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UNDERSTANDING THE INFLUENCE OF DATA VISUALIZATION TECHNIQUES ON DECISION-MAKING PROCESSES IN BUSINESS

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In this era of data-driven business, information processing is a challenge as well as an opportunity for business firms and society as a whole. Data visualisation techniques have emerged as the best-fit solution to these dynamic challenges of information processing and information management. Visualisation methods also have a profound impact on data collection, data quality, data presentation, and the decision-making process of e-commerce firms in particular, and on society in general.The primary objective of this study is to explore the impact of data visualisation techniques on the decision-making process for e-commerce business firms. The sub-tasks include the role and magnitude of effective data visualisations, their benefits and drawbacks for the decision-making process, identification of factors affecting the data visualisation quality, and identifying the emerging data visualisation techniques for an effective decision-making process. The methodology of this research study includes qualitative as well as quantitative methods. We adopt a theoretical framework and perform an assessment with a case study to validate the impact of data visualisation on the decision-making process. This mixed-method approach provides multi-dimensional insights for the research study; it helps us to assess the decision-making process theoretically as well as empirically. The mixed method also jointly assesses the decision-making process within the context of the data visualisation techniques. The primary contribution of this research study is to explore the relationship between data visualisation techniques and the decision-making process of e-commerce firms. The research study explores data visualisation techniques, assesses the quality of information available for decision-making, develops a theoretical framework to upscale data visualisation, and also examines emerging visualisation techniques like augmented reality (AR), virtual reality (VR), and explainable AI visualisations. The study thoroughly investigates the role of data visualisation techniques to enhance the decision-making process. It also provides a theoretical framework to facilitate information quality for effective decision-making with emerging data visualisation methods. The research provides insights on data visualisation techniques within the context of the decision-making process of business firms. The research also provides an assessment for data quality, data presentation and lists appropriate visualisation techniques for each goal.

Key words: *data analytics, visualization tools, decision support systems, graphical representation, performance metrics, information management.*

Нестеров В. Ф. Визначення впливу методів візуалізації даних на процеси прийняття бізнес-рішень

У теперішній час, коли світ насичений даними, обробка інформації є викликом, а також можливістю для бізнесу і суспільства в цілому. Методи візуалізації даних стали найкращим рішенням для вирішення проблем обробки та управління інформацією. Методи візуалізації також мають глибокий вплив на збір даних, їх якість, представлення і процес прийняття рішень компаніями у сфері електронної комерції, зокрема, і на суспільство в цілому. Основна мета цього дослідження полягає у визначенні впливу методів візуалізації даних на прийняття рішень у компаніях, що займаються електронною комерцією. Завдання статті включають вивчення ролі і ефективності візуалізацій даних, її переваги та недоліки для процесу прийняття рішень, визначення факторів, що впливають на якість візуалізації, а також визначення впливу нових методів візуалізації на ефективність процесу прийняття рішень. Методологія цього дослідження включає як якісні, так і кількісні методи. Щоб підтвердити вплив візуалізації даних на процес прийняття рішень були досліджені наукові публікації і роглянуті приклади. Цей змішаний підхід забезпечує багатовимірне розуміння взаємозв'язків, що допомагає оцінити процес прийняття рішень як теоретично, так і емпірично. Змішаний метод також спільно оцінює процес прийняття рішень у контексті методів візуалізації даних. Основним внеском цього дослідження є вивчення зв'язку між методами візуалізації даних і процесом прийняття рішень компаніями електронної комерції. У дослідженні розглянуто методи візуалізації даних, надана

оцінка якості інформації, що доступна для прийняття рішень, розроблено теоретичну основу для високоякісної візуалізації даних, а також вивчено нові методи візуалізації, такі як доповнена (AR) та віртуальна реальність (VR), а також рішення на основі штучного інтелекту. Ретельно досліджено роль методів візуалізації даних для покращення процесу прийняття рішень. Дослідження також забезпечує оцінку якості даних, представлення даних і перераховує відповідні методи візуалізації для кожної цілі.

Ключові слова: *аналітика даних, засоби візуалізації, системи підтримки прийняття рішень, графічне представлення, показники ефективності, управління інформацією.*

Introduction. Information visualization in business decision-making is a multidisciplinary phenomenon that remains poorly understood due to its integration of knowledge from various conventional and analytical disciplines, including information technology, business studies, cognitive psychology, architecture, art theory, philosophy, design profession, and other social sciences. Muhovič (1997) highlighted that the statistical rise in image data since the 1970s has prompted a fresh comprehension of the significance of pictures in cognitive processes, leading to a surge in scientific studies of information visualization across separate fields like psychology, art theory, philosophy, information technology, and management of information systems. Current research in information visualization primarily focuses on empirical methodologies and applications aimed at designing effective visualizations (Liu et al., 2014).

Problem statement. The influence of information visualization on business decision-making is multifaceted and complex. Visually representing data can offer several benefits, including facilitating pattern recognition, uncovering hidden trends and relationships, and communicating intricate information more effectively. Well-designed visualizations have the potential to make large datasets more accessible, enabling decision-makers to swiftly identify key insights and anomalies that may have been obscured in raw numerical data. Additionally, information visualization can aid in conveying findings and recommendations to stakeholders, fostering a shared understanding and facilitating more informed decision-making processes.

However, it is crucial to acknowledge the potential pitfalls associated with information visualization. Poorly designed or misinterpreted visualizations can inadvertently distort or obscure vital information, leading to flawed decision-making outcomes. Furthermore, the effectiveness of information visualization can be impacted by several things, such as the intricacy of the data, the decision-maker's level of expertise, and the specific visualization techniques employed.

Given the profound impact that information visualization can have on business decision-making, it is imperative to develop a comprehensive understanding of the factors that contribute to its effectiveness and the specific ways in which it can improve the quality of information provided to decision-makers.. By addressing these considerations, businesses can leverage the power of information visualization to enable more informed and data-driven decision-making processes.

Analysis of recent research and publications. The role of information visualization in enhancing decision-making processes has been extensively studied across various domains, including business, finance, and healthcare. Numerous researchers have investigated the potential benefits and challenges associated with employing visual representations of data to support decision-making.

Information visualization has been found to facilitate cognitive processes involved in decision-making, such as pattern recognition [1], trend identification [2], and insight generation. The research [3] demonstrated that graphical representations of data can improve decision-making performance by enhancing the decision-maker's ability to extract relevant information and identify relationships within the data. Similarly [4],

found that well-designed visualizations can reduce cognitive load and improve decision accuracy, particularly in complex decision scenarios.

The efficacy of information visualization in decision-making has been attributed to several factors. Firstly, visualizations leverage the human visual system's ability to process and interpret visual information more efficiently than raw numerical data [5]. Secondly, effective visualizations may highlight patterns, trends, and outliers that are difficult to recognise from tabular data representations [6]. Additionally, visualizations can facilitate the communication and sharing of insights among decision-makers, fostering collaboration and consensus-building.

However, research has also highlighted potential pitfalls and limitations associated with information visualization in decision-making contexts. Poorly designed or inappropriate visualizations can mislead decision-makers, leading to erroneous conclusions or decisions [7]. Furthermore, the effectiveness of visualizations may be inclined by individual differences, such as the decision-maker's level of expertise, cognitive abilities [8], and familiarity with the visualization techniques employed [9].

Researchers have also explored the interplay between information visualization and decision-making processes within specific business contexts. For instance, in the realm of finance and investment, visualizations have been found to aid in identifying market trends [10], evaluating portfolio performance [11], and communicating investment strategies [12]. In supply chain management, visualizations have been employed to optimize resource allocation, monitor inventory levels, and identify bottlenecks in logistics operations [13].

Despite the substantial body of research on information visualization and decision-making, further research is needed on the precise aspects that contribute to the usefulness of visualisations in business decision-making processes.. Additionally, the impact of emerging visualization techniques, such as interactive and immersive visualizations, on decision-making quality warrants exploration.

Task statement. This research aims to explore the intricate relationship between information visualization and quality of information in corporate decision-making processes. By analysing actual data and theoretical frameworks, this study seeks to provide insights into optimizing the use of information visualization techniques, ultimately empowering organizations to make more informed and data-driven decisions.

Results. Data visualization involves representing data or information in visual formats like charts, graphs, maps, and diagrams. The main purpose is to effectively communicate complex datasets or insights in a way that is easy for the human brain to understand and process. Well-designed visualizations can reveal patterns, trends, outliers, and relationships inside data that may not be readily apparent from raw numbers alone. This aids in exploratory data analysis and gaining meaningful insights from the information. Beyond just exploring data, visualizations are powerful tools for communicate information effectively and simply to both technical and non-technical audiences. Techniques like line charts, bar graphs, scatter plots, and histograms allow for identifying trends over time, making comparisons across categories, and visualizing the distribution of values. Maps and location-based visualizations are particularly useful for displaying geographic or spatial data. Interactive dashboards that incorporate various chart types can enable monitoring of key metrics and tracking changes dynamically.

Combining visualizations with narratives can help communicate findings, conclusions, or messages from data analysis in a compelling and memorable way. Common visualization tools and techniques include charts, plots, diagrams, dashboards, and increasingly advanced interactive and dynamic methods. Effective visual representations facilitate

data-driven decision-making across numerous domains, from business intelligence to scientific research and data journalism [14]. Ultimately, visualizing data leverages the human brain's ability to process visual information efficiently. By presenting data visually, patterns and insights can be derived more easily compared to working with raw numbers or tables alone. As data volumes continue to grow, the importance of data visualization in understanding and communicating insights from complex datasets will only increase. Data visualization techniques play an important role in businesses across various functions and industries. Here are some common data visualization techniques used in business settings:

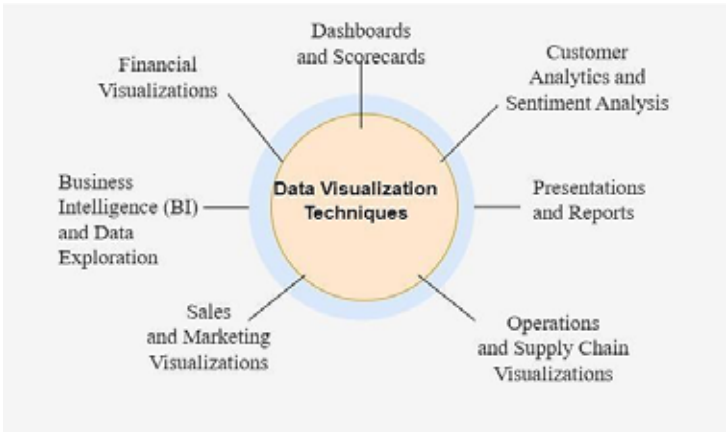

Fig. 1. Data Visualization Techniques in Business

1. Dashboards and Scorecards: Executive dashboards provide an at-a-glance view of key performance indicators (KPIs) and metrics through charts, gauges, and scorecards. These visualizations help monitor business performance, track goals, and identify areas that require attention.
2. Financial Visualizations: Line charts and candlestick charts are used to visualize stock prices, trading volumes, and financial trends over time. Pie charts and bar charts can represent revenue streams, expenses, and budget allocations.
3. Sales and Marketing Visualizations: Geographical maps and heat maps are used to visualize sales data, customer locations, and market penetration. Funnel charts illustrate the customer journey, conversion rates, and drop-off points in the sales pipeline. Bar charts and histograms can display product sales, website traffic, and campaign performance.
4. Operations and Supply Chain Visualizations: Gantt charts help plan and track project timelines, tasks, and resource allocation. Sankey diagrams visualize the flow of materials, products, or resources through different stages of a supply chain. Control charts and run charts are used for quality control and process monitoring.
5. Customer Analytics and Sentiment Analysis: Word clouds and tag clouds visually represent customer feedback, opinions, and sentiments from social media or reviews. Scatter plots and correlation matrices can identify relationships between customer attributes and behaviors.
6. Business Intelligence (BI) and Data Exploration: Interactive dashboards and data visualization tools (e.g., Tableau, Power BI, Qlik) combine multiple visualizations for data exploration and analysis. These tools enable drill-down, filtering, and slicing of data to uncover insights and patterns.

7. Presentations and Reports: Well-designed charts, graphs, and infographics are commonly used in business presentations and reports to effectively communicate data-driven insights and findings to stakeholders.

Data visualization plays a pivotal role in facilitating informed decision-making processes across various domains. By transforming complex datasets into visually compelling representations, such as charts, graphs, maps, and diagrams, data visualization techniques enable decision-makers to quickly grasp patterns, trends, and relationships that may be obscured within raw numerical data. Well-designed visualizations act as powerful tools for communicating insights and fostering a shared understanding among stakeholders, ultimately supporting more data-driven and collaborative decision-making.

Moreover, data visualization is particularly valuable in situations where decision-makers need to analyze and interpret large volumes of data from multiple sources. Interactive dashboards and dynamic visualizations can real-time insight into important metrics and performance indicators allows decision-makers to monitor vital elements. and respond promptly to emerging trends or anomalies. Additionally, data visualization techniques can aid in scenario analysis and forecasting, allowing decision-makers to explore potential outcomes and evaluate the impact of various decisions before implementation. Data visualization [15] enables decision-makers by taking use of the human brain's capacity to efficiently interpret visual information to derive insights more effectively and make better-informed choices based on the available data. Here are some key ways in which data visualization supports effective decision-making:

Identifying Patterns and Trends. Visualizations like line charts, scatter plots, and time-series graphs help decision-makers quickly identify patterns, trends, seasonality, and outliers in data. These insights can inform decisions related to forecasting, strategic planning, and identifying areas for improvement or optimization.

Comparing Performance and Metrics. Bar charts, pie charts, and radar charts allow decision-makers to easily compare performance across different categories, regions, products, or time periods. This comparative analysis supports data-driven decisions related to resource allocation, investment prioritization, and performance evaluation.

Monitoring Key Indicators. Dashboards and scorecard visualizations provide at-a-glance visibility into key performance indicators (KPIs) and metrics. Decision-makers can monitor these critical measures in real-time, enabling timely and informed decisions based on the current state of the business.

Exploring Relationships and Correlations. Scatter plots, correlation matrices, and advanced visualizations like parallel coordinates can help uncover relationships, correlations, and interdependencies between different variables or factors. These insights support decisions related to root cause analysis, risk assessment, and understanding the impact of potential changes.

Communicating Insights Effectively. Well-designed visualizations can effectively communicate complex data, findings, and recommendations to stakeholders, including non-technical decision-makers. Clear visual representations facilitate buy-in, alignment, and informed decision-making across teams and organizations.

Facilitating Data-Driven Storytelling. By combining visualizations with narratives, decision-makers can create compelling data stories that provide context, highlight key insights, and support their recommendations or decisions with evidence-based arguments.

Enabling Interactive Exploration. Advanced data visualization tools and dashboards allow decision-makers to interactively explore data, ask "what-if" questions, and dynamically analyze the impact of different scenarios or assumptions before making decisions.

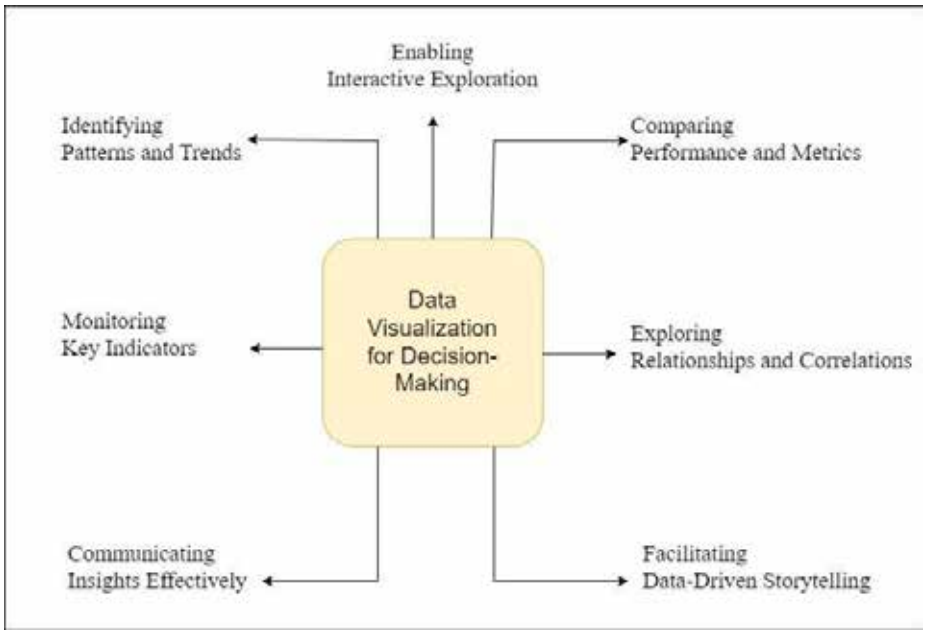

Fig. 2. Decision Making using Data Visualization

Data visualization has become an indispensable tool for businesses, significantly enhancing the decision-making process across various functions and levels. By transforming complex datasets into clear and visually appealing representations, visualizations empower decision-makers to rapidly identify patterns, trends, and insights that may be obscured in raw data. This accelerated analysis and improved understanding of underlying factors and relationships enable more informed and accurate decisions. Moreover, well-designed visualizations serve as a universal language, facilitating effective communication and collaboration among teams and stakeholders, fostering alignment and consensus-building. Dashboards and scorecards highlight critical metrics and key performance indicators, allowing decision-makers to quickly pinpoint areas requiring attention or prioritization. This focused approach drives targeted and impactful business strategies. Additionally, the ability to create compelling data stories through a combination of visualizations and narratives strengthens the persuasiveness of proposals and recommendations, aiding in more convincing decision-making processes.

Interactive visualizations and scenario analysis tools empower decision-makers to explore various "what-if" scenarios, test assumptions, and evaluate the potential impact of different choices before implementation. This proactive approach supports risk-informed decision-making and encourages a culture of data-driven experimentation [14]. Furthermore, embedded visualizations in reporting systems enable continuous monitoring of decision outcomes, enabling agile course correction and driving a cycle of continuous improvement in decision-making processes. Data visualization has become a powerful catalyst for data-driven decision-making in businesses, enhancing analytical capabilities, fostering collaboration, and enabling more informed, strategic, and adaptive choices that drive better performance and competitive advantage.

Table 1

Impact of Data Visualization of Decision Making

Title	Key Findings/Contributions	Tool/Technique Used	Purpose
"Narrative Visualization: Telling Stories with Data"	Proposed a framework for designing effective narrative visualizations that combine data, visuals, and textual elements to create compelling data-driven stories.	Narrative visualization design principles and techniques	Develop a framework for effective data storytelling through visualizations.
"Visual Analytics for Decision-Making in Business Intelligence"	Developed a visual analytics system for interactive exploration and analysis of business data, enabling better decision support and insights discovery.	Visual analytics system with interactive visualizations	Provide a visual analytics system for enhanced business intelligence and decision support.
"The Role of Data Visualization in Strategic Decision-Making: A Case Study of a Retail Company"	Examined the impact of data visualization on strategic decision-making processes in a retail company, highlighting improved understanding, communication, and alignment.	Dashboards and data visualization tools (e.g., Tableau)	Evaluate the impact of data visualization on strategic decision-making in a retail company.
"Enhancing Financial Decision-Making with Interactive Visualization Tools"	Proposed a novel interactive visualization tool for financial data analysis, demonstrating its effectiveness in supporting investment and portfolio management decisions.	Custom interactive visualization tool for financial data	Develop an interactive visualization tool to support financial decision-making.
"A User-Centric Approach to Data Visualization for Supply Chain Management"	Developed a user-centric data visualization framework tailored for supply chain management, enabling better decision-making through improved visibility and insight into complex supply chain operations.	User-centric data visualization framework and tools	Propose a user-centric data visualization framework for supply chain management.
"Augmented Reality Visualization for Data-Driven Manufacturing Decisions"	Explored the potential of augmented reality (AR) visualizations for enhancing data-driven decision-making in manufacturing environments, demonstrating improved efficiency and accuracy in production planning and quality control decisions.	Augmented reality (AR) visualizations	Investigate the use of augmented reality visualizations for data-driven decision-making in manufacturing.

Table 1 (continuance)

"Visualizing Customer Behavior for Targeted Marketing Decisions"	Presented an interactive visualization dashboard for analyzing customer data and identifying customer segments, informing targeted marketing strategies and campaign decisions.	Interactive visualization dashboard	Develop a visualization dashboard to support targeted marketing decisions based on customer data analysis.
"Immersive Data Visualization for Collaborative Decision-Making in Virtual Environments"	Developed an immersive data visualization system leveraging virtual reality (VR) technology, enabling collaborative exploration and decision-making among dispersed teams in a shared virtual environment.	Virtual reality (VR) immersive data visualization system	Explore the use of virtual reality for immersive data visualization and collaborative decision-making.
"Explainable AI Visualizations for Transparent Decision-Making in Healthcare"	Proposed a framework for visualizing explainable AI models in healthcare, supporting transparent and trustworthy decision-making processes by providing interpretable insights into model predictions and recommendations.	Explainable AI visualization framework and techniques	Develop a framework for visualizing explainable AI models to support transparent decision-making in healthcare.
"Data Visualization for Sustainable Business Decisions: A Case Study in the Energy Sector"	Examined the use of data visualization techniques to support sustainable business decisions in the energy sector, demonstrating how visualizations can inform decisions related to energy efficiency, resource management, and environmental impact.	Data visualization tools and techniques for sustainability data	Explore the use of data visualization for supporting sustainable business decisions in the energy sector.

According to the literature table, data visualization has been playing an increasingly important role in supporting effective decision-making processes across various business domains. The studies cover a wide range of applications, including strategic planning, financial management, supply chain operations, manufacturing, targeted marketing, collaborative decision-making, healthcare, and sustainable business practices in the energy sector. The research efforts have focused on developing novel visualization techniques, frameworks, and systems that leverage emerging technologies such as augmented reality (AR), virtual reality (VR), and explainable AI models. These advancements aim to enhance data exploration, communication, and collaboration, enabling more informed and transparent decision-making. Several studies have emphasized the importance of user-centric and narrative approaches to data visualization, combining visuals with textual elements and storytelling techniques to create compelling data-driven narratives that resonate with decision-makers and stakeholders.

Conclusions. Data visualization has become an indispensable tool for enhancing business decision-making processes across various industries and domains. This study has comprehensively explored the intricate relationship between information visualization and the quality of information available to decision-makers. Through an extensive review of empirical evidence and theoretical frameworks, several key findings have emerged. First, well-designed visualizations have the remarkable ability to transform complex datasets into clear and visually appealing representations, enabling decision-makers to rapidly identify patterns, trends, and insights that may be obscured in raw numerical data. This accelerated analysis and improved understanding of underlying factors and relationships empower more informed and accurate decision-making.

Second, the study has highlighted the crucial role of data visualization in facilitating effective communication and collaboration among teams and stakeholders. By presenting information in a universal visual language, visualizations foster alignment, consensus-building, and shared understanding, ultimately supporting more collaborative and inclusive decision-making processes. Furthermore, the research has underscored the value of interactive visualizations and scenario analysis tools in enabling decision-makers to explore various "what-if" scenarios, test assumptions, and evaluate the potential impact of different choices before implementation. This proactive approach supports risk-informed decision-making and encourages a culture of data-driven experimentation and continuous improvement.

Additionally, the study has explored the potential of emerging visualization techniques, such as augmented reality (AR), virtual reality (VR), and explainable AI visualizations, in enhancing decision-making processes. These cutting-edge technologies offer new avenues for immersive data exploration, collaborative decision-making in virtual environments, and transparent decision-making through interpretable AI models.

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