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Faculty of Business Economics

Master of Management

Master's thesis

Business Process Insights Through Data Visualizations

BINITA NEPAL

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

SUPERVISOR :

Prof. dr. Benoit DEPAIRE

MENTOR :

Mevrouw Leen JOOKEN

2023
2024

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Preface

This research study is part of the thesis requirement for a master's degree in Management specializing in Business Process Management. It concludes the journey to earn a master's degree.

This journey has been fascinating, characterized by personal development and the pursuit of excellence. Thinking back on the journey that brought me to this point, I am very grateful for the guidance and support that have helped shape my work.

I appreciate my supervisor, Prof. Dr. Benoit Depaire, and my mentor, Miss Leen Jooken, whose guidance has been a fundamental aspect of this journey. The unwavering support, insightful feedback, and encouragement have been invaluable. Their expertise and constructive feedback also motivated me to pursue perfection. I am grateful for the invaluable efforts which have played a crucial role in achieving this significant milestone.

On a personal note, I would like to express my gratitude to my husband, Paribartan Poudel, for his continuous support and encouragement in finishing this journey.

Binita Nepal

August, 2024

Summary

Research Purpose

In the rapidly evolving and competitive banking sector, data-driven decision-making is critical for operational efficiency, risk management, and customer satisfaction. However, the sheer volume and complexity of data generated by digitalized banking processes make it challenging to extract actionable insights. There is a lack of specific knowledge regarding the most suitable data visualization techniques for presenting banking insights, particularly in crucial processes such as loan approval and customer onboarding. This gap limits the ability of bank managers to make informed, data-driven decisions that could enhance process efficiency and effectiveness.

Due to digitalization and the increasing adoption of IT systems, the banking sector produces vast amounts of data. This data holds immense potential for improving decision-making and operational efficiency, yet its value can only be fully realized when effectively visualized to provide clear and actionable insights. Different data visualization techniques offer varying strengths and limitations, but without proper guidance, banking managers may struggle to select the appropriate techniques to achieve specific insights from critical business processes.

The research questions guiding this study are:

1. What insights do managers seek from banking processes?
2. Which visualization techniques are they currently using to extract these insights from the data?
3. How can process data be most effectively visualized to achieve specific process insights?

This study aims to bridge the knowledge gap by evaluating current data visualization techniques used by bank managers in the context of loan approval and customer onboarding processes. Through a comprehensive academic literature, this research identifies the most appropriate visualization techniques for achieving specific insights. The ultimate goal is to provide practical recommendations that guide bank managers in selecting and using data visualization techniques that best suit their needs, enhancing their ability to make data-driven decisions.

Research Methodology

The study used qualitative research methodology to explore insights managers seek from two banking processes—customer onboarding and loan approval—and their data visualization techniques. Purposive sampling was used to identify five bank managers directly participating in these processes. Data was collected using semi-structured interviews. The data was analyzed using narrative analysis and in vivo coding to identify key insights and visualization techniques. Finally, the study evaluated the insights managers seek against various visualization techniques from literature results to propose a best-suited method. The suitability of different visualization techniques was assessed based on the data type and the purpose of visualization. The goal was to recommend the most appropriate techniques for extracting specific insights into banking processes.

Interview Results

Based on the results of the interview, it was found that from the loan approval process, managers seek insights such as total time taken to process loan applications, loan application volume and the approval rate, cost per loan application processed, demand trends for loans, and the composition of loan portfolio composition and their performance metrics. These insights are helpful for bank managers in optimizing and ensuring the efficiency of the loan approval process, identify bottlenecks, allocate resources effectively, detect fraud, evaluate cost-effectiveness, understand and predict market demand patterns, and manage risk by reducing or adjusting potential risk.

Similarly, in the customer onboarding process, managers seek insights such as customer onboarding time, preferred channels by customers to onboard, major drop-off points and their rates, customer satisfaction level, and the error types and frequency encountered during the onboarding process. These insights are essential for bank managers to enhance the customer onboarding process. By closely monitoring these key metrics, managers can streamline operations, improve customer satisfaction, and ensure efficient and pleasant onboarding experiences.

Managers use a range of techniques, such as bar charts, line charts, tables, lists, and pie charts, to obtain insights from loan approval and customer onboarding processes. The findings indicate that each manager seeks different insights from their managing process and uses general visualization techniques to get these insights.

Evaluation Results

The research evaluated the suitability of data visualization techniques based on the visualization techniques obtained from the literature. It recommended the most effective techniques for extracting specific insight sought by managers. The evaluation of different techniques was based on the data type and the purpose of visualization. The study aims to guide banking sector managers in choosing and utilizing the right visualization technique to achieve specific insights that enhance decision-making and operational efficiency.

The evaluation results suggested that alternative visualization techniques, such as grouped bar charts, dual-axes charts, stacked bar charts, line charts, bubble charts, heatmaps, and funnel charts, provide more detail and a clear view and offer significant advantages over the ones used by managers.

It was found that grouped bar charts are appropriate for detailed comparisons across multiple categories and sub-categories, for instance, comparing the turnaround time for processing loan applications by loan type and the time to onboard customers by customer type. It is also effective in comparing the satisfaction level of customers across different onboarding stages. In addition, the grouped bar chart effectively identifies and compares several types of errors encountered in the onboarding stages and the frequency of errors. When there are many error types, heat maps effectively provide a quick overview of stages with the highest error type.

A dual-axes chart provides insights into relationships between two different metrics on the same graph. For instance, it can effectively compare and identify loan application volume trends and approval rate trends.

Similarly, a stacked bar chart helps understand the breakdown of categories along with total value. For instance, it can be used to compare the total cost incurred while processing loan applications by type and cost breakdown by application status (approved and rejected).

The line chart is effective in comparing and identifying trends. For instance, the trend of loan demand for different loan types can be visualized using line charts.

A bubble chart can present three dimensions of data, providing a comprehensive view of the loan portfolio composition and default rate based on loan types.

A funnel chart visualizes a process's stages and helps identify the stage that needs improvement. For instance, it can visualize a complete view of the onboarding process stages and highlight the customer drop-off points and rates.

Overall, these visualization techniques make interpreting data accurately and making informed decisions easier, providing a clearer picture than simpler methods. The study also aligns with the previous studies on data visualization, emphasizing the significance of choosing visualization techniques according to the data type and purpose of visualization. The evaluation results also validate the utility of the recommended techniques in gaining specific insights.

Practical Implications and Research Limitations

Managers can use these findings to enhance their decision-making process, particularly in the banking sector. Most importantly, they can use the overview of recommended visualization techniques to get more accurate insights effectively. They can use the presented overview as guidance to select an appropriate technique based on their purpose. The implications of these findings are significant for bank managers and decision-makers managing the loan approval process and customer onboarding process. By utilizing the most effective visualization techniques, managers can enhance their ability to interpret and understand data and make informed decisions; they can get more precise insights into critical performance metrics, identify trends, assess risks, and detect inefficiencies in processes, enabling more informed decision-making. Effective visualizations can enhance understanding of loan defaults, process bottlenecks, customer pain points, and fraud detection, leading to better resource allocation and improved customer experiences.

However, despite its importance, the study has limitations, including a narrow focus on two specific banking processes that may limit applicability to other sectors. The study's reliance on subjective assessments of data collected from a limited sample size and evaluation of visualization techniques using subjective assessments may introduce bias. Additionally, there is not a single "best" visualization, as it is heavily dependent on the purpose and available data types, and this research serves more as a guidance.

Future research could address these issues by expanding the range of banking processes studied, incorporating larger and more diverse samples, and using objective assessments to validate visualization techniques. Additionally, exploring how user expertise affects the effectiveness of visualizations and testing these techniques across different domains could provide further insights.

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Business Process Insights Through Data Visualizations

Binita Nepal

Abstract. The banking sector has experienced a substantial increase in the volume of data generated from financial transactions and customer interactions as a result of the digital transformation. This data is an asset for the banking sector for acquiring insights that can be used to make strategic decisions and operational enhancements. However, the challenge lies in effectively visualizing this data to extract actionable insights, especially in critical processes such as loan approval and customer onboarding. To address this problem, this study evaluated various data visualization techniques to determine their suitability for presenting insights related to loan approval and customer onboarding processes. For this, interviews were conducted with bank managers to identify the specific insights they sought and the techniques they used to get these insights. Then, the suitability of various data visualization techniques was evaluated based on the literature, and the most appropriate technique to achieve these insights was recommended. The study found that managers used effective visualization techniques such as bar charts, line charts, pie charts, and tables. Furthermore, this study contributes an overview of the insights managers seek in the loan approval and onboarding processes, where grouped charts, stacked charts, line charts, pie charts, bubble charts, and funnel charts are the most suitable visualization techniques for these insights. Managers can use this overview as a guidance to select appropriate techniques to achieve specific insight. Furthermore, this study emphasizes the significance of appropriate data visualization techniques in the banking sector in obtaining precise and actionable insights. Banks can enhance customer experience, optimize operational efficiency, and improve decision-making using the most effective visualization techniques.

Keywords: Business Process Management, Data Visualization, Data Visualization Techniques, Insights, Banking Processes

1 Introduction

To thrive in today's competitive business world, one must have a deep understanding of various business processes. In any organization, several procedures, also called processes, make it possible for the business to carry out its regular operations. A group of logically connected actions taken to accomplish a specific business objective is known as a "business process" [1]. Business processes are fundamental to all companies[2]. Therefore, a detailed understanding of their business processes is crucial for organizations to effectively manage the series of actions, identify and rectify deviations, and ensure that tasks are executed correctly to achieve specific business objectives [3].

Organizations put much effort into studying and improving their business processes to boost operational efficiency. However, a company's efficiency and capacity to compete are heavily influenced by how well it can get valuable insights from its business processes [4]. The significance of using data to get insights into different business processes is becoming more evident in today's corporate environment. Organizations can uncover hidden inefficiencies by leveraging data analytics tools and techniques, predict future performance, and proactively address potential issues before they escalate[5]. Data-driven insights enable businesses to better comprehend their operations, spot trends and patterns, and make educated choices that promote continuous progress[6].

Further, insights have been defined in numerous ways by various scholars. For instance, [7] described insights as “complex, deep, qualitative, unexpected, and relevant revelations.” Additionally, "insights" in the field of visualization

are usually thought of as discrete pieces of “information” or “knowledge”[8], [9], [10] defined “insights” as observations, hypotheses, and generalizations directly retrieved from the data. On the contrary, trends and comparisons are considered insights [11].

As the size of businesses continues to rise, companies are producing large amounts of data, making it challenging to efficiently extract meaningful insights from the massive amount of data and gain a clear and comprehensive understanding of data [12]. Nevertheless, data visualization tools and techniques offer a powerful solution to businesses, as the primary objective of data visualization is to reduce the complexity of data and improve problem-solving abilities by presenting data in a visual format [13].

There is a growing recognition that visualizing process data can provide valuable insights and aid in identifying areas for improvement [14], by presenting complex data in an easy-to-understand form [15]. Data visualization is a powerful tool for getting actionable insights, as it helps to understand data better and facilitates the identification of patterns, hidden stories, trends, and relationships in data that are challenging to understand from raw data[16], [17].

In recent years, with the development of information technologies and digitalization, a vast amount of data is being produced and processed in different sectors. One business sector that creates vast amounts of data is the banking sector. It is well known that most banks have implemented digitalization to provide consumers with superior and more timely services and to remain competitive. Implementing digital technologies in the banking sector has enhanced accessibility and convenience for customers, thereby facilitating the expansion of the client base and cost reduction [18]. However, due to digitalization, there has been a dramatic increase in the volume of data produced by banks because of a massive client base using banking services, an increase in the digitalization of services, the growth of digital payment, and the use of IT systems supporting banks' business processes [19]. Banks' vast amount of data is critical for making informed decisions.

These data give banks an opportunity to gain new insights, understand what customers want, and lower risks. Insights obtained from data empower financial institutions to detect and prevent fraud in financial transactions, manage and mitigate potential risks, enhance customer satisfaction, help optimize operations and make informed decisions, help to understand customer behavior, optimize internal processes, and improve security through fraud management[20], [21]. Using insights, banks can streamline processes across organizational divisions, products, customers, and even countries, which results in significant savings while improving the cost-to-savings ratio [22]. Overall, data insights are essential for banks because banks rely on accurate and actionable data insights to make better decisions, improve the customer experience, make operations more efficient, and manage risks.

The critical nature of the decision-making in the banking sector requires accurate and effective data visualization techniques to interpret data and extract actionable insights. While the data has the potential for enhancing decision-making and operational efficiency, the primary challenge lies in effectively analyzing and utilizing these data to extract actionable insights. The banking sector deals with highly sensitive and complex datasets, including financial transactions and customer information, which require precise and clear visualization techniques to be accurately interpreted. There are various data visualization techniques, and knowing which visualization technique is appropriate to get specific insight to make an informed decision is essential, as the effectiveness of data visualization influences data-driven decision-making [23]. However, there needs to be more specific knowledge on which data visualization

techniques are most suitable for presenting banking insights, particularly in critical processes like loan approval and customer onboarding, and whether these techniques are used in practice. This knowledge could improve the extraction of accurate insights and the ability of bank managers or decision-makers to make accurate data-driven decisions.

For this reason, this study focuses on current data visualization techniques used by managers in the banking sector and cross-references these with proven data visualization techniques obtained from the literature to evaluate whether the techniques used are suitable to extract insights and recommend the most appropriate method. The selection of appropriate visualization techniques is based on the purpose of visualization and the data type used.

The research questions guiding this study are:

1. What insights do managers seek from banking processes?
2. Which visualization techniques are they currently using to extract these insights from the data?
3. How to most effectively visualize process data to achieve specific process insights?

This research provides an overview of visualization techniques and their purpose, strengths, and limitations, which are compiled from literature; an overview of insights banking managers seek to extract from the two processes compiled from interviews; and an evaluation of various techniques to recommend the most appropriate technique that is suitable to achieve a specific insight.

This study intends to provide knowledge on using the right visualization techniques to get specific insights and guide managers in the banking sector in selecting and using data visualization techniques that suit their specific needs. To this end, a literature study is carried out to provide an overview of general data visualization techniques along with their purpose, strengths, and weaknesses. Then, various insights from two banking processes and the techniques used to get those insights are collected from the interviews with bank managers. Finally, the results from the interview are compared with the results from the literature study to identify the most appropriate technique to achieve a specific insight.

This paper is structured as follows. Section 1 contains the study context, research gap, and research questions and outlines the structure of the paper. Section 2 describes the results of a literature review. Section 3 describes the research design and methods used in the study. Section 4 presents the findings from the interviews conducted with bank managers. Section 5 evaluates visualization techniques based on their ability to achieve insights identified from the interview. Section 6 discusses and interprets the findings from interviews and the evaluation results. Section 7 concludes the paper by summarizing the study and suggests future research.

2 Literature Review

This literature review aims to provide a comprehensive overview of data visualization techniques and their intended applications, with a particular emphasis on the banking sector and general applications. The review will examine the critical business processes in the banking sector that rely on data visualization and identify the current literature on effective visualization techniques for these processes. Furthermore, it seeks to highlight gaps in the literature regarding the application of these techniques in the banking sector and provide a comprehensive overview of common visualization techniques, their uses, their strengths, and limitations.

2.1 Business Processes in Banking Sector

Business processes in the commercial bank encompass a wide range of activities and procedures in which resources are used to create banking products and services to satisfy customer demands, deliver timely banking products, and ensure the smooth operation of a bank. The business processes of the bank can be categorized into:

Fundamental Processes. These are customer-facing activities such as introducing customers to products and services, lending services, deposits, and card services to meet their needs [24].

Secondary Processes. These activities support the functioning of the bank's fundamental and administrative activities, such as accounting, reporting, and maintaining cash flow [24].

For the study purpose, fundamental processes such as a) the customer onboarding process[25], [26] and b) the loan approval process [27], [28], [29], [30], [31] were used. The focus on the customer onboarding and loan approval processes in this study is driven by the critical importance of customer relationships and loan processing in the banking sector.

Customer onboarding is the first point of interaction between a bank and its customers. It is the gateway to establishing a long-term customer relationship that impacts customer satisfaction, loyalty, and retention. On the other hand, the loan approval process is fundamental to a bank's revenue generation and risk management. It involves accessing the creditworthiness of customers which directly impacts the bank's financial health and risk exposure.

Customer Onboarding Process. The customer onboarding process is the series of activities involved in introducing a new customer to the bank's products and services. Generally, it begins with the customer showing interest in the bank's offering. This process involves fulfilling various procedures such as document collection, ID verification, and Know Your Customer (KYC) checks, and then new customers start using the bank's products and services [32]. The main objective of customer onboarding is to foster long-term positive relationships through an excellent onboarding journey.

Loan Approval Process. The loan approval process refers to all the activities involved before the loan is approved and sanctioned. The loan approval process begins with a loan request application by a customer (borrower) to the bank (lender). It includes a step-by-step process of reviewing documents, including creditworthiness verification assessment, collateral and associate risk assessment, and income and employment verification. The following process is determining loan terms and making a loan application decision. Finally, the customer is notified of the loan decision (approved or rejected), and the loan disbursement decision is implemented [33]. The main objective of the loan approval process is to maintain the quality of the loan portfolio and minimize loan default, which directly impacts the bank's financial health.

2.2 Data Visualization and its Importance in the Banking Sector

In the era of big data, businesses are overwhelmed with vast amounts of information. Data visualization is pivotal in enabling businesses to extract critical insights from a large amount of data, which is essential for making critical informed decisions [34]. Data visualization is extensively used in business processes to enhance managerial knowledge

and improve organizational performance. It provides managers with intuitive and interactive tools to explore data, identify patterns, and derive actionable insights [35]. Visualizing business process data can reveal insights into process performance, enabling managers to identify and prioritize areas for improvement in business processes [2], [36]. This capability is crucial for process optimization and resource allocation, as visual tools can highlight inefficiencies and areas for improvement. Moreover, [37] highlighted the role of data visualization in identifying vulnerabilities, enhancing process efficiency, and preventing unfavorable consequences within business operations. Studies by [38], [39], [40], [41] all acknowledged data visualization as a critical tool for analyzing and understanding business processes.

The literature also underscores the significance of data visualization in corporate decision support systems. [42] emphasized its role in enhancing analytical ability across all levels of an organization, empowering decision-makers to make better decisions. [16] also discussed how data visualization makes data more accessible and understandable, aiding decision-makers in gaining insights from business processes. [43] further contributed to the discussion by highlighting that data visualization enables data exploration and analysis, allowing decision-makers to capture further insights.

Nevertheless, data visualization itself does not provide insights; instead, it assists the reader in interpreting data and extracting valuable insights. [44], [45] explained that readers' brains process the graphical image to obtain insights. Managers can effectively perceive insights using visual tools such as charts, graphs, maps, and interactive dashboards [46].

Visualization techniques aid in comprehending and evaluating data, facilitating data-driven decision-making. Consequently, using effective visualization is essential to leveraging the full potential of data visualization and gaining useful insights. Therefore, determining which visualization techniques work best for the given data type is important for effective visualization [47].

In the current scenario, banks manage an immense volume of information daily, such as customer data, operational data, financial transactions, and market data. Effectively interpreting and utilizing this data is essential to ensuring regulatory compliance, driving strategic growth, and maintaining competitiveness. By converting raw data into visually intuitive formats, such as charts, graphs, and dashboards, data visualization becomes a potent tool for addressing these requirements.

Banks need data visualization to understand large amounts of complex data produced by banks' processes for timely decision-making [48]. In addition, [49] highlighted the need for data visualization to detect suspicious behaviors and fraudulent patterns in banking transactions. The author proposed a visualization tool, VaBank, for banking transaction data analysis to detect suspicious behavior. By analyzing data generated in banks, banks have identified and prevented fraudulent activities, enabling them to make well-informed decisions [50].

In the study [51], a bank's customer data was examined using visualization techniques like bar charts, scatterplots, and histograms, which helped the bank to recognize customer behavior and preferences and identify trends and patterns that affect customer satisfaction and loyalty, leading to customer relationship management and strategic decisions. In the study [52], visualization techniques like bar charts, pie charts, and line charts were used, using the marketing data set of a bank, to identify hidden patterns and predict customers' likelihood to enroll in the bank's term deposit. Data

visualization in the banking sector aids in identifying data discrepancies, discovering risk patterns, and predicting default risk [53].

Like every business, financial institutions are also prone to risk. It has always been crucial for financial institutions to predict certain situations in the future [54]. Predicting the risk associated with granting credit to the customer is an essential aspect to consider in the loan approval process. In addition, predicting loan approval is also crucial for banks to minimize the risk of loan defaults and improve decision-making [55]. A study assessed a Thai bank's loan approval process data through process mining using fuzzy and social network graphs. It gained insights into process bottlenecks such as average time to complete loan requests, loan approval processing days, workload, and iterations, which help managers make decisions to improve efficiency in the process [30].

Visualizing data relationships can help identify emerging trends and patterns in a bank, customer behavior, transaction patterns, and fraud detection. Visualization techniques are used to explore and understand large data sets, helping banks identify patterns and trends that can inform strategic decisions to improve customer satisfaction and loyalty.

2.3 Overview of Data Visualization Techniques

There is a notable lack of focused studies on the best visualization techniques tailored to the banking sector. Particularly in areas such as loan approval and customer onboarding processes, the application of these techniques remains underexplored. However, there is a considerable amount of research on general visualization techniques and their uses [47], [56], [57], [58], [59], [60].

Line charts, pie charts, bar charts, area charts, bubble charts, scattered plots, heat maps, tree maps, histograms, cartograms, Gantt charts, etc., are some techniques to represent raw data in a visual format [15], [61]. Each technique has strengths and weaknesses; therefore, visualization techniques should be used based on their intended use. The choice of visualization techniques is dependent on several factors:

- the type of data (numerical or categorical)[52], [62], [63], [64]
- the nature of the domain of interest and visualization purpose [52] [64]
- dimensionality (number of attributes), and scalability (number of records) [62]

Data types are numerical or quantitative data, further classified as discrete and continuous data, consisting of numbers that can be ordered and measured. In contrast, categorical or qualitative data, further classified as nominal and ordinal data, consists of non-numerical values that fall into categories or groups and are presented using labels or names[58], [63], [65].

[66] provides a complete guide to the principles and practices of creating compelling visualizations. The author emphasized the importance of understanding data types, such as qualitative and quantitative, and the specific tasks that users need to perform, such as comparing values and finding patterns and trends, while selecting the right type of visualization techniques that represent accurate information and are easy to understand. The author further emphasized that depending on context and readability, one should choose the visualization techniques, and use appropriate colors to differentiate the datasets and to highlight the specific or important data points.

Several types of data visualization techniques, their uses, their strength, and limitations, are defined as follows[47], [56], [57], [58], [59], [60].

Line Charts. Line charts are useful for comparing changes and presenting relationships between variables using single or multiple lines over the same period. Line charts help display continuous data and identify trends and patterns in data[66], [67]. Line graphs present time series data, where a sequence of data points is linked by a straight line representing a data point. Each data point displays the information. The line graph measures the change between points. The x-axis in the line graph represents time-series data, while the y-axis represents the scale and values of the measurement. So, it is best to visualize continuous (interval and ratio) variables. Hence, a line graph is useful for representing change, trend, pattern, behavior, and correlation in the data set over a specific time interval. Color codes can be given. However, it will become cluttered and harder to understand when too many lines are plotted in the same graph.

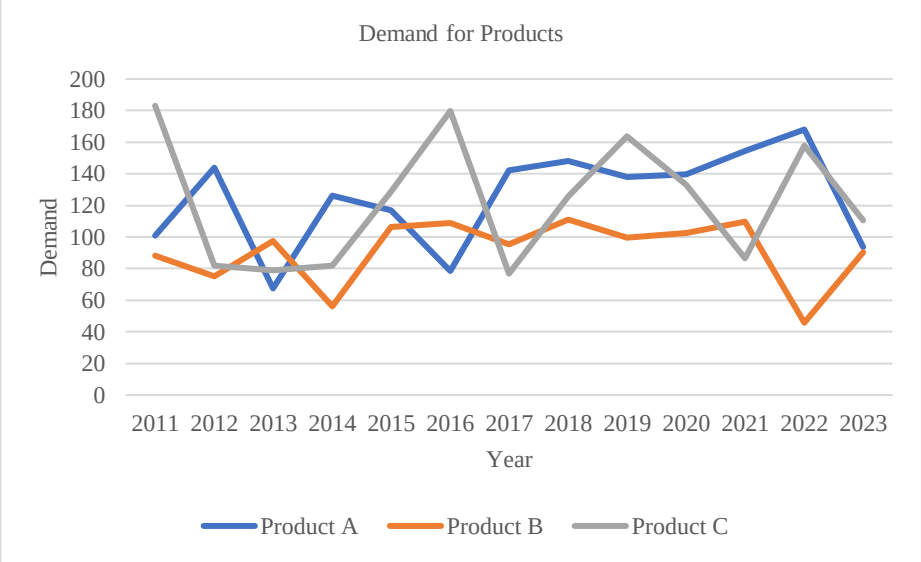

Figure 1: Line Graph

Area Charts. Area charts are used to display quantitative data. They are useful for showing trends over time while emphasizing total values and making comparisons. The x-axis represents categorical data or time series, and the y-axis represents continuous data. The area chart is like a line chart, but it displays datasets with the area between the line and the x-axis, which is filled using color or shading to produce an area graph representing the data's volume. The filled area makes trends more apparent and more accessible to interpret. A stacked area chart can be used when multiple categories exist. However, with large datasets, stacked area charts may create complexity in analyzing the data, as overlapped area charts can be challenging to read.

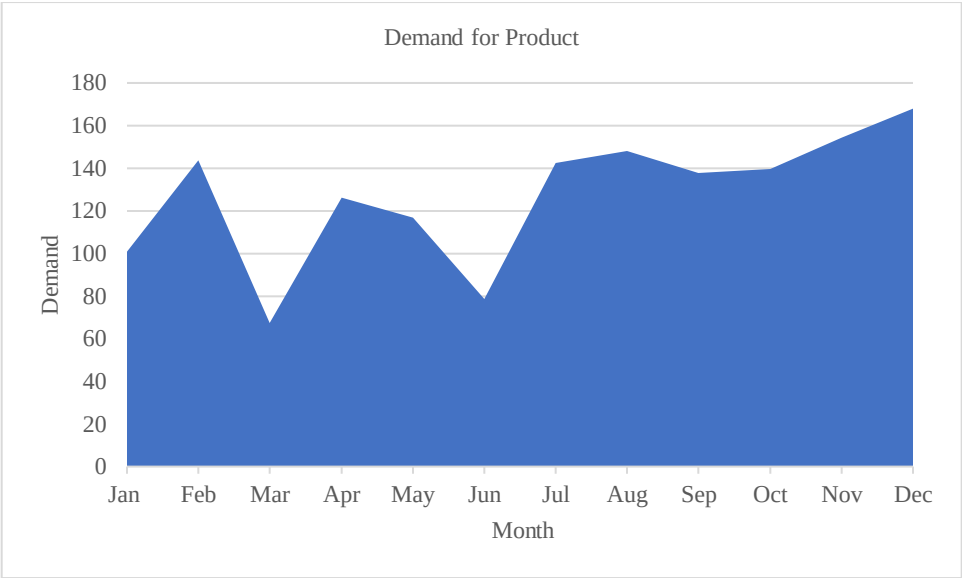

Figure 2: Area Chart

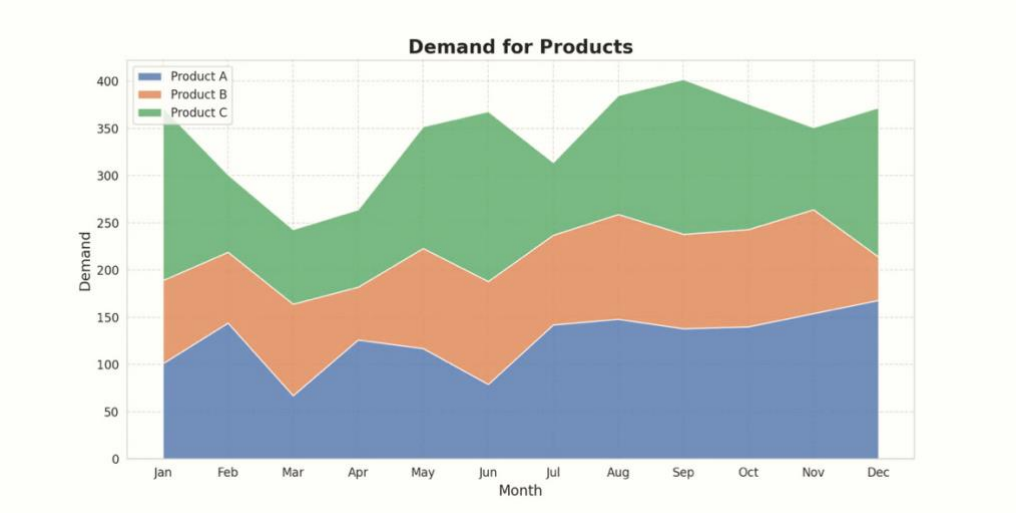

Figure 3: Stacked Area Chart

Bar Charts. A bar chart is a graph with rectangular bars commonly used to present categorical data [66]. The bar graph also helps to compare discrete data over multiple categories and effectively shows differences in values across different categories [67]. It is useful to present and compare quantitative data across qualitative variables by grouping data into categories. The x-axis in the chart presents categories being compared, and the y-axis presents measured values. The length of the bar represents the value of each category. Based on the number of categories and size of each category, bars can be presented vertically or horizontally. A vertical bar chart is useful for presenting negative values. It works better with ordinal data having limited categories,

whereas a horizontal bar chart is better for presenting more categories and longer label names and works better with nominal data.

A grouped/or clustered bar chart uses separate bars to present values within a category and compares multiple categories across different groups [66]. It is useful to present categories having two or more data sets (sub-categories). It is effective in making easy comparisons of multiple categories or sub-categories by using color code. However, too many categories and subcategories make the chart cluttered and challenging to read.

Stacked bar charts show the composition of different categories within a single bar and highlight how sub-categories contribute to the total [66]. Stacked bar charts present one or more segments of individual categories and a total for each category. Different colors are used to show different segments within a category. Though analyzing the total values and values of the first segment in a category is easier, it isn't easy to quantify the remaining segments. Also, presenting many segments within a category makes it difficult to analyze. When there are many bars to be presented, and bars are close together, different colors can be used to show each bar. Color coding and labeling are crucial while using bar charts.

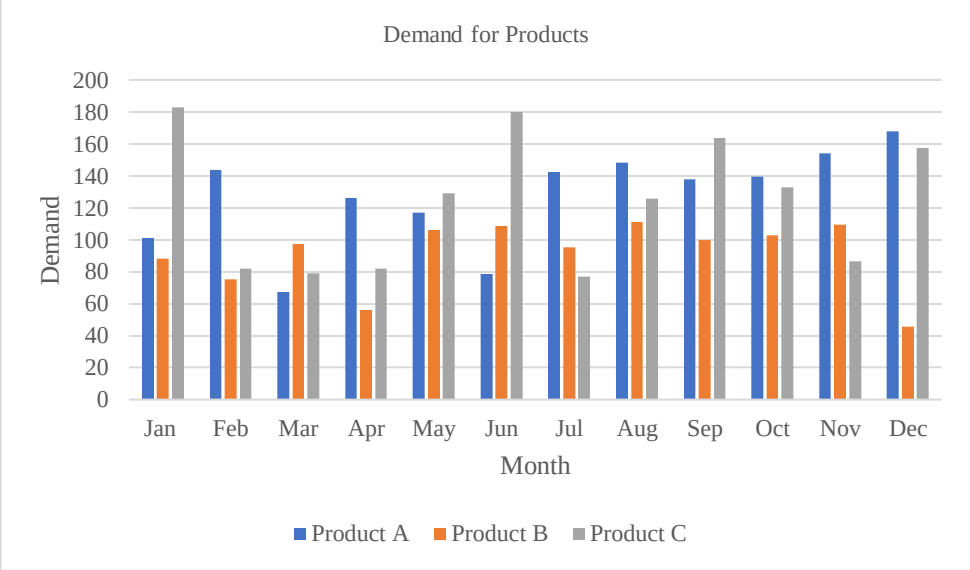

Figure 4: Grouped Bar Chart

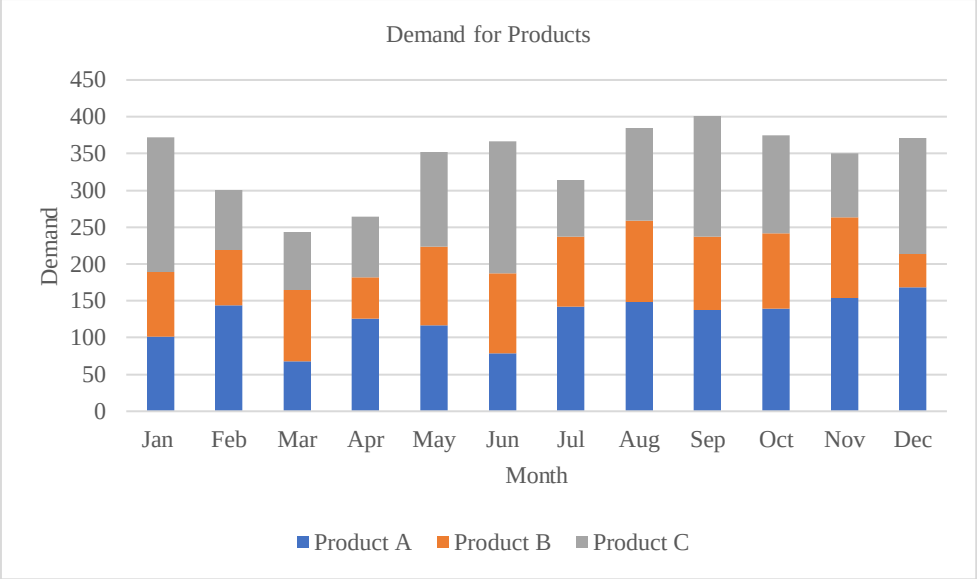

Figure 5: Stacked Bar Chart

Pie Charts. A pie chart displays data in a circular graph. It is generally used to compare the percentage of each category to the whole rather than comparing categories to each other. The pie chart presents data in a circle divided into different sections. Each section presents different categories, and the size of each section determines the proportion of a category to the whole. It contains categorical variables (categories) and numeric variables. The pie chart is most effective when there is limited content to present and additional information, such as percentages and text, is provided to describe the data presented.

There are two variants of pie charts: doughnut charts and exploding pie charts. Doughnut charts are quite like pie charts, but hollows in the center give space for additional information. On the other hand, in exploding pie charts, one or more sections of the chart are separated from the rest, which helps emphasize important information. Thus, several pie charts are useful for comparing parts to the whole [66]. For all kinds of pie charts to be effective, limited information should be presented to avoid cluttering with clear labeling.

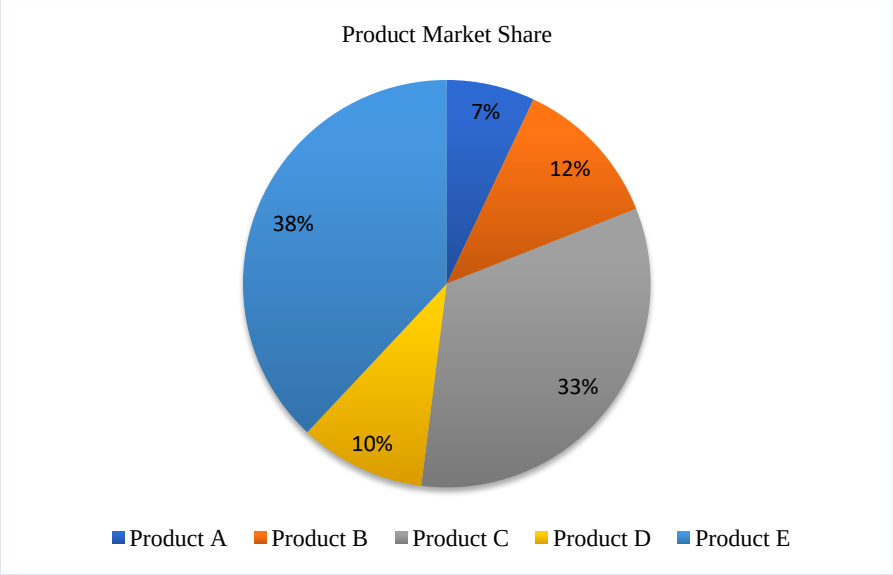

Figure 6: Pie Chart

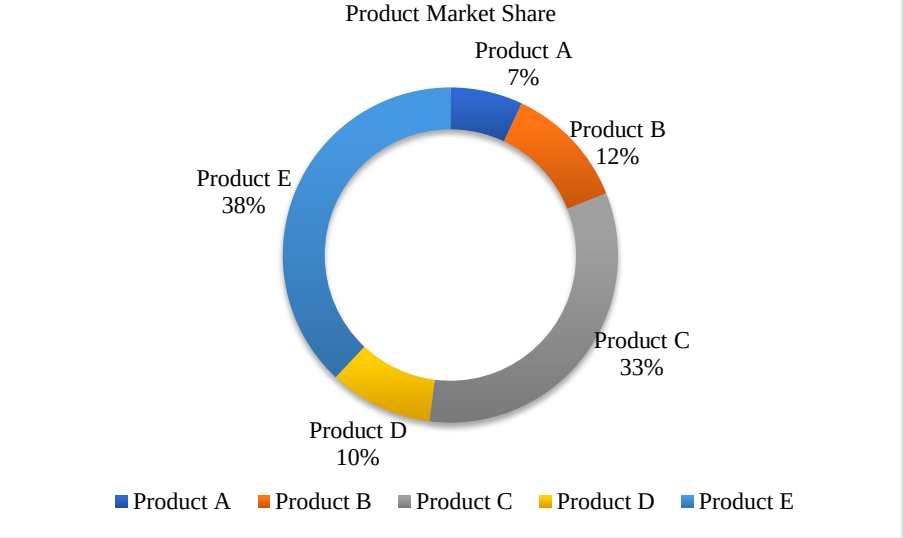

Figure 7: Donut Pie Chart

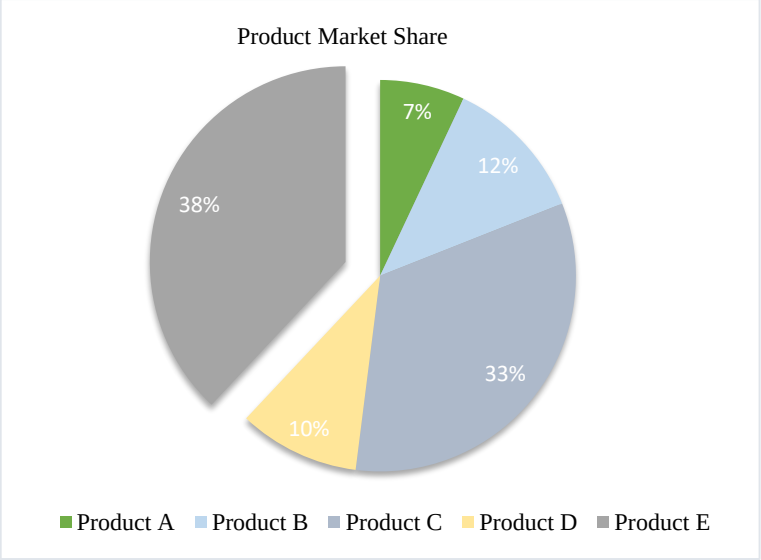

Figure 8: Exploded Pie Chart

Scatter Plots. Scatter plots are useful in exploring relationships between two quantitative data and identifying correlations and relationships in data [66], [67]. Here, one variable is independent (x-axis), and the other is dependent (y-axis). A dot in a scatter plot represents an observation, and the dot's position indicates the value of the observation. The scatter plot effectively visualizes relationships and correlations, patterns, and trends in variables, mostly when there are many datasets. It is also useful to identify outliers from the data set. Scatter plots are useful in presenting the relationship in data when there are many data points, but a clear interpretation is required to understand the significance of patterns. scatter plots are useful in exploring relationships between two quantitative data and identifying correlations and relationships in data

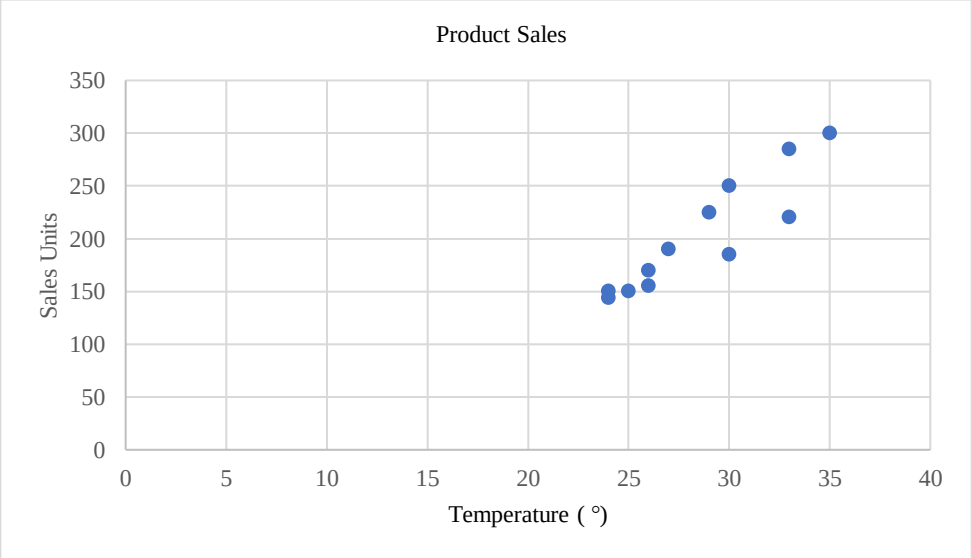

Figure 9: Scatter Plot

Bubble Plots. Bubble plots are variations of scatter plots in which a bubble represents an observation, however, they are useful for presenting three variables. The position of a bubble represents the values of the x-axis and y-axis, and the size of the bubble represents the value of the third variable. Like scatter plots, bubble plots are also effective in visualizing the relationship between any three variables and useful in comparing values, except dots are replaced by bubbles. However, too many data points may create difficulty in interpretation and difficulty in comparing bubble sizes accurately.

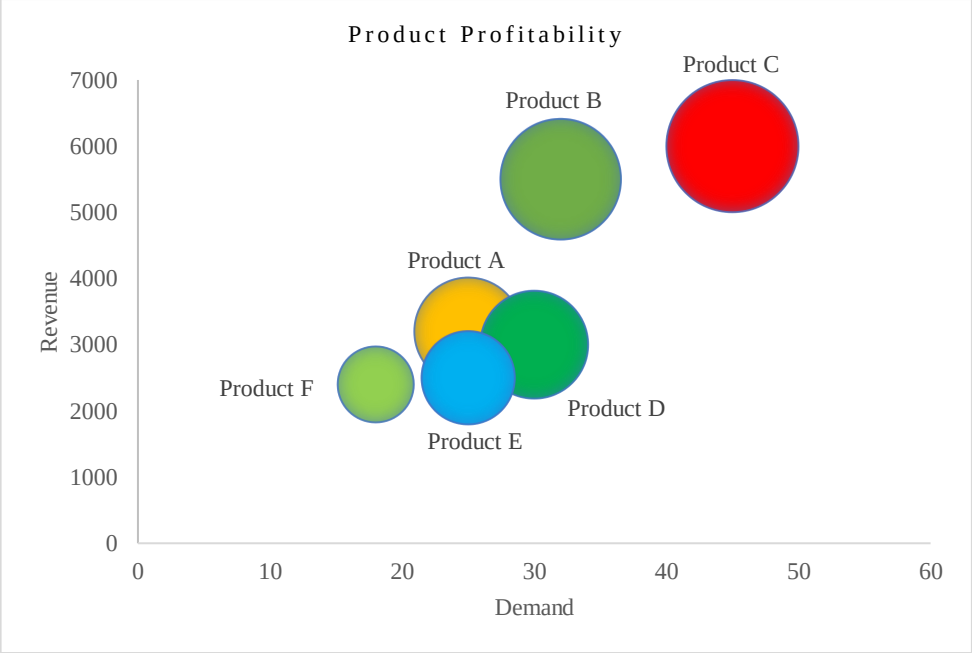

Figure 10: Bubble Chart

Heat Maps. Heat maps represent data in a matrix form where colors present data values. Color represents data intensity or density within a two-dimensional space that has categorical and continuous data. Heatmaps show intensity variations and represent matrix data [66]. Heatmaps are mostly useful for identifying patterns, and correlations, comparing data, detecting outliers, and highlighting high and low intensity in large quantitative datasets. However, precise values cannot be interpreted, and careful color selection is very essential.

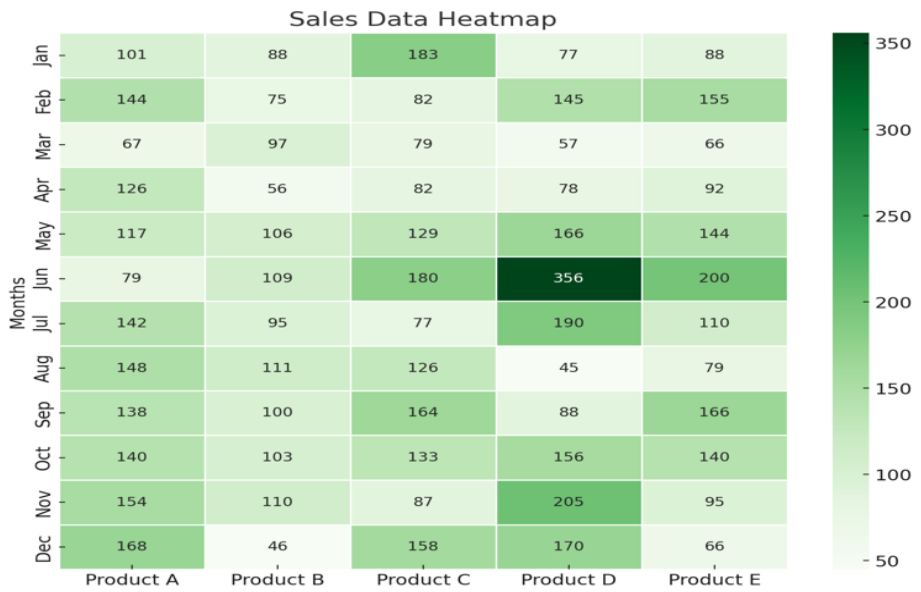

Figure 11: Heat Map

Funnel Chart. A funnel chart displays data in the form of a funnel. It resembles the shape of a funnel, begins with a broader head, and ends with a narrow neck. It is divided into sections, the width of which represents the number of items or participants remaining at each stage. It is mainly used to visualize stages in a sequential process, such as the sales process, purchase process, and development process when the progressive reduction of data as it moves through each stage is to be presented [68], [69]. It uses categorical data to represent different stages in a process and quantitative data to represent percentages or counts. Funnel charts are useful tools for identifying areas of improvement, especially when dealing with sequential stages and conversion rates [70]. Thus, it helps identify bottlenecks or problem areas in the process. However, detailed data within each stage cannot be presented.

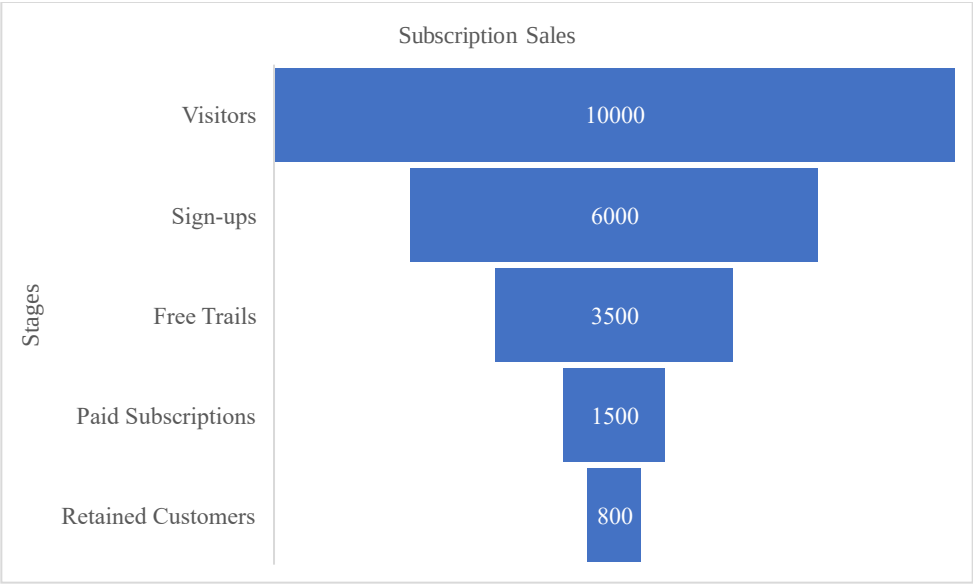

Figure 12: Funnel Chart

Dual Axes Chart. Also known as a combination chart, is useful to visualize two sets of quantitative data simultaneously. It shows comparisons and relationships between variables having different units in the same graph. It typically combines bars and lines to display data. It features two independent y-axes: each representing a different data series and sharing the same x-axis for both data series. It can display a large amount of information in a single graph, enabling direct comparison and visualize relationships such as correlations, trends, and patterns. However, if scales are not clearly labeled or if data ranges are significantly different, this graph may lead to misinterpretation[71], [72].

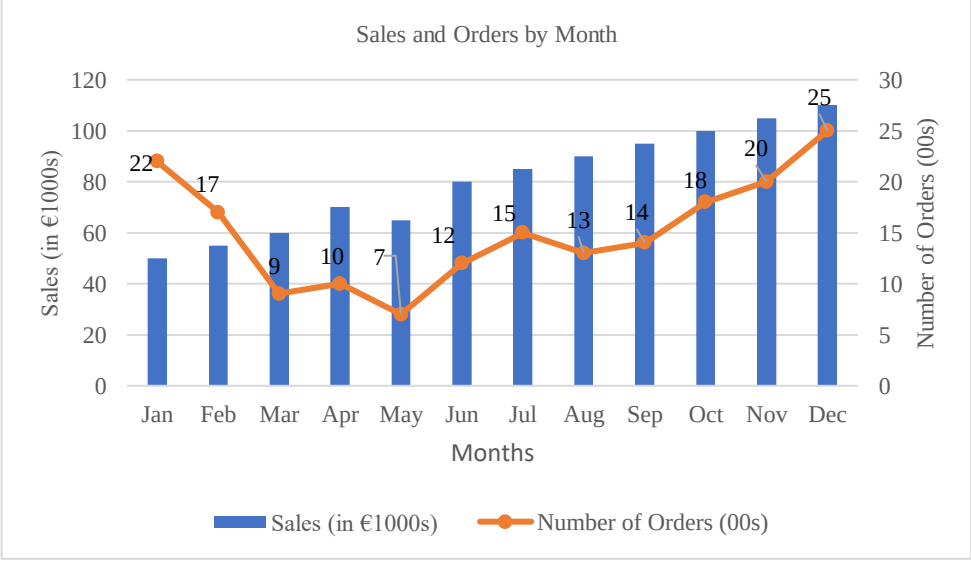

Figure 13: Dual Axes Chart

The table below summarizes an overview of several visualization techniques, along with their intended purpose, data used, strengths, and limitations.

Table 1: Overview of Data Visualization Techniques

S.N.	Visualization Techniques	Data Used	Purpose	Strengths	Limitations
1	Line chart	Time series data and continuous.	To show trends/changes over time or to show relationsip between two related continuous variables.	- Clearly shows trends, patterns, and changes over time. - Can handle multiple data series (lines) for comparison.	- Can become cluttered and difficult to read when there is too many lines or data points.
2	Area chart	Time series, categorical and continuous.	To show the magnitude of change over time, emphasizing the total value or quantity represented by the line.	- Good for showing the size/volume of the change over time, visual impact with filled areas. - Unlike line chart, it shows trends and cumulative values over time.	- Can become difficult to interpret with too many data series, overlapping multiple areas. - Not ideal for precise comparison between data series.
3	Stacked area chart	Time series, categorical and continuous.	To display part-to-whole relationships and show how individual parts contribute to the whole over time.	- Displays cumulative contribution of each category over time. - Useful for presenting overall trends and composition changes over time.	- Difficult to compare changes in individual segments if they are small or the data series are not distinct. - Multiple segments create multiple stacked areas making difficult to interpret the area values.
4	Bar chart	Categorical and continuous.	To compare values across different categories.	- Effective for comparing categorical data. - Simple and easy to interpret.	- Not suitable for presenting trends over time. - Not ideal for displaying too many categories, can become cluttered with too many bars.
5	Grouped bar chart	Categorical and continuous.	To compare multiple sub-categories within categories, showing distribution of groups.	- Facilitates direct comparison of multiple categories and sub-categories. - Displays differences within and between groups.	- Can become cluttered and hard to read with too many groups. - Requires proper labeling and distinct color to differentiate.
6	Stacked bar chart	Categorical and continuous.	To show the composition of categories and compare both total and sub-component contributions.	- Visualizes composition within a category, showing how different components contribute to the total. - Ideal for comparing individual components and overall total.	- Harder to compare sizes of individual components across different categories. - Can be cluttered and visually confusing if there are many components.
7	Pie chart	Categorical data as percentages or proportions.	To show parts of a whole as percentages or proportions.	- Simple and effective for showing data as percentages. - Useful for small datasets with a limited number of categories.	- Not effective for presenting large datasets, difficult to compare sizes and get precise values of categories. - Proper labelling is essential to differentiate categories.
8	Donut pie chart	Categorical data as proportions.	Similar to a pie chart, but with a blank center, to emphasize labels or other additional information.	- Allows more space for better data labelling or display additional information in the center. - Modern aesthetic and visually appealing.	- Similar limitations to pie chart, with additional difficulty of labeling the center. - The central additional information can distract from main data.
9	Exploded pie chart	Categorical data as proportions.	To emphasize individual slices of a a pie chart, specially specific category.	- Draws attention to important categories, highlighting significant data.	- Can be misleading if the separation is not based on a significant difference. - Less effective for presenting exact proportions.
10	Scatter plot	Continuous (numeric) data for both axes.	To show relationships between two continuous variables.	- Effective for identifying correlations, outliers, and clusters. - Displays large number of data points.	- Can become cluttered with too many data points; requires careful axis scaling. - Clear interpretation is required to understand the significance of patterns.
11	Bubble plot	Continuous data and categorical (additional variable for bubble size)	To show three dimensions of data.	- Effective for displaying relationship between three variables simultaneously. - Highlight trends and outliers with additional dimension.	- Size perception can be misleading; difficult to compare bubble sizes accurately. - Can become cluttered and difficult to interpret if too many data points are plotted.
12	Heat map	Continuous or categorical data, represented with a color gradient.	To show data density (frequency), intensity, or relationships using color.	- Excellent for visualizing patterns, intensity, and density. - Provides quick overview of the data distribution.	- Color perception can be subjective; precise values are harder to identify. - Careful selection of color scales is required to avoid misleading interpretations.
13	Funnel chart	Sequential categorical data, continuous and numeric	To show stages in a process and the drop-off rate between stages.	'- Visualizes the reduction of data across stages, making easy to see bottlenecks or drop-offs. - Helps identify stages where improvements are needed.	- Not suitable for showing detailed data within each stage. - Limited to processes with a clear progression.
14	Dual Axes Chart	Quantative/numerical data	To visualize comparison and relationship between two different data.	- Combines two different charts to visualize relationship between data simultaneously. - Displays large amount of information in single graph.	- May create confusion is scales are not labelled properly.

While there is extensive research on general data visualization techniques, a notable gap remains in understanding which specific visualization techniques can be used to achieve insights in the banking sector, particularly in loan approval and customer onboarding processes. Current literature highlights the general uses of data visualizations and how they benefit businesses. However, it lacks a detailed exploration of the exact insights managers seek and which visualization techniques are most effective for these needs, especially within banking. This gap leads to uncertainty about which visualization techniques are best suited to achieve specific banking insights, potentially resulting in less effective decision-making and operational strategies. This thesis addresses this gap by interviewing bank managers to

identify the particular insights they seek and evaluate various data visualization techniques gathered from literature against the goal of achieving those insights.

3 Method

3.1 Research Design

The primary objective of this study is to understand the specific insights managers are looking for from two specific banking processes: the customer onboarding process and the loan approval process and to understand the data visualization techniques they use to get these insights. The study aims to evaluate the suitability of the used visualization techniques and provide guidance on which techniques to use to extract specific insights. The research questions guiding this study are (1) What insights do managers seek from banking processes? (2) Which visualization techniques are currently used to extract these insights from the data? (3) How to most effectively visualize process data to achieve specific process insights?

To this end, the study utilizes a qualitative research approach to explore how to present data to extract specific insights into the business processes of a bank. Firstly, an explorative literature review was conducted to compile an overview of visualization techniques and their intended use. Next, qualitative interviews were carried out to obtain the insights managers seek from the banking processes. Lastly, the insights extracted from the interview were compared to the overview of visualization techniques resulting from the literature review to evaluate the suitability of the used visualization techniques and provide guidance on which techniques to use to extract specific insights.

3.2 Participant Selection

Participants for this study were chosen using purposive sampling, also called non-probabilistic sampling, [73] to ensure relevant participants were included. The selection of these participants was deliberate, taking into consideration the study's purpose and their relevance to the research objective. The participants selected were managers from banks directly involved in these processes under investigation. A total of five managers participated in the study. This methodology is employed to gain an understanding of specific phenomena, as opposed to extrapolating findings to the entire population.

3.3 Data Collection

As a first step, a literature review identified two banking processes and an overview of various data visualization techniques. Various sources of literature, such as Google Scholar, Springer, Taylor & Francis, and Research Gate, were used.

Data was collected from participants using semi-structured interviews, an approach that incorporates open-ended questions [74]. To get an understanding of the insights, managers seek from these processes, interviews were conducted with the five selected managers. At the beginning of the interview, two banking processes under study were explained

(as explained in the literature) to the participants and confirmed they were directly involved in these processes. Further, participants were informed that an interview would be recorded and subsequently obtained their consent for this. Each interview lasted between 15 to 20 minutes, with an average length of approximately 10 minutes, and was conducted using a virtual meeting platform.

3.4 Data Analysis

In this study, data analysis aimed to compile an overview of the type of insights managers seek from two banking processes—loan approval and customer onboarding—and the data visualization techniques they use to get those insights.

For the qualitative data collected from interviews, data were analyzed using narrative analysis [75]. Specific sentences from the interview were selected that provided answers to the research questions. The selected sentences were coded, in which relevant portions of the text were labeled that provided key information shared by participants. In vivo coding form of coding was used in which participants' own words are emphasized and used as code [76].

3.5 Evaluation of Insights and Visualization Techniques

In the end, this study evaluated the insights managers seek against various data visualization techniques to propose a best-suited method. This involved identifying which data visualization techniques can be used to obtain insights. Firstly, an overview of several visualization techniques was obtained from the literature review. Then, based on the data type and purpose of visualization, the utility of different visualization techniques obtained from the literature review results was evaluated and compared to obtain specific techniques for specific insights.

4 Findings

This section outlines the key findings derived from the interviews with managers of commercial banks regarding insights they seek from two specific banking processes and the data visualization techniques they utilize to extract these insights. Data are organized based on the research questions and the answers to these questions are essential in understanding and evaluating visualization techniques to achieve specific insights.

Loan Approval Process Insight. Key insights sought by bank managers include:

Loan application processing time (turnaround time). It involves tracking and comparing the time taken to process a loan application from start to end (until approval) to evaluate the efficiency of the loan approval process and identify bottlenecks. This insight helps improve loan approval process speed, enhance customer satisfaction, and optimize operational efficiency.

Loan application volume and approval rate. It involves monitoring the loan applications received and the percentage of applications that get approved. This insight provides knowledge on overall loan demand and the effectiveness of loan approval criteria and helps in planning and resource allocation.

Cost per loan application processed. This involves calculating and tracking the cost incurred for processing each loan application to evaluate cost-effectiveness. This insight helps identify areas of cost reduction in the loan approval process, thereby improving profitability.

Demand for loans. This involves analyzing the loan application trends to understand the demand trend and pattern and predict future demand. This insight helps predict market needs, manage resources efficiently, and tailor loan products to meet customer demands.

Loan portfolio composition and performance. This involves assessing the diversification of loan portfolios (spreading the loan across different sectors to reduce the risk associated with a single sector) and their performance to maintain a balanced portfolio and identify risk factors. This insight helps maintain a bank's balanced portfolio, identify risk factors, and ensure the stability and profitability of the bank's loan operations.

These insights are crucial for bank managers in optimizing and ensuring the efficiency of the loan approval process, identifying bottlenecks, allocating resources effectively, detecting fraud, evaluating cost-effectiveness, understanding and predicting market demand patterns, and managing risk by reducing or adjusting potential risk.

Data Visualization Techniques Used. In response to questions concerning how managers get that information, it is found that managers employ a range of visual aids, including bar charts, tables, line charts, and pie charts, to extract and comprehend these crucial insights. These visual aids facilitate the interpretation of data, allowing loan approval managers to make well-informed decisions.

The table below shows the summary of the findings.

Table 2: Loan Approval Process Insights

Interviewees	Interviewees Quotes Loan approval process insights	Coding	Interviewees Quotes Visualization techniques used	Coding	Labelling Details	Limitations
P1	"As a manager, I need to make sure everything is happening smoothly and efficiently, mostly how timely all the loan applications are handled and how long it takes to process application from start to finish are important"	Processing time from start to end - **Turnaround Time (TAT)**	"Monthly report is submitted to me.. data is presented in bar charts to compare the time taken by each type of loan application"	**Bar charts**	X-axis - Types of loan application Y-axis - Processing time	Restricts the ability to compare multiple sub-categories within a category, as only single data series can be presented.
P2	"Understanding the volume and type of loan applications received and their approval/rejection rate helps me plan accordingly, I mean I can use this information to allocate resources properly…to identify trends"	Loan applications received by type and applications approved - **Loan Application Volume and Approval Rate**	"Normally I don't work on visualization, I get a report on loan performance where I get this information summarized in a table"	**Table**	Table includes list of loan application volume by loan type and their approval rate	Reading and interpreting large tables with many rows and columns can be overwhelming, making it harder to quickly understand trends, patterns and relationships in data.
P3	"For me cost factor for each loan applied is essential…as a profit oriented business how to reduce cost, where to reduce cost and increase profit is prime concern, so cost incurred by both approved and rejected loans is my concern"	Cost associated with each loan processed (approved/or rejected) - **Cost per Loan**	"I get this information in a monthly report …usually data are presented in bar charts"	**Bar charts**	X-axis - Approved and rejected loan Y-axis - Cost per approved and rejected loan	Restricts the ability to compare multiple sub-categories within a category, as single data series can be presented.
P4	"Today's business environment is very volatile, in these recent years there are changes in regulations, and interest rates which have affected the demand for loans time to time"	Predict demand for loan over time - **Loan Trend**	"Line graph is helpful to see the trend of loan"	**Line charts**	X-axis - Time period Y-axis - Loan demand (in amount)	Too many lines on same chart makes difficult to read and understand.
P5	"I need to make sure the composition of lending portfolio is diverse and reduce default rate because this helps to diversify risk that can be caused by loan default"	Diverse lending composition - **Loan Portfolio and Performance**	"My team gives me a loan portfolio report…for comparison data is presented in pie charts"	**Pie charts**	Pie chart shows proportion of each loan type within total loan portfolio	Not effective for large datasets with many categories.

Customer Onboarding Process Insights. For the customer onboarding process, managers aim to gain insights that help optimize the process, reduce the time and resources required, identify bottlenecks, enhance customer experience and satisfaction, and improve customer retention. Key insights include:

Customer onboarding time. Monitoring average onboarding time helps managers pinpoint areas for improvement and streamline processes to reduce onboarding duration. This insight helps new customers use the bank's services quickly and efficiently and facilitates a smooth onboarding experience, enhancing customer satisfaction.

Preferred channels to onboard. Knowing channels, physical, online, and mobile apps customers prefer for onboarding helps managers allocate resources effectively and ensure that most preferred channels are well-optimized and catered to enhance user experience. This insight helps improve customer experience, leading to higher satisfaction and retention rates.

Drop-off point and drop-off rate. Identifying where customers drop off at a high rate provides insights into the pain points or stages where customers face difficulties. For example, during the online bank account opening process, a high drop-off rate at the "identity verification" stage might be due to a cumbersome and time-consuming document upload process. Such insight helps managers implement additional support at those points to retain customers and address issues that cause drop-offs.

Customer satisfaction level. Collecting feedback from customers on the onboarding experience provides an understanding of the satisfaction level and the need for improvement. This insight helps identify areas of dissatisfaction and make improvements to enable customer satisfaction.

Types and frequency of errors encountered. Identifying common errors during the customer onboarding process faced by customers and bank staff allows managers to implement necessary steps to mitigate the root causes of issues. This insight helps minimize errors and reduce delays, leading to an efficient onboarding process that benefits customers and banks.

These insights are crucial for bank managers to enhance the customer onboarding process. By closely monitoring these key metrics, managers can streamline operations, improve customer satisfaction, and ensure efficient and pleasant onboarding experiences.

Data Visualization Techniques Used. In response to questions concerning how managers get that information, it is found that managers employ a range of visual aids, including bar charts, pie charts, tables, and lists of information, to extract and comprehend these crucial insights.

The table below shows the summary of the findings from the interviews.

Table 3: Customer Onboarding Process Insights

Interviewees	Interviewees Quotes Customer onboarding process insights	Coding	Interviewees Quotes Visualization techniques used	Coding	Labelling Details	Limitations
P1	"Nowadays customer wants quick service, or they go to other banks…minimizing time taken to onboard customer while ensuring accurate regulatory checks is important to reduce risk and provide better experience"	Total time taken to onboard customer - **Customer Onboarding Time**	"Mostly, I get this information presented in bar charts"	**Bar charts**	X-axis - Customer types Y-axis - Onboarding time	Restricts the ability to compare multiple sub-categories within a category, as single data series can be presented.
P2	"Customer preferences of channel to onboard like in-person/or online so that we can optimize resource allocation and give better onboarding experiences"	Identify channels preferred by customers - **Preferred Channels**	"Customer service report contains information in pie charts about channel used by customers to onboard"	**Pie charts**	Pie chart shows proportion (percentage) of customers who prefer onboarding channels (in-person, online, mobile app).	Not effective for large datasets with many categories.
P3	"Since we have implemented customer onboarding through digital platform, we have observed a higher drop-off rate…so we started tracking drop-off points and drop-off rates to understand pain-points of customers"	Identify major drop-off points by customer - **Drop-off Point/Rate**	"In a monthly report all these information is presented in a table"	**Table**	In a table data are presented in columns. Each column contains stages of onboarding process, number of customers started, number of customers completed and corresponding drop-off rate respectively.	Reading and interpreting large tables with many rows and columns can be overwhelming, making it harder to quickly understand trends, patterns and relationships in data.
P4	"We normally collect feedback from customers to know their experiences during the onboarding process and after the process to analyse satisfaction level and make improvements"	Customer experience in whole process - **Customer Satisfaction Level**	"Normally, I get this information in bar chart"	**Bar chart**	X-axis - Customer satisfaction level (very satisfied…very dissatisfied) Y-axis - Number of customers	Restricts the ability to compare multiple sub-categories within a category, as single data series can be presented.
P5	"Our team encounter various errors which causes rework and slows the process. As a manager, to minimize errors and save time, I try to understand reasons for delay in several stage of process and the frequency of occurence"	Type and frequency of errors encountered in several stages - **Type and Frequency of Errors**	"I see list of errors and its frequency in a monthly report"	**List/table**	In table data are presented in columns. One column contains list of types of errors and another column contains frequency of occurrence of errors.	Reading and interpreting large tables with many rows and columns can be overwhelming, making it harder to quickly understand trends, patterns and relationships in data.

5 Evaluation

In this section, various data visualization techniques suitable for gaining insights managers seek from the loan approval and customer onboarding processes are evaluated. The findings indicate that each manager seeks different insights from the process they are managing and uses general visualization techniques to get these insights.

Choosing the right data visualization techniques is essential to conveying insights effectively. As mentioned earlier, visualization techniques should be chosen based on the data type and purpose of visualization. Therefore, data that provide insights are first classified to evaluate the visualization techniques against the goal of achieving specific insights.

Below are various recommended visualization techniques for each insight. The analysis includes identifying the data types needed and selecting the appropriate visualization technique to communicate the insights effectively. Several visualization techniques are evaluated, each serving a different purpose but using the same data. At the end of the analysis, the most appropriate visualization technique is recommended for each insight based on the specific needs of the managers.

i. Loan Approval Process

1. Turnaround Time

   Purpose: Present and compare the time taken to process the loan applications from submission to approval.

   Data type: Quantitative/Continuous (time), time-series, and categorical (loan types)

   Number of attributes: 3 (turnaround time in hours or days; months/quarters/years; loan types (personal/business))

   Recommended visualization techniques:

   a. Grouped bar chart: Useful for comparing turnaround time for each loan type at a given period. The x-axis represents categories (different loan types) using a group of bars. Within each group in the x-axis, bars are

divided based on periods to show comparisons across various periods. The y-axis represents the turnaround time taken in hours/or days for processing the corresponding loan type. Different loan turnaround times can be compared over different periods or segments.

b. Line chart: Useful for presenting turnaround time changes/or trends over time for each loan type, allowing for easy comparison of turnaround times across different periods. The x-axis represents time data in weeks/months. The y-axis represents turnaround time, which is measured in days or hours. Each line on the chart represents a different loan type, connecting the data points for each month. A color code is given to each line to differentiate loan type.

Most Appropriate Visualization Technique. A grouped bar chart is most effective in presenting and comparing multiple categories across different secondary dimensions side by side. A grouped bar chart helps to compare each loan application's processing times (turnaround time) based on loan types and over different periods by presenting data with values. Figure 14 compares the turnaround time taken to process the loan application.

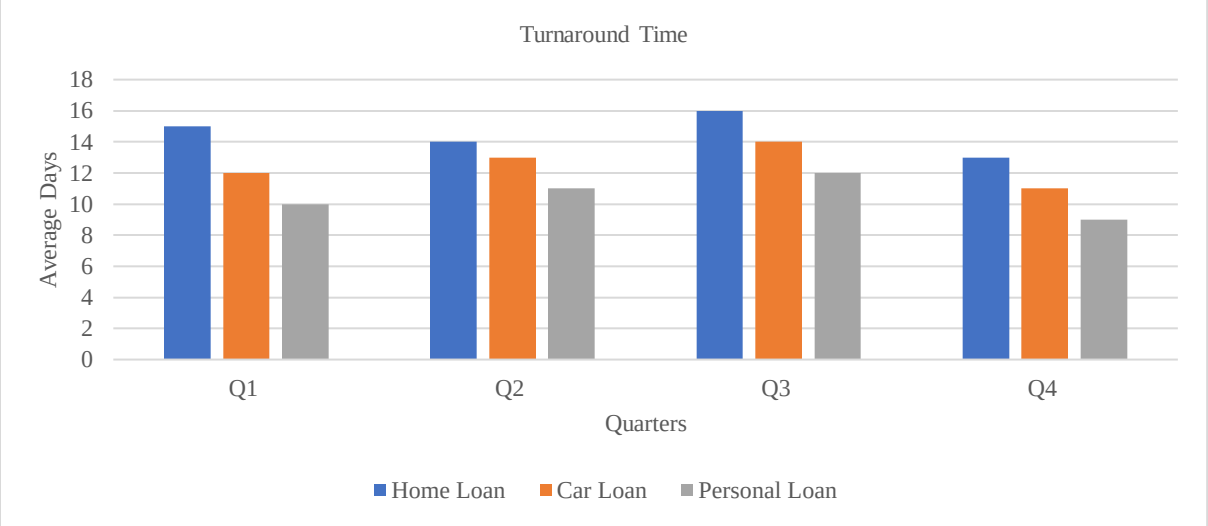

Figure 14: Turnaround Time Taken

2. Loan Application Volume and Approval Rate

Purpose: Compare and identify trends in the volume of loan applications and their approval rate over time.

Data Type: Quantitative/Numerical (count/number), categorical (loan types), time series, and continuous (percentage of approved applications)

Number of Attributes: 4 (application volume; loan types (personal/business); months/quarters/years, and approval rate)

Recommended Visualization Techniques:

a. Line chart: Useful for tracking changes in loan application volume and approval rate over time. It helps understand the direction and pace of changes, highlighting trends and seasonal patterns. The x-axis

represents the timeline in months/quarters while displaying trends in data. The y-axis represents the volume of loan applications received and applications approved in each period. Separate lines are plotted for each loan type to indicate the trend in approved applications, allowing direct comparisons across loan types. To distinguish data, lines are color-coded.

b. Grouped bar chart: Useful to compare and track total loan application volume by loan types and their approval rate in a single chart for easy comparison. The x-axis represents the loan types. The y-axis represents the total loan application volume and the number of approved applications. Each loan type will have two bars grouped; one shows the volume of applications, and another shows the approved applications of the corresponding loan type. The rate can be derived from comparing the volume and the number of approved applications. Bars are color-coded to distinguish volume and approval rate.

c. Dual-axis bar chart: Useful for comparing two different datasets together. It combines bars and lines to show the volume of applications and their approval rate on the same chart. A loan application volume and approval rate in a single graph helps to compare values and identify trends. The x-axis represents time. The y-axis (left) represents the total volume of applications, and the y-axis (right) represents the approval rate. The bar and its height represent the total loan application volume, and the line chart above the bars represents the approval rate (%) of corresponding loan types.

Most Appropriate Visualization Technique. A dual-axis bar chart, or a combination chart, is one of the best options for presenting loan application volume using bars and approval rate using a line together. Combining a line chart (for approval rates) with bars (for application volumes) can effectively highlight loan demand and trends over time and make it easier to see how changes in the volume of applications might correlate with changes in the approval rate. Figure 15 shows the trend of loan application volume and their approval rate.

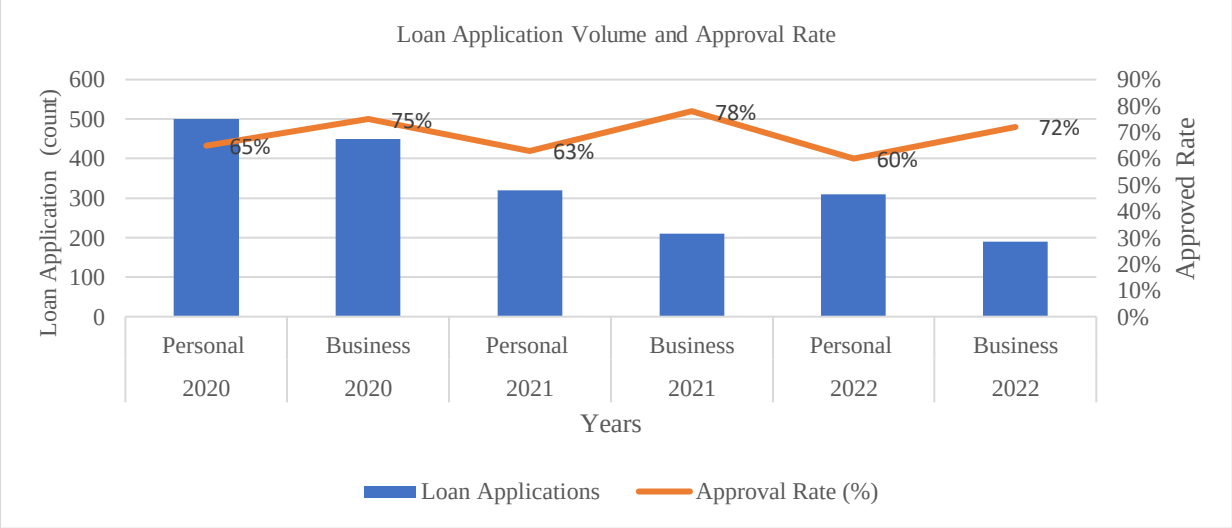

Figure 15: Loan Application Volume and Approval Rate

3. Cost per Loan

Purpose: Compare the total cost incurred to process loan applications (by types) and status (approved or rejected).

Data Type: Quantitative/Numerical (cost); categorical (loan types); categorical (application status)

Number of Attributes: 3 (cost; loan types; approved/or rejected)

Recommended Visualization Techniques:

a. Stacked bar chart: Useful to compare total costs across loan types and application status. A stacked bar chart can show the total cost incurred to process the loan and its breakdown by status (approved vs. rejected) within each loan type. The x-axis represents loan types, and the y-axis represents the total cost. Each bar represents the loan types divided into segments representing costs associated with approved and rejected applications. Different colors can be used to differentiate approved and rejected segments.
b. Grouped bar chart: Useful to compare cost by application status (approved or rejected) side by side for each loan type. The x-axis represents loan types with grouped bars for each approved and rejected status. The y-axis represents the total cost incurred in processing the loan application by status. Different colors can be used to distinguish loan status bars.

Most Appropriate Visualization Technique. A stacked bar chart is the most appropriate visualization technique for comparing overall composition. A stacked bar chart can display the total cost of each loan type and the breakdown of approved and rejected loans. The segments within the bar represent the approved and rejected loan applications, while the height of each bar represents the total cost for a specific loan type. Proper labeling and appropriate color should be used to differentiate approved and rejected segments within a bar. Figure 16 shows the cost incurred for processing loan applications by loan types and status.

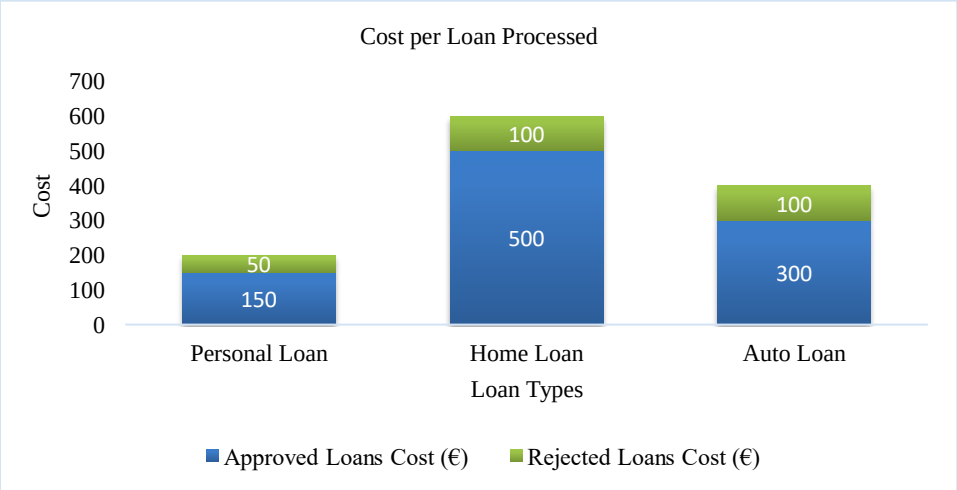

Figure 16: Cost per Loan Processed

4. Loan Trend

Purpose: Identify the demand trend for different loans (in amount) over time.

Data Type: Continuous (amounts), categories (loan types), and time series

Number of Attributes: 3 (loan amounts; loan types; months/quarters/years)

Recommended Visualization Techniques:

a. Line chart: Useful for tracking changes in demand for loan volume (in amount). The x-axis represents the period. The y-axis represents the loan amount. Each line in a graph represents different loan types, showing the trend of loan amounts over time. The lines representing loan types are color-coded and help to find if the demand for loans (in terms of amount) for each type is increasing, decreasing, or constant. It helps in understanding the direction and pace of changes in loan demand, highlighting trends and seasonal patterns.
b. Stacked bar chart: Useful for showing the total loan amount and the contribution of each loan type to the total. The x-axis represents the time period. The y-axis represents cumulative loan demand (in amount). Each bar represents total loan demand at a certain time and is divided into segments representing loan types. The area of the segment shows the amount of loan type. This chart is helpful for seeing how total loan demand changes over time and which loan types contribute most to the total.
c. Area chart: Useful for identifying and comparing trends in the demand (in amount) for different loans over time. The x-axis represents time, and the y-axis represents the loan amount. Area charts display multiple data series (different loan types) stacked on each other. The uppermost line shows the total value of all loan types. At the same time, the stacked individual areas distinguished by colors represent the contribution of different loan types to the total loan value. This helps to visualize and compare trends in demand for every loan that has changed along with the total loan demand.

Most Appropriate Visualization Techniques. The line chart having multiple lines is most effective in representing the demand for loans over time, where the lines' color or shape distinguishes the loan type. Each loan type can be visualized and analyzed separately. An area chart is appropriate when the focus is to visualize both the trend of loan demand and the relative proportion of each loan type over time, as it has the strengths of both a line chart and stacked chart and provides a clear view of demand trend along with the total volume. Figure 17 shows the trend of demand for loan over time.

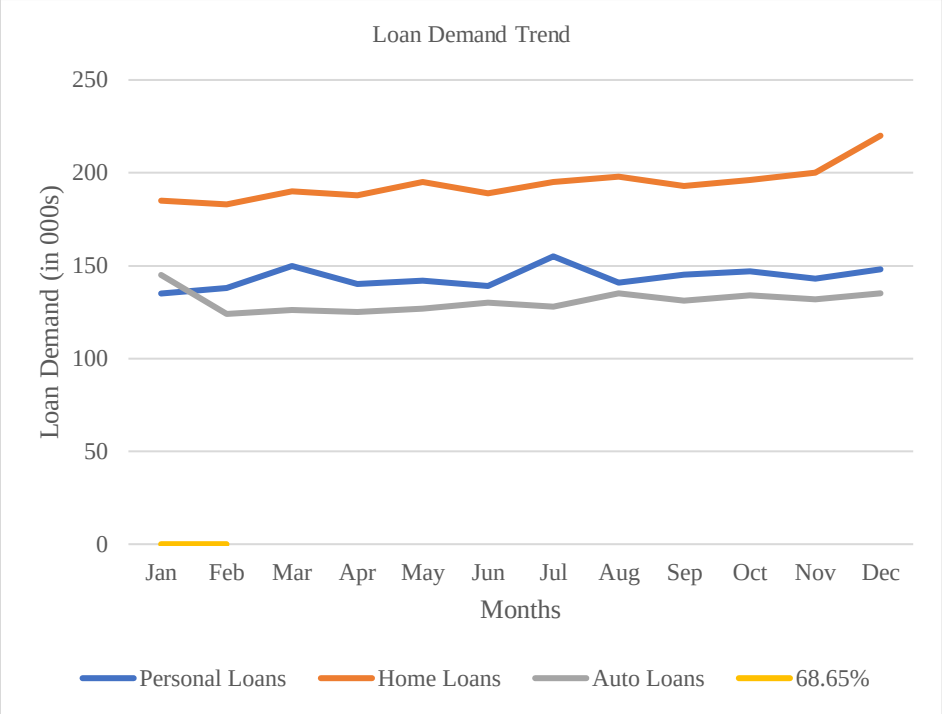

Figure 17: Loan Demand Trend

5. Loan Portfolio and Performance

   Purpose**:** Show the loan portfolio composition and performance of the loan portfolio.

   Data Type: Categorical (loan types), continuous (portfolio size and performance metrics)

   Number of Attributes: 3 (loan types, portfolio size, default rate/return on investment)

   Recommended Visualization Techniques:

   a. Bubble chart: Useful for visualizing the composition and performance of a loan portfolio. Each bubble represents a different type of loan. Each bubble size represents portfolio size (value of loan types). A larger bubble indicates a higher share, while a smaller one indicates a lower share. The bubble's position in the x and y axes represents two additional loan performance metrics: default rate and return on investment. The color can indicate the risk level associated with each loan type, from green (low risk) to red (high risk).
   b. Pie chart and line chart: A pie chart is useful for presenting the composition of a loan portfolio and a line chart shows the performance (default rate) of each loan portfolio over time. Thus, two different charts can be used separately to visualize the data.

Most Appropriate Visualization Technique. A bubble chart is very effective in presenting multiple dimensions of data simultaneously. It is suitable to highlight the size of each loan portfolio (loan type) and compare them in terms of size

and performance metrics. It is also appropriate to explore the relationship between performance metrics. Figure 18 shows the composition of loan portfolio and its default rate.

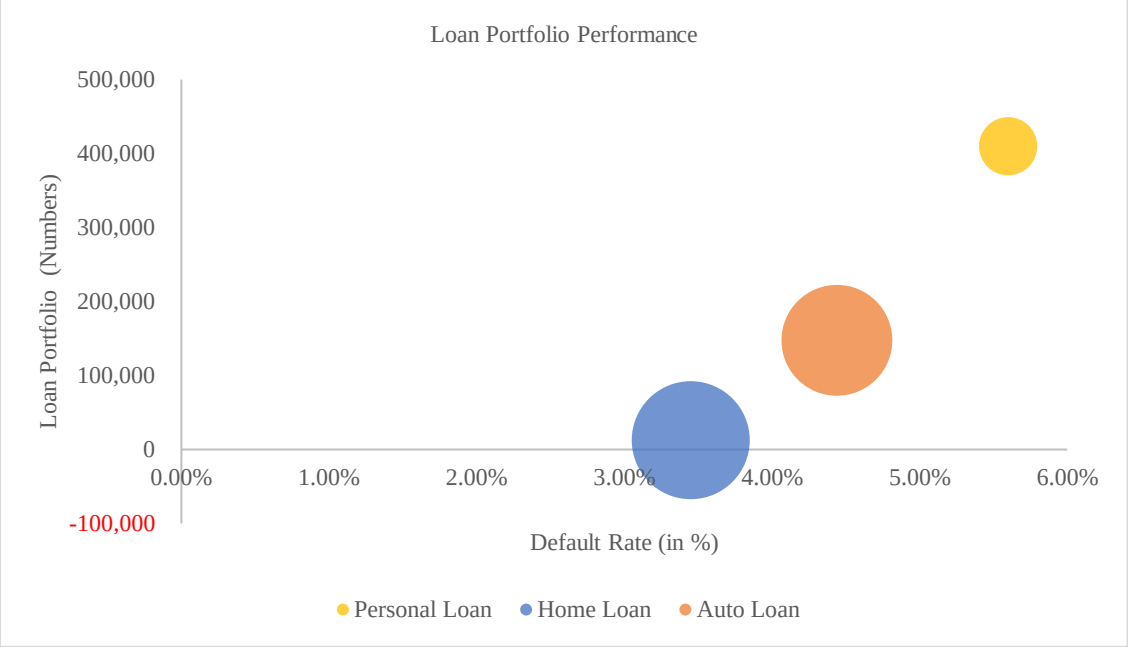

Figure 18: Loan Portfolio Performance and Default Rate

ii. Customer Onboarding Process

1. Time to Onboard

   Purpose: Present and compare the average time taken to onboard customers.

   Data type: Quantitative/Continuous (time), categorical (customer types), and time series

   Number of attributes: 3 (onboarding time in hours or days; individual/ business customers; months/quarters/years)

   Recommended visualization techniques:

   a. Grouped bar chart: Useful for comparing the time taken to onboard customers across different categories, such as customer type in different periods. The x-axis represents the customer types that are being compared over a period. The y-axis represents the onboarding time for each customer type. Bars are grouped by period, and bars represent customer type within each group. Proper labeling or color coding of bars is required to differentiate customer types and to show what is being compared.

b. Line chart: Useful for presenting changes in onboarding time over time for each customer type, allowing for easy comparison of customer onboarding time across different periods. The x-axis represents time data in weeks/months. The y-axis represents the time taken to onboard customers measured in days or hours. Each line on the chart represents a different customer type, connecting the data points for each month. A color code is given to each line to differentiate customer type.

Most Appropriate Visualization Technique. A grouped bar chart is most effective in simultaneously presenting and comparing multiple categories across different secondary dimensions. It helps to present and compare the time taken to onboard customers based on customer types and over different periods by presenting data with discrete values. Figure 19 compares the average time taken to onboard customers.

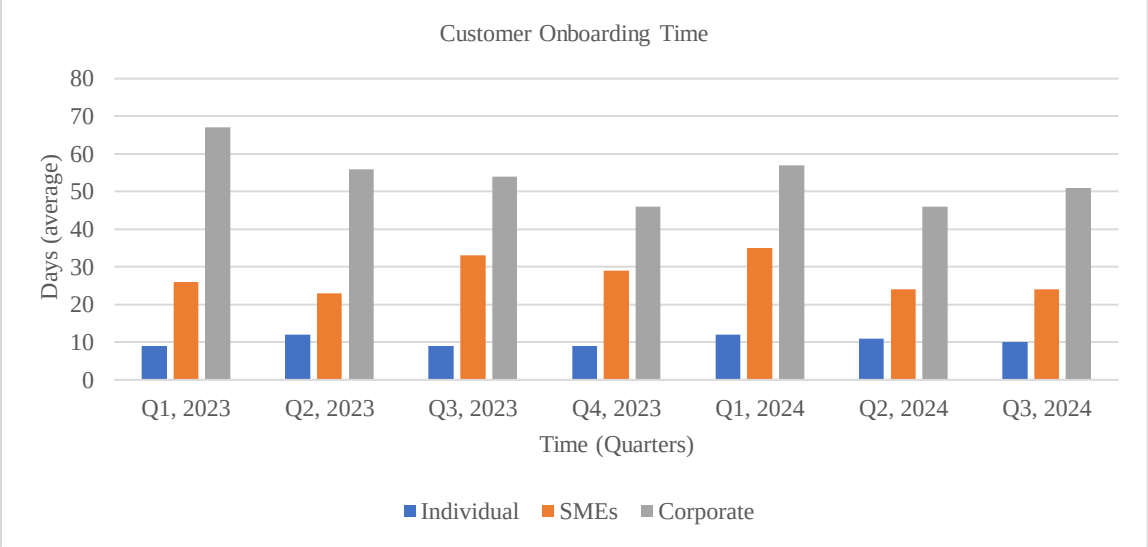

Figure 19: Customer Onboarding Time

2. Preferred Channels to Onboard

Purpose: Compare the most preferred channels by customers to onboard.

Data Type: Categorical (channel types), and numerical (number of customers)

Number of Attributes: 2 (channels- in-person, online, mobile app; number of customers by customer type)

Possible breakdowns by other factors (e.g., customer type, customer demographics) can also be done.

Recommended visualization techniques:

a. Grouped bar chart: Useful for easy comparison of customer preference across different channels, and segmented by customer type. In the graph, the x-axis represents the preferred channels. The y-axis represents

the number of customers or the percentage of customers. Bars are grouped by channel, each containing bars for customer types. A different color is used to represent each customer type.

b. Pie chart: Useful for showing the relative proportions of customers for each preferred channel. A single pie chart may become hard to read, so multiple (separate) pie charts can be created. For example, create one pie chart to present the composition of preferred channels by a single customer type. It is effective for comparison when there are fewer channels to present, and the goal is to show proportionate distribution.

c. Stacked bar chart: Useful to show the composition of customers preferring each channel. The x-axis represents different preferred channels, and the y-axis represents the number of customers. Each bar representing a channel is divided into segments of varying customer types. The height of each segment shows the contribution of that customer type to the total number of customers for that channel. This makes it easy to compare the total number of customers across different channels while showing the composition of customer types.

Most Appropriate Visualization Technique. A stacked bar chart is most effective for emphasizing the total number of customers per channel. It helps compare the number of customers across different channels for each customer type, helping to identify preferences and effectively showcase how different customer types prefer different channels. It also provides valuable insights for marketing, customer service, and product development decision-making. Figure 20 shows preferred channel by customers (types) to onboard.

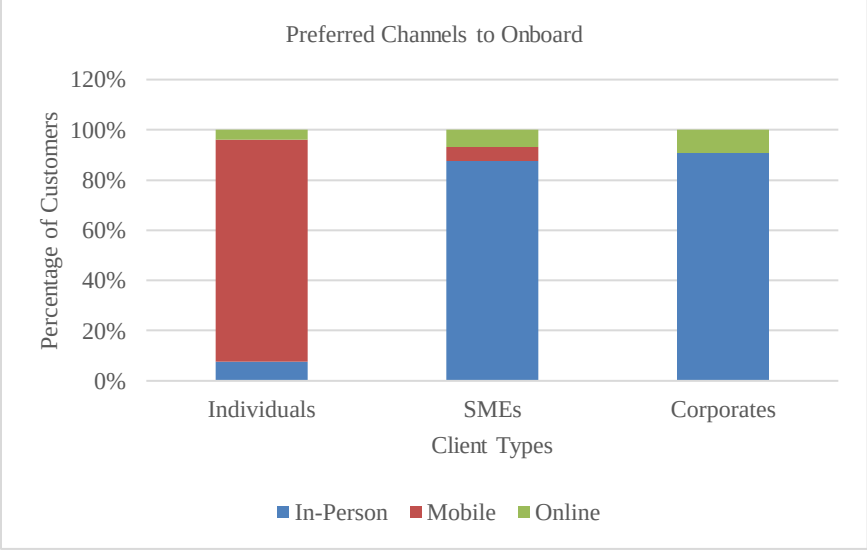

Figure 20: Preferred Channels to Onboard

3. Drop-off Point and Rate

Purpose: Identify stages with the highest drop-offs and compare rates of drop-offs.

Data Type: Categorical (drop-off point), quantitative (number), and continuous (rate)

Number of Attributes: 3 (drop-off stage; number of customers, drop-off rate)

Recommended visualization techniques:

a. Dual-axis bar chart: Useful for visualizing drop-offs, especially when comparing the number of customers at each stage of the onboarding process and tracking dropping-off rates. The x-axis represents different stages of the process. The bars in the y-axis (left) represent the number of participants at each stage, and the line graph in the y-axis (right) illustrates the drop-off rate (%) at each stage. This allows simultaneous comparison of numbers and drop-off rates.
b. Funnel chart: Useful for presenting stages in a process and the drop-off rate at each stage. It resembles the shape of a funnel and is divided into several customer onboarding stages. The width of each stage represents the number of customers that reach that stage. The wider stage means more customers, and vice versa. Each stage is labeled with its name (left side) and includes the number of customers, and an additional label (right side) may indicate the drop-off rate between stages, showing the number of customers who did not proceed to the next stage. Color can also be used to differentiate the stages or highlight significant drop-offs.

Most Appropriate Visualization Technique. A funnel chart is best to visualize different stages in the onboarding process where sequential reduction occurs and show at what stage significant drop-offs occur. Unlike the dual-axis bar chart, it provides a visual breakdown of each stage, the number of participants at each stage, and the drop-off percentage. These are crucial to identify stages where the company loses potential customers and allow it to take action to reduce drop-offs and improve conversion rates. The decreasing number of customers at each subsequent stage helps to find at which stage most customers drop off and presents a drop-off rate. Figure 21 presents the drop-off stages and the rate.

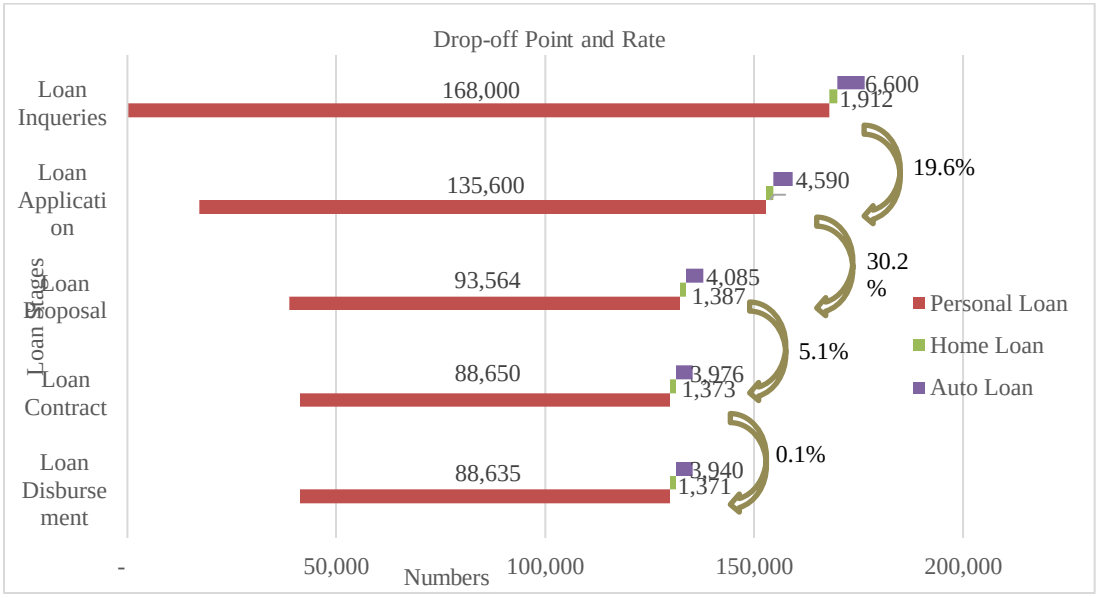

Figure 21: Customer Drop-off Point and Rate

4. Customer Satisfaction Level

   Purpose: Measure customers' satisfaction levels in each stage.

   Data Type: Categorical (ordinal – satisfaction scale); categorical (onboarding stages) and numerical (number)

   Number of Attributes: 3 (satisfaction level (very satisfied to very dissatisfied), onboarding stages, and count of respondents)

   Recommended visualization techniques:

   a. Grouped bar chart: Useful for comparing satisfaction levels of customers across different stages of the onboarding process. The x-axis represents each stage of the onboarding process. The y-axis represents the number of customers satisfied/dissatisfied. Bars in the x-axis are grouped by stages of the onboarding process, with each group containing bars for different satisfaction levels, and the length of the bar represents the number of respondents. A distinct color can be used for each bar to represent satisfaction levels.
   b. Heat map: Useful for presenting multidimensional data, such as displaying customer satisfaction levels across various onboarding stages and customer segments. Each row represents a stage of the onboarding process. Each column represents a level of very satisfied, satisfied, neutral, dissatisfied, and very dissatisfied. Each cell at the interaction of row and column presents the number of respondents at a specific stage of the process who fall into the particular satisfaction level. Heat map uses a gradient color scale to represent the frequency of responses; dark color means a high number and light color means a low number of responses.

Most Appropriate Visualization Technique. A grouped bar chart is best for measuring the satisfaction level of customers across various onboarding stages. Unlike a heatmap, a grouped bar chart provides a precise comparison of the number of respondents across different stages as each bar can be labeled with specific values. Figure 22 shows the customer satisfaction level at each stage of onboarding process.

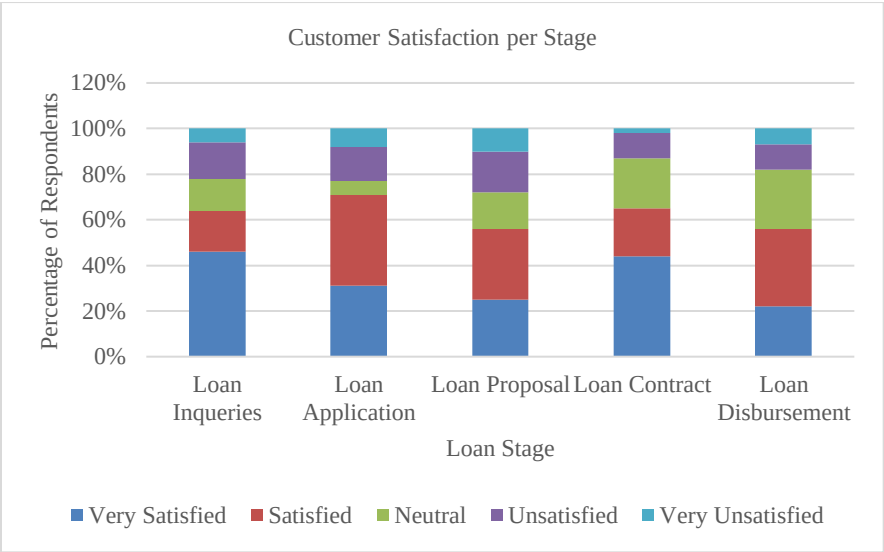

Figure 22: Customer Satisfaction Level

5. Type and Frequency of Errors

   Purpose: Identify and compare types of errors encountered across different stages in the onboarding process and their frequency of occurrence.

   Data Type: Categorical (stages), categorical (error types), and numeric (frequency)

   Number of Attributes: 3 (stages, error types, error frequency)

   Recommended visualization techniques:

   a. Grouped bar chart: Useful for presenting and comparing different types of errors and their frequency of occurrence across various stages. The x-axis represents the stage of the customer onboarding process. The y-axis represents the frequency of errors. Bars in the x-axis are grouped by stage; within each group, bars represent different error types corresponding to the stage. Each bar's height indicates the occurrence frequency of error type at a particular stage. Distinct color combinations can be used to differentiate error types.
   b. Stacked bar chart: Useful for showing the composition of the types of errors at each stage in a process, and showing how the total number of errors varies at each stage. The x-axis represents stages in the onboarding process. The y-axis represents the frequency of error. Each bar is divided into segments representing different error types. The height of each segment represents the frequency of that error type.
   c. Heat map: Useful to show a quick visual overview of the stages with the highest error rates. The row represents stages, and the column represents error types. Each cell in the heatmap is color-coded based on the frequency of the corresponding error type at that stage, with darker colors representing higher frequencies and lighter colors representing lower frequencies. It highlights stages with common error types and high error rates.

Most Appropriate Visualization Technique. A grouped bar chart is effective for comparing the frequency of different types of error across the stages of the onboarding process, identifying which types are most common at which stages. Unlike stacked bar charts, grouped bar charts allow for direct side-by-side comparison of errors and their frequency. However, the heat map is the best option for a quick visual overview if the error type is large. Figure 23 shows the types and frequency of errors.

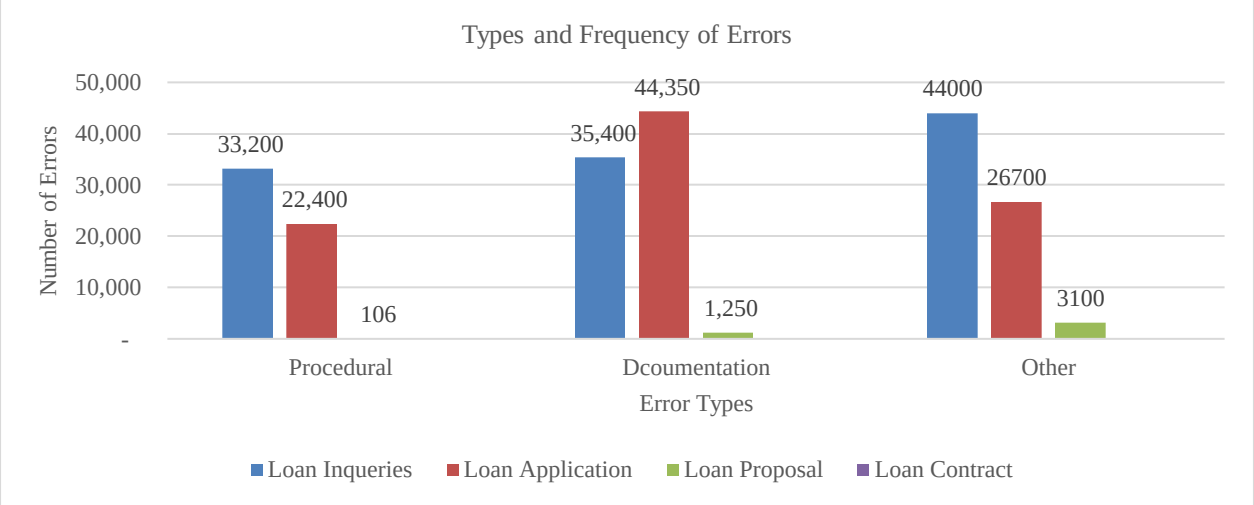

Figure 23: Types and Frequency of Errors

The result of the evaluation is summarized in the table below.

Table 4: Summary - Evaluating Data Visualization Techniques Against Insights

Insights	Purpose	Data Type	Techniques Used by Managers	Recommended Techniques	Most Appropriate (Based on Data Type and Purpose)	Why
Loan Approval Process						
Turnaround Time	Compare time taken to process the loan applications from submission to approval	1. Continuous (time in hours or days) 2. Categorical (loan types) 3. Time series (months/quarters/years)	Bar chart	1. Grouped bar chart 2. Line chart	Grouped bar chart	Grouping bars facilitates easy side by side comparison of turnaround time among different loan types over a period (weekly/monthly).
Loan Application Volume & Approval Rate	Compare and identify trends on volume of applications by type and approval rate	1. Numerical (application volume) 2. Categorical (loan types) 3. Continuous (percentage of approval rate) 4. Time series (months/quarters/years)	Table	1. Line chart 2. Grouped bar chart 3. Dual-axis chart	Dual-axis chart	Dual-axis chart with bars (loan volume by type) and line chart (approval rate) is useful here. Bars provide visual clarity and makes comparison easier among different loan types, and line chart allows to identify approval rate change (trend) over time.
Cost per Loan	Compare the total cost incurred to process loan applications (by type) along with status (approved or rejected).	1. Numerical (cost) 2. Categorical (loan types) 3. Categorical (application status)	Bar chart	1. Stacked bar chart 2. Grouped bar chart	Stacked bar chart	Stacked bar allows easy comparison of total costs along with the breakdown of costs for approved and rejected applications within each loan type.
Loan Trend	Identify the trend of demand for different loans (in amount) over time.	1. Continuous (amounts) 2. Categorical (loan types) 3. Time series (months/quarters/years)	Line chart	1. Line chart 2. Stacked bar chart 3. Area chart	Line chart	Line chart is simple and easy to interpret how demand for loan has changed over time and forecast future trends. Multiple lines allow for easy comparison of loan demand trends accross different loan types, composition of loan portfolio over time. However, use of color coding or line styles is essential.
Loan Portfolio & Performance	Present composition of loan portfolio and their performance	1. Categorical (loan types) 2. Continuous (portfolio size) 3. Continuous (default rate/ return on investment)	Pie chart	1. Bubble chart 2. Pie chart and line chart	Bubble chart	Bubble chart provide most comprehensive view of the total loan portfolio composition, default rates (performance), and loan types at a single glance. The size of each bubble give information about share of each portfolio, position of bubble represents default rate of corresponding loan portfolio and the color of bubble represent risk level associated with each loan type.
Customer Onbooarding Process						
Time to Onboard	Compare the average time taken to onboard customers.	1. Continuous (time in hours or days) 2. Categorical (customer types) 3. Time series (months/quarters/years)	Bar chart	1. Grouped bar chart 2. Line chart	Grouped bar chart	Grouping bars facilitates easy comparison of average onboarding time based on customer types over a period (weekly/monthly) simultaneously.
Preferred Channels to Onboard	Compare the most preferred channels to onboard based on proportion.	1. Categorical (channel types) 2. Numerical (number of customers)	Pie chart	1. Bar chart 2. Pie chart 3. Stacked bar chart	Stacked bar chart	Stacked bar chart is effective in showing the composition of customers prefering each channel, along with total customer. It helps to identify preferences and effectively presents how different customer types prefer different channels.
Drop-off Point and Rate	Identify stages with highest drop-offs and compare rates of drop off.	1. Categorical (drop-off point) 2. Continuous (drop-off rate) 3. Numeric (number of customers)	Table	1. Dual-axis chart 2. Funnel chart	Funnel chart	Funnel chart provides a complete view of stages in a onboarding process and highlights where drop-off occurs. It clearly shows the point at which customer drop-off and rate of drop-off between stages.
Customer Satisfaction Level	Measure customers' satisfaction levels in each stage.	1. Categorical (ordinal- satisfaction level) 2. Categorical (onboarding stages) 3. Numerical (number of respondents)	Bar chart	1. Grouped bar chart 2. Heat map	Grouped bar chart	A grouped bar chart facilitates precise comparison of satisfaction levels across different onboarding stages.
Types and Frequency of Errors	Identify and compare types of errors encountered across different stages and their frequency of occurrence.	1. Categorical (stages) 2. Categorical (error types) 3. Numeric (frequency)	List/table	1. Grouped bar chart 2. Stacked bar chart 3. Heat map	Grouped bar chart (if fewer error types) Heat map (if large number of error types)	Grouped bar chart allows for comparison of errors in detail maintaining readibility. Multiple errors types are grouped for each stage, and the length of bar represents the frequency of occurence. Using color code helps to differentiate error types. Heat map provides quick overview of the stages with the highest error rates. It is best to use when there is large error type.

Based on the interview results, managers rely on simple visualization techniques like bar charts, tables, line charts, and pie charts to present data, which have limitations in conveying information. These recommended techniques, such as grouped bar charts, dual-axis charts, stacked bar charts, line charts, bubble charts, heatmaps, and funnel charts, provide more detail and a clear view, offering significant advantages. For instance, grouped bar charts allow for detailed comparisons across multiple categories and sub-categories, and stacked bar charts help understand the breakdown of categories and total value. In contrast, dual-axis charts provide insights into relationships between two different metrics on the same graph. Line charts are great for showing trends over time. Also, multiple datasets can be presented and compared, and bubble charts add an extra layer of information by incorporating data such as size or intensity. Funnel

charts are useful for visualizing processes and spotting where things might be going wrong. At the same time, heat maps are great for highlighting data intensity, especially when dealing with a large number of variables. Overall, these advanced visualization techniques make interpreting data accurately and making informed decisions easier, providing a clearer picture than simpler methods.

For each insight, it is crucial to identify the required data and choose the right visualization technique. This analysis demonstrates the importance of considering data types and visualization's primary purpose/goal while selecting appropriate visualization techniques. All the recommended visualizations are useful for gaining insights; however, the most effective visualization techniques are tailored to the specific needs of the managers, ensuring that the data is presented most effectively for their decision-making processes.

6 Discussion

In this study, an overview of various insights that bank managers seek from two specific banking processes, the loan approval process and the customer onboarding process, and the visualization techniques they use to achieve these insights were collected. Then, the suitability of these techniques was evaluated based on academic literature, and recommendations on the most appropriate technique to achieve specific insight were made.

This research aims to evaluate the data visualization techniques currently used by bank managers, compare them with proven methods from the literature, and recommend the most appropriate technique for extracting specific insights from banking processes. The study seeks to guide managers in the banking sector in selecting and using the right data visualization techniques to improve decision-making and operational efficiency.

The evaluation results on the loan approval process demonstrate that choosing an appropriate visualization technique is crucial for effectively communicating specific insights. Grouped charts excel in comparing multiple categories simultaneously, making them ideal for showing and comparing variations in loan application turnaround times across different periods and loan types, helping identify bottlenecks and improving process efficiency. Dual-axis charts (which have grouped bars and line graphs) help compare two datasets and present trends or any relationship between two datasets over time, providing a comprehensive view of how changes in application volume impact approval rates, aiding in capacity planning and resource allocation. Stacked bar charts provide a clear representation of the distribution of total costs per loan along with the breakdown of cost, making it easier to identify which cost components are most significant and assist in identifying cost-saving opportunities. Line charts effectively track changes over time, thus being the best choice for trend analysis to help predict future loan demand. Bubble charts, with their ability to represent three dimensions of data, offer a comprehensive view of loan portfolios and performance metrics. They enable a detailed analysis of factors such as loan portfolio composition, default rate, loan types, or risk categories and guide risk management. In a nutshell, the evaluation results indicate that grouped charts are effective for visualizing loan application turnaround time, dual-axis charts for loan application volume and approval rate, stacked bar charts for cost per loan, line charts for loan trends, and bubble charts for loan portfolio and performance.

The evaluation results on the customer onboarding process demonstrate that grouped charts provide a detailed comparison of turnaround times across different periods and customer types, helping to identify bottlenecks or

inefficiencies and improve process efficiency. Stacked bar charts offer a clear visual representation of customer preferences for onboarding channels, aiding in determining the most and least popular methods. Funnel charts are particularly effective for visualizing customer drop-off points, showing at which point the most significant attrition occurs. Grouped bar charts facilitate easy comparison of customer satisfaction levels, while grouped charts allow easy comparison of types and frequency of errors, however, if the number of errors is too high a heat map is most appropriate to use. In a nutshell, the evaluation indicates that grouped charts, stacked bar charts, funnel charts, grouped bar charts, grouped bar charts/or heatmaps are effective in presenting these insights: customer onboarding time, preferred channels to onboard by customers, customer drop-off point and its rate, customer satisfaction level and types of errors occurred and their frequency respectively.

The interviews and evaluation results indicate that the visualization techniques currently employed by managers are useful for deriving specific insights. However, literature suggests alternative visualization techniques can provide more detailed and precise information, making it easier to spot insights. These recommended techniques, including improved versions of graphs and charts, convey information more clearly and efficiently, enhancing the ability to gain specific insights.

The findings from this study align well with existing research in the field of data visualization. The study's results are consistent with the research emphasizing the importance of selecting appropriate visualization techniques based on data type and visualization purpose. For instance, [66] some researchers have emphasized the importance of choosing the appropriate technique to achieve specific insight, considering the data type and the user's intended purpose. The study confirms the significance of trends and comparisons in data visualization, as noted by [11]. The results show that managers frequently seek to understand trends in loan approvals and customer onboarding processes, which aligns with [11]'s observation that such insights are highly valuable for decision-making. The evaluation of various visualization techniques supports the conclusions of [56] and [66]. These researchers emphasized the effectiveness of bar charts, grouped charts, doughnut charts, bubble charts, and line charts for presenting quantitative data. This study found similar results, highlighting the utility of these techniques in visualizing different metrics such as loan turnaround times and customer satisfaction levels. Using dual-axis charts to compare loan application volumes and approval rates aligns with the existing literature recommending dual-axis charts for comparing two related datasets with different units[72]. Stacked bar charts were effective for cost breakdowns per loan, consistent with previous research that advocates for their use in showing parts of a whole. The findings validate the use of funnel charts for visualizing customer drop-off points, as endorsed by[68], [69], [70]. These charts effectively illustrate the progression through various process stages, which is crucial for identifying where significant reduction occurs in the customer onboarding process.

Practitioners, particularly in the banking sector, can use these findings to enhance their decision-making process. Most importantly, they can use the overview of recommended visualization techniques to get more accurate insights effectively. Managers can use the presented overview as guidance to select an appropriate technique based on their purpose. The implications of these findings are significant for bank managers and decision-makers managing the loan approval process and customer onboarding process. By utilizing the most effective visualization techniques, managers can enhance their ability to interpret and understand data and make informed decisions. They can get more precise insights into critical performance metrics, enabling more informed decision-making. Effective visualizations can help

identify patterns of loan default, enable accurate risk assessments, identify bottlenecks and inefficiencies, enable areas for process improvement, identify trends, aid in predicting future loan demand, and enable proper resource allocations. In addition, effective visualization helps identify customers' pain points and areas for improvement, leading to a smoother onboarding experience. This includes identifying and addressing bottlenecks in the onboarding process, reducing delays and errors, and improving efficiency. Additionally, it helps detect suspicious patterns, which is crucial for fraud detection. Integrating customer feedback into the onboarding process allows for continuous improvement and personalization of services. In a nutshell, by utilizing the most effective visualization techniques, managers can get deeper insights into the process performance, identify bottlenecks and areas for process improvement, and make data-driven decisions to enhance customer experience.

While this study provides valuable insights into using specific visualization techniques to visualize process data, it is not without limitations. These include the potential lack of generalizability to other domains due to the study's focus on two specific banking processes – loan approval and customer onboarding. The insights gathered from interviews are subject to personal biases, and the dependence on subjective assessment to evaluate visualization techniques may introduce bias. The sample size and scope were limited, potentially affecting the robustness and applicability of the findings. Additionally, there is not a single "best" visualization, as it is heavily dependent on the purpose and available data types, and this research serves more as a guidance.

7 Conclusion

In the rapidly evolving banking sector, banks increasingly leverage large volumes of data generated from various digital channels to improve their services and make informed business decisions. The critical nature of these decisions necessitates accurate and effective data visualization techniques to interpret complex datasets and extract actionable insights.

Despite the significance of data visualization in the banking sector, there is a significant gap in the literature regarding the most effective visualization techniques designed to gain insights from critical processes such as loan approval and customer onboarding. This research was essential for identifying the most suitable visualization techniques to present clear and precise insights for enhancing operational efficiency and decision-making in the banking sector.

This study has provided a comprehensive overview of various data visualization techniques, focusing on their applicability and effectiveness. Then, data visualization techniques were evaluated against the goal of achieving specific loan approval, and customer onboarding process insights based on the academic literature and recommendations were provided. This research contributes to understanding which visualization techniques are most suitable for presenting data related to specific insights based on the purpose and available data within the context of banking business processes.

Interviews were conducted with bank managers to identify the key insights that they seek from the loan approval and customer onboarding processes and the techniques they use to gain these insights. Subsequently, various visualization techniques—including dual-axis charts, grouped charts, stacked bar charts, line charts, bubble charts,

scatter plots, heat maps, and funnel charts—were assessed for their ability to provide these insights. This evaluation was grounded in the literature review results and practical applications in presenting specific insights to ensure a robust comparison.

The findings indicated that specific visualization techniques are more effective for particular insights. For instance, dual-axis charts were determined to be optimal for contrasting loan application volumes and approval rates, while funnel charts effectively emphasized customer drop-off points. These findings resolve the research problem by providing guidelines on which visualization techniques are suitable for which purposes, as there is no single "best" visualization technique to achieve specific insights using banking data. Ultimately, this research underscores that data visualization stands as an important instrument for managers in the banking sector as it enables them to dig into business processes and make informed decisions by presenting data in a visually understandable manner. Consequently, more precise and insightful decision-making is facilitated.

Despite the valuable insights it provides, this research does have several limitations. Findings may only apply to some sectors due to the exclusive emphasis on two particular banking processes. Additionally, the study relied on subjective assessments from a limited sample size of bank managers, which could introduce bias. The evaluation of visualization techniques was also subjective, which may affect the perceived effectiveness of different techniques.

Future research could extend this work by investigating a broader range of banking processes and integrating more samples of respondents. Furthermore, the effectiveness of various visualization techniques could be validated using objective assessments such as experiments where banking managers could evaluate their current techniques against your recommended techniques. Further, future research could investigate the impact of user expertise on the effectiveness of different visualization techniques, as preferences and needs of users may vary, and provide insights into how to tailor visualizations to various audiences. In addition, future research may explore the effectiveness of these visualization techniques across other domains with different data types.

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