence or decreasing confidence in a decision.

The Contribution of data visualization in facilitating collaborative decision-making

In reply to the impact of data visualization dashboards on collaborative decision-making, all participants 1, 2, and 4 noted that it effectively converges people to a common agreement faster in the company. They explained a similar concept with different words like common agreement(P1), reference point(P2), and common ground(P4). Further, participant 2 referred to the term SSOT and noted that visualization and data on dashboards could act as a source of truth that people in the company can refer to for making conversations and decisions in the organization. Participant 4 has the same reasoning but with a different expression.

The effect of data visualization in making framing bias while decision-making

Lurie and Maison(2007) argue that visual representations may irritate biases by altering how decision-makers absorb and process information. The framing effect could result from changing the reference point against which data are compared.(Lurie & Maison, 2007)

In response to whether participants have had any experience with the framing effect because of data visualization, they mentioned that they had experienced it. All respondents referred to the point that the way data is visualized and presented and the reference point that data are compared against can represent the same information in different ways.

Participant 2 named it a kind of storytelling in which the dashboard design or UI can change the story and make it different.

Participant 3, with an example, emphasized that the same data could be presented and visualized differently, considering its purpose.

In this regard, Participant 4 mentioned that it matters to whom the data is presented, so the way of presenting data could be different considering the audience.

The Contribution of data visualization in understanding risks while decision-making

The interviewees were asked whether the data visualization affected their understanding of risk and risk-taking.

Except for participant 4, who did not have any experience in this regard, the responses were positive, though there was not a predefined definition of risk for them, and they replied to this question according to what they knew as risk.

In total, they emphasized the effect of monitoring the trends for predicting probable outcomes and doing the necessary activities to prevent risks. This is mentioned particularly in Participants 2 and 3's replies.
There is not much in the research literature about the effect of data visualization on risk-taking and collaborative decision-making.

R4 Are there factors influencing managers' use of visualization and dashboards for decision-making?

Experience

All the participants have several years of experience working with data visualization and dashboards, from at least 2.5 years (P3) to a maximum of five years (P1).

The five managers mentioned that their experience with data visualization has positively affected their decision-making, from speeding up finding results and more precise decisions (P2, P3, P4) to finding a possibility to check and test the results of decision-making on a smaller scale (P5).

Related training
Only participants 2 and 4 had related training among managers.

Visual memory
Participants 1 and 2 had good visual memory, whereas it was normal for participants 3 and 5. Participant 4 noted that he forgets details, but for him, trends are important.

Mathematical ability

All five participants have had a good understanding and mathematical ability.

Dashboard design

The respondents approved that dashboard design is important for them, including dashboard layout, shape, and color of the charts. This aligns with the literature. In their article, Zingde and Shroff (2020) emphasize the importance of using the proper visuals and layout in dashboard design, like locating the key information design at the top of the dashboard screen and the related details at the bottom for more efficient dashboard design.(Zingde & Shroff, 2020)

Company culture

The participants believed that even if the organization's culture is not data-driven, data visualization still can be effective in decision-making, except Participant 2, who believed that in this case, people do not tend to use dashboards and visualization and developing dashboards would be without added value, and makes costs for the company.

In summary, Participant 3 believed that the effect of using data visualization and dashboards can depend on the managers' attitude. If they try to use it and request other staff to use it, this culture could spread in the organization. He believed that using data in the company could decrease wrong decisions.

Participant 4 pointed out the importance of the organization's type in working with data and visualization tools. However, he mentioned that even if people in the company resist accepting data, data could still be effective and can change the not-data-driven culture of the company during the time.

Participant 5 believed that when an organization spends money applying data tools like dashboards and visualization tools, such an organization values data.

In continuing, the participants' views regarding whether data visualization can still be helpful for decision-making in a non-data-driven company culture are written.

Participant 4, contrary to Participant 2, believed that data can change the company culture slowly. He had evidence of his recent work experience as an insight and reporting manager in the printing industry. He started this role for the first time in the company. He said there was resistance initially to his role because people do not like to be monitored continuously. Still, dashboarding reflects numbers and trends and attracts attention to the numbers and performances. Then, it stimulates people's curiosity about the numbers, and they search for the reasons behind them, and it can disrupt the organization's routine.

As he noted, when the organization is old-fashioned, people do their routine tasks without daily or monthly monitoring, and the decisions are made yearly. No one focuses on reasons and details, but continuous monitoring based on data makes the errors and deficiencies become exposed, so the organization starts to change little by little in this way.

One of the interesting points he mentioned was the comparison he made between his previous company in the ride-hailing industry as a start-up and his recent company in the printing industry.

He mentioned that in his previous company, as it was a start-up and it was young, like 3 to 4 years ago, the culture of working with data existed from the beginning. The infrastructure, like clouds and databases, was designed properly for this purpose. In such a company, data and dashboarding presentation is more effortless. In his current company, the business is 50 years old. The database is 30 years old. Hence, it does not have standards, and whenever he learned something and wanted to test it on the company's databases, it took a long time for him because our databases were old.

As he noted, another difference between these two experiences in previous and current organizations goes back to the fact that in his previous company, as an IT-based start-up, data and IT were the main tools to make revenue; the solutions were new, and people were creative in the organization; but here, the company is a factory active in the printing industry, so they are two different businesses with different structures for making revenue.

Participant 3 believed that he works in a not data-driven company in which, based on the engineering manager of each team, working with data differs from team to team. He assumed that many wrong decisions were made in the company due to this, but one factor that makes the company culture is alignment from higher management layers. He reasoned that if the managers do their tasks using dashboards and visualization, and the teams are asked to do the assigned tasks this way, this data-driven culture can be spread from higher to lower layers in practice. They will not do so if the lower organization layers are not requested to present their functions through visualization and dashboards.

In contrast to Participant 3, participant 5 believed that because the company he works for spends on dashboards and visualization tools, data has value in practice in such an organization. He believed that the value an organization considers for data is reflected in the company's spending on it. He argued that even if a manager does not care about data, convincing a manager with data is easier from his experience.

The effect of organization type and maturity level

In the interview, Participants 1 and 2 mentioned the significance of the organization's life cycle and maturity level in applying data and visualization tools in decision-making.

Participant 2 also emphasized the importance of organizational structure in using the ability of dashboard developers to use data and visualization in the organization effectively.
From Participant 2's point of view as a data product manager, in a practical and realistic overview, some dashboard developers probably make the dashboards for other people's use. This could be a very serious issue. He reasoned that in a small start-up company with limited data, if someone gets the data to a point where it becomes ready for use, a person who aims to use it can carry out any desired exploitation from that data, visualize it, and decide based on it.

Additionally, he mentioned that when talking about an at-scale company, the data's complexity and nature are so overwhelming that people cannot, even if they want to, put that much energy into data because they do not have the time and technical ability.

In such a company, a team is needed to capture people's analytical requirements, visualize them, and develop dashboards as a service. This team implements a decision support system in the organization so people can make decisions based on it. In this case, results can depend on the organization's selection for this team formation and the positioning of these teams at different levels. To clarify, if a central team decides which dashboards should be developed for which requirements, this team may turn into a silo and have no connection with different business layers.

This disconnect between the central data team and dashboard developers could be risky for the organization because, on one side, people need to see visualized data. Still, on the other side, they have no control over the choice of chart type or the way data is presented in practice. He emphasized the importance of an organization's maturity in accepting and using dashboards to decrease the mentioned risk. He stated that if an organization's structure is designed based on the data use case and the decision-making requirements based on that data, this risk might be reduced.

He added that in a decentral structure where dashboard developers are in different layers of the business, they act as a data analysis arm for someone who wants to perform business analysis, regardless of whether he knows the different charts or their differences (the way dashboards are developed and from where their data come from). He might request this arm to show him the trend properly. In this way, a professional with a business mindset can provide the decision-maker with the proper data visualization, which results in more accurate and faster decision-making.

The comparison between Participant 4's previous company, an IT-based start-up ride-hailing company, and his current company, a manufacturing firm in the printing business, is also insightful about this effect of organization type on the use of visualization dashboards for decision-making.

Referring to what Participant 4 explained about this difference, there are three main differences between the previous and current companies.

The first difference is that the former business was a start-up, young, and data-based from the beginning, whereas the latter business in printing is old-fashioned and not an IT-based business. The first business had the necessary infrastructure with current solutions, but in the current business, the infrastructures and company culture are different; people have more resistance to accepting data, and it takes more time to use data compared to the start-up company.

Secondly, in his previous company, as data and IT were the main tools to make revenue, the solutions were new, and people were creative in the organization; it is different in a factory active in the printing business.

The third difference is that the business type was B2C in the previous company and B2B in the current organization. The B2B business activities are mainly mid-term and long-term, and short-term acts are related to the operation, not the sales department, where he works as a report and insight manager. Their dashboards for sales are mainly for mid-term actions because they need mid-term solutions for their organization clients as their problems are not immediate.

In summary, as they have a B2B business, they are not at risk of losing a customer immediately, and their dashboards, monitoring, and decision-making are for the mid-term.
On the other hand, in his previous company they had a B2C business. It was probable in that kind of business to lose a customer immediately, and this caused them to make immediate decisions sometimes.

The effect of task characteristic

Data visualization is not always preferred over tables. In some situations, the managers mentioned that they prefer to use tables instead of data visualization and charts for decision-making. When the numbers have more significance compared to trends, changes over time, and composition percentages, using tables might be easier for them.

Participant 1 prefers to use tables when the table is small and needs to focus on numbers. He also mentioned that making a chart and seeing the trend is easier when the table is big.

Participant 2 pointed out the fact that some people's eyes might get used to searching and tracking figures easily, like the people working in the finance and accountancy department, so for these people, it might be preferable to track the trends by eyes in the tables, so it can be a matter of habit and behavior. Still, even these people during time can change to use visualization for their decision-making.

Participant 5, as the marketing manager, sometimes uses tables instead of charts to see the breakdown of the campaign's costs because, in such cases, only numbers matter to him, not the composition percentage, which changes over time.

These findings align with the literature in this regard. Referring to Eberhard (2023), charts and graphs do not necessarily work better than tables, as they work efficiently when they present the required data for the task and do not create more complexity. (Eberhard,2023)

Moreover, Luo (2019) noted that when choosing a visualization format, users prefer tables for easier tasks and graphic visualization format for harder tasks. (Luo, 2019)

The response to the research question about whether some factors influence managers' use of data visualization for decision-making is that some factors can influence this effect.

One of them is the experience of the decision-maker, as confirmed by the interviewees. The participants approved that they could make more precise decisions due to their increased experience working with data visualization tools. This aligns with the findings in the research literature.

Lurie and Mason(2007) noted that the decision-maker characteristics, including the decision-maker's experience and involvement with visualization tools, affect the use of data visualization in decision-making. The user experience refers to the user's understanding of important factors and the ability to alter the visual representation. (Lurie & Mason, 2007).

Considering what the managers discussed during the interviews, other factors modifying the effect of visualization dashboards on managerial decision-making could be dashboard design, company culture for using the data, organization maturity level, and the company type.

Chapter 6: Conclusion

6.1 Conclusion

This study shows that dashboards are mainly used for monitoring, decision-making, analysis, planning, and visualization. The main changes in an organization by using dashboards are creating new possibilities and facilitating different aspects of tasks. The most common charts used for this purpose are line, bar, and pie charts. Additionally, different KPIs and scorecards are used to monitor the business over time and to see trends.

The managers' main and most common use of data visualization dashboards is for tactical and mid-term decisions to monitor trends. The use of data visualization dashboards for operational and short-term decisions is the least compared to their use for tactical and strategic decisions, and it is mainly for fixing sudden problems with the system.

Using dashboards can be helpful for strategic and long-term decisions, as many parameters are involved. However, all the involved parameters in long-term decision-making might not be presentable and monitorable in dashboards during strategic decision-making by managers.

Visualization dashboards enhance decisions speed, accuracy, clarity, and validity. Additionally, regarding their effect on other aspects of decision-making, the research shows that collaborative decision-making is facilitated in this way. Moreover, using dashboards positively affects risk understanding by showing the trends and increasing the predictability of probable outcomes.
The study shows that the way data is visualized and presented and the reference point that data are compared against can represent the same information differently. This study did not have any findings regarding the effect of data visualization dashboards in creating overconfidence.

In addition, the research indicates that experience working with data visualization and dashboards, dashboard design, task characteristics, organization maturity level, and organization type can influence using data and visualization dashboards for managerial decision-making.

6.2 Theoretical Contribution

This study searches the effects and contributions of using data visualization dashboards in the managers' operational, tactical, and strategic decision-making. In this regard, the study explores the applications of data visualization and dashboards in decision-making in different companies and the factors influencing this effect in focused research on the topic. This study explains the dashboards' function in the business domain at the strategic, tactical, and functional levels.

6.3 Managerial Contribution

This study contributes to the managers who tend to improve their decisions by using decision support tools like data visualization dashboards and the business owners who would like to apply newer technologies like business intelligence tools and techniques to make changes in their business. There are insights about the practical experiences of professional decision-makers as managers in different companies who convey their experience and knowledge during this study to find a reply to the previously mentioned questions. It provides insights into the company's better use of data visualization dashboards.

6.4 Limitations

It is worth mentioning that there were limitations to this study. The research literature search was mainly done through Google Scholar for articles between 2017 and 2024, including these years as well.

The keywords were those directly related to the topic, such as Data Visualization, Dashboard, Decision-making, Management, Analytics, Business Intelligence, interactive visualization, and visual analytics.

Another limitation is related to the number of managers interviewed for this research. Considering the time limitation for conducting this study, the interview participants were limited to five managers. A bigger and more diverse sample could increase its generalizability. Also, the results might differ if the sampling design becomes arranged differently or the questions are designed differently. All the managers in this study reside in Iran except for Participant 4, who has experience working in Iran and Belgium and currently resides in Belgium.

The interviews were transcribed from Persian to English by the researcher. Although there were few applications for this purpose, they were not designed to transcribe all the details and points from the main language to English, nor were they the proverbs and expressions used when answering the questions by the participants.

In addition, the apps were not tailored to the context of business and management. As a result, the interviews were transcribed manually so the reader could get the most out of the language. It is impossible to translate from one language to another 100% perfectly. However, the aim has been to convey the content honestly, with minimal errors.

Another potential limitation could be that the questions asked from the participants were broader than the research questions, and they included some questions about participants' experiences and limitations of using the dashboards and visualization in their role for decision-making. However, while writing the results, this part became excluded from the findings because it was unrelated to the research.

Furthermore, since it was an explorative study with semi-structured interviews, the interviews were, to some extent, adjusted following the participant flow. This caused the emergence of terms and contents that have the potential to be defined more precisely. these words were used in the research in the same way the participants mentioned them. Considering the interview time limit and research topic constraint, this study does not focus on their academic and precise definitions. The concepts like silo, SSOT, organization maturity level, and organization life cycle can be mentioned as some of these terms.

6.5 Suggestions for future research

An opportunity for future research could be the role of artificial intelligence (AI) in using visualization dashboards for business decision-making. The significance of AI applications in data visualization and data analysis tools in the future was recommended by one of the participants in the interview(P3) as an engineering manager.

He suggested that AI could present new visualizations based on the data given to it. For example, the tool may indicate to the user how to visualize three dashboards based on the data presented, or it can offer a set of new data for use on dashboards. The effect of the organization's type and the business type on the application of data tools and techniques could be another research opportunity.

Furthermore, the effects of an organization's life cycle and culture on applying dashboards, visualization tools, and techniques are worth studying and investigating in future research. Lastly, an important area for future investigation is to study the significance of business process management in using data analysis and visualization tools and techniques, and the application of decision support tools such as dashboards in the organization.

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Appendix

Interview Questions

Hello, I invite you to take part in this interview as a part of the fulfillment of my research dissertation in the Master of Business Process Management at Hasselt University. The interview will be about your experiences using visualization dashboards in your work, especially when making decisions. I expect the interview will last about one hour. Since I would like to record the interview, please let me know if you agree to record the online interview. This interview will be anonymous. You can ask for the next question when the conversation becomes uncomfortable. Considering the limited time, it might happen to interrupt a non-related or long explanation to stay aligned with the research questions.

General Questions

In which industry are you active?

What do you generally do in your business?

How old are you, and what is your field of study?

What is your job position/ role in the organization? How long have you been in your current role?

R.1: What are the roles of dashboards in a company?

For which purposes do you use dashboards in your role/business?(like monitoring, planning, making decisions, etc…)

Which visualization techniques, charts, and metrics are mainly used in your applied dashboards?

Have you ever had the same tasks without using dashboards and visualization? And if so, how did the visualization/dashboards change your tasks and decision-making?
How do dashboards give added value to your previous insights in your role?

R.2: For what kinds of decisions do managers use dashboards in a company?

Do you have regular and specific situations in which you should make decisions in your job? Do you get help from dashboards to make these decisions?

In which kind of decisions do you use dashboards? Short-term, mid-term, or long-term?
Do you use dashboards for your decision-making at the operational level? How?

Do you use it in tactical decisions or for making strategic decisions? How?

R.3: How do visualization dashboards contribute to managerial decision-making?

How do data visualization in dashboards contribute to decision-making in your task?

(If the interviewee asks for more clarification, these questions can be asked:

- Have they helped you understand a problem better?
- Do they help you improve your decision accuracy?
- Do they help you make a decision faster? In which way? (for example, are there indicators or contrast factors like colors that highlight your intended parts or deviations)?
- Do they help you decide with more confidence? …What else?)

Do you remember any time that data visualization has helped you in risk situations to understand the risk better? Or will it affect you for less/more risk-taking?

What about framing bias?

If the company culture is not data-driven, would it still be helpful to use dashboards for decision-making?

Does dashboards/data visualization enable you to have a collaborative way of decision-making with your colleagues?

Has it caused overconfidence in your decisions? Or caused more uncertainty about making a decision?

Do the dashboards help you to define actionable steps to meet the goals of decisions?

R.4: Are there factors influencing managers' use of visualization and dashboards for decision-making?

How long have you had experience working with dashboards and data visualization? Do you feel that your experience has affected your decision accuracy based on data visualization?

Are your previous insights and experiences in the field helpful when working with dashboards?
Is there enough familiarity with the technology used to present data visualization?

Is there any training related to working with dashboards and data visualizations? Or is there any support from the visual presenter if you face difficulty using them?

Do the colors and format of the visuals affect making better use of them in your point of view?

Do you find it easy or challenging to remember visual details or images in your mind?

How has your mathematics been?

(Extra: What experiences and challenges are there regarding visualization and dashboards?

Are the data provided in dashboards accurate and optimal? Is it real-time? Is it integrated data?

Which features do you have in your organizational dashboards? Which features and capabilities are more helpful for your business goals/ applications?

Which features do you need to add to these features for better performance? (like drill down or interactive features)?

Do you have any feature on dashboards that can predict trends?
Have you had any experience in which visualization has any negative effect, like misleading your attention or making you make a wrong decision with more confidence? What was the reason?

Have you ever had any experience of framing bias as a result of the way data is presented to you in visuals?

Does the data visualization presenter add any value to the presented data for you? (Present data in a way that is in the direction of your task demands)?

(Does the way information is presented aligns with your problem-solving approach?)

(what are the benefits and limitations of using dashboards and visualization in your business?))

Is there anything you want to add to the above or mention from your experience concerning the topics we have discussed?

Wrap up

We arrived at the end of the interview. It was so insightful. Thank you for your helpful and valuable participation.