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COLLEGE OF BUSINESS AND ECONOMICS

ADOPTION OF EMERGING TECHNOLOGY TOOLS IN LOGISTICS INDUSTRY: PRIORITIZATION USING ANP AND BOCR METHODS

BY

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ABSTRACT

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Master of Business Administration

Title:_Adoption of Emerging Technology Tools in Logistics Industry: Prioritization Using ANP and BOCR methods

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This study aims to prioritize technology tools in the logistics industry. It focuses on four key technology trends: Augmented Reality (AR), the Internet of Things (IoT), Big Data, and Robotics and Automation (R&A). The objective is to determine the prioritization and ranking of these technologies in the logistics sector using the Analytic Network Process (ANP) model and analyzing using the Benefits, Opportunities, Costs, and Risks (BOCR) model.

The study identified specific criteria and sub-criteria to evaluate the technologies, and experts from the fields provided judgments based on these criteria. Applying the ANP and BOCR models, the research presents the ranking of the technology trends, highlighting their importance and potential impact on the logistics industry. The findings of this research help to gain further knowledge of the technology adoption in the logistics sector and provide valuable insights for industry professionals and decision-makers.

DEDICATION

I dedicate this project to my beloved husband and daughter. Your unwavering support and encouragement have been my driving force. Thank you for being my inspiration and the center of my world.

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CHAPTER 1: INTRODUCTION

The logistics industry is a critical sector that plays a crucial role in the global economy by providing efficient and successful movement of goods from one place to another. According to a report by the World Bank (2021), global trade in goods and services accounted for approximately 59% of the world's gross domestic product (GDP) in 2019. This highlights the significant economic impact of the logistics sector on a global scale. The industry has witnessed significant changes over the past few years, with technologies playing a crucial role in shaping the industry. The adoption of these technologies has been recognized as a key strategy for improving the competitiveness and sustainability of the logistics industry (Abdirad & Krishnan, 2021).

The logistics sector in Qatar has perceived notable development in recent years. According to a study by the Qatar Chamber (2020), the logistics sector in Qatar has experienced a firm expansion, driven by the country's efforts to enhance its transport infrastructure and establish itself as a regional logistics hub. Qatar's strategic location and world-class infrastructure, including modern ports, airports, and logistics facilities, have positioned it as a key player in the logistics landscape of the Middle East.

Furthermore, Qatar's logistics sector has been supported by various government initiatives aimed at further enhancing its competitiveness. The Qatar National Vision 2030, for instance, emphasizes the development of a sustainable and diversified economy, with logistics playing a vital role in achieving these goals ("Qatar National Vision 2030 - Government Communications Office", 2023). This commitment is reflected in ongoing projects such as the development of Hamad Port and the expansion of Hamad International Airport, which aim to strengthen Qatar's logistics capabilities and increase its global connectivity.

Despite the potential benefits, the adoption of technology in the logistics sector poses challenges for firms. The decision-making process for adopting new technologies is complex and involves evaluating various criteria, including technological feasibility, financial capability, and organizational readiness (Khan et al., 2022). Prioritizing these criteria and selecting the most appropriate technologies can be an overwhelming task for logistics firms, especially in the environment of the rapidly emerging technological landscape.

To address these challenges, several studies have proposed the use of decision-making tools and techniques to support the technology adoption process in the logistics industry. One such tool is the Analytic Network Process (ANP), which is a multi-criteria decision-making approach that considers both qualitative and quantitative factors (Hassini, Surti, & Searcy, 2012). ANP is compatible with evaluating complex decision-making scenarios with interdependencies among decision criteria and alternatives. Another tool that has been proposed is the Benefits, Opportunities, Costs, and Risks (BOCR) method, which is a structured approach for evaluating the overall impact of new technologies on logistics firms (Hassini, Surti, & Searcy, 2012)

Given the potential of these decision-making tools, this study aims to examine the adoption of technology tools in the logistics industry and prioritize them using ANP and BOCR. The study will focus on four technologies that have gained big attention in the logistics industry: Augmented Reality, the Internet of Things, Big Data and Robotics and Automation. These technologies have been identified as critical enablers of the digital revolution of the logistics industry.

A mixed-methods research approach will be applied in this study, including qualitative and quantitative data collection and analysis methods. Semi-structured interviews will be conducted with logistics experts and practitioners to gather the data.

The collected data will be analyzed using ANP and BOCR methodologies to prioritize the four technologies based on their overall impact on logistics firms.

1. What are the major factors affecting the adoption of Augmented Reality, Internet of Things, Big Data and Robotics & Automation technologies in the logistics industry?
2. How do logistics firms evaluate the benefits, opportunities, costs, and risks associated with the adoption of AR, IoT, R&A, and Big Data technologies?
3. What is the prioritization of AR, IoT, R&A, and Big Data technologies in the logistics industry based on their overall impact on logistics firms' operations, competitiveness, and sustainability?

The Findings are expected to contribute to the decision-making process for adopting technology tools in the logistics industry. The use of ANP and BOCR methods will provide a structured approach for prioritizing these technologies, considering their benefits, opportunities, costs, and risks. The study's recommendations are expected to advise logistics firms' technology adoption strategies, enabling them to identify and prioritize technologies that offer the most significant potential for improving their operations, competitiveness, and sustainability. The adoption of these technologies presents several challenges to logistics firms, including complex decision-making processes.

CHAPTER 2: LITERATURE REVIEW

Logistics Industry: Overview

The logistics industry is a crucial sector that plays a critical role in the global economy. It encompasses various activities, including planning, execution, and management of the flow of products, commodities, and data from the generation site to end consumers (Jenkins, 2020). According to a report by the World Bank, global trade in goods and services accounted for approximately 59% of the world's gross domestic product (GDP) in 2019 (World Bank, 2021).

One of the main functions of the logistics industry is supply chain management. Supply chain management includes coordinating all activities related to the procurement, manufacture, and the movement of goods and services. Effective supply chain management ensures the timely delivery of products to the end consumer, reduces costs, and minimizes inventory holding. Effective supply chain management is a crucial driver of competitiveness in the logistics industry.

The logistics industry heavily relies on transportation, which is crucial in facilitating the movement of goods and services between different locations. Various factors, such as distance, urgency, cost, and the nature of the goods transported, influence the mode choice. Market Research Future (2021) predicted that the global transportation industry will grow by 3.4% from 2020 to 2027.

In the logistics industry, warehousing and inventory management play integral roles. Warehouses serve as storage facilities for goods before distribution to the end consumer. Active inventory management ensures the availability of the appropriate product quantities at the right time, thereby reducing the risk of stockouts and lowering holding costs. Effective inventory management is essential in minimizing supply chain costs and enhancing operational efficiency within the logistics industry (Shah & Mittal, 2020).

Customs brokerage is another critical aspect of the logistics industry, especially for international trade. Customs brokers facilitate the clearance of goods through customs by ensuring compliance with all customs regulations, documentation, and payment of duties and taxes. Customs brokerage facilitates international trade and reduces trade barriers (Gwardzińska, 2014).

Logistics is essential in boosting trade and commerce across industries and geographies. It encompasses various activities such as shipping, storage, inventory management, supply chain management, and logistics consultancy. Efficient logistics operations are crucial for the successful functioning of businesses as they enable the timely delivery of goods and services to customers at a reasonable price. The growth of the logistics industry has been steady over the years, driven by factors such as globalization, e-commerce, and the increasing complexity of supply chain operations (Kain et al., 2018).

In recent years, there has been a significant shift in the logistics sector towards adopting new technological innovations like Internet of Things, automation and big data analytics (Zakery, 2011). These innovations could revolutionize logistics operations by improving efficiency, cutting costs, and creating new avenues for development and innovation. However, the proliferation of new technologies challenges businesses in determining which technologies to adopt and in what order.

The logistics industry is witnessing another trend driven by the growth of e-commerce and the escalating need for prompt delivery services, including same-day and next-day delivery (Castillo et al., 2018). In response to this demand, new logistics models, such as micro-fulfillment centers and last-mile delivery solutions, have emerged. These models aim to enhance delivery speed and minimize expenses by positioning products near consumers and implementing more effective delivery approaches.

The logistics industry faces several challenges, including changing customer demands, increasing competition, and the need for trade liberalization and transparency throughout the supply chain. The COVID-19 pandemic has also highlighted the industry's vulnerabilities, such as disruptions to supply chains and the need for more resilient and flexible logistics networks (Aloui et al., 2021). Logistics companies must adapt to these challenges by adopting new technologies, improving operational efficiency, and developing sustainable logistics practices.

Technology Trends: Overview

As technology advances, it becomes increasingly interconnected and complex. Computer software is now integral to various sectors, including automobiles, aircraft, medical devices, financial transactions, and electricity systems, making them difficult to comprehend and control (Rotolo et al., 2015). The logistics industry has not been spared from this phenomenon, as it has become necessary for logistics providers to adopt advanced technological solutions to remain competitive in the market (Olorunniwo et al., 2020). Logistics technology achieves the expectations of modern consumers, who are technologically savvy, by providing prompt delivery, real-time visibility, flexibility, and excellent customer service. Therefore, it is now an option for logistics companies to stay caught up in technological trends if they want to survive in the long term.

The logistics industry is experiencing significant technological change. As logistics companies adopt new emerging technologies, it is increasingly important to be aware of the trends and developments in this field and to make informed decisions about which technologies to adopt (Schwab, 2017). Technological advancements such as artificial intelligence (AI) and blockchain are transforming the logistics industry and creating new opportunities for growth and innovation (Schwab, 2017). Businesses in the logistics industry must be proactive in their approach to technology adoption, rather than reactive, to remain competitive and provide the best possible service to their customers.

Technological advancements significantly impact the logistics industry. To remain competitive, logistics companies must understand the latest technological trends. The logistics industry's ability to keep up with technological advancements is critical to meeting consumer demands, increasing efficiency, and reducing costs. Therefore, businesses in the logistics sector must carefully choose their technology and be proactive in adopting new solutions to stay ahead of their competitors.

Automation and robots are employed for inventory monitoring and other logistics activities to increase productivity and reliability in warehouse operations. Robots and other automated systems may carry out operations like picking and packaging, resulting in quicker and more precise completion of orders. Additionally, businesses can utilize automation to increase inventory tracking accuracy, reducing the risk of stockouts and excess inventory (Radivojević & Milosavljević, 2019). Furthermore, IoT technology enables the internet-based interconnection of devices and things, enabling data sharing and communication between them.

Companies may collect and evaluate data in real time by providing connectivity, which enables them to decide more effectively and increase efficiency. Integrating IoT in logistics has the potential to enhance supply chain visibility, track and monitor goods, and improve delivery accuracy (Malik et al., 2021)

Likewise, by analyzing vast volumes of data, big data analytics gives businesses fresh perspectives and empowers them to make more educated decisions. Big data analytics may help logistics organizations understand consumer behavior, market trends, and supply chain efficiency better. Studies have shown that the logistics industry benefits from applying big data analytics, as it improves operational efficiency, optimize routes, and enhances overall supply chain performance (Fosso et al., 2018).

Integrating AR technologies such as Machine Learning (ML) and Natural Language Processing (NLP) into logistics activities can offer real-time data analysis, predictive maintenance, and decision-making functionality. Moreover, routing and scheduling can be made more efficient, inventory control can be enhanced, and customer support can be automated using AR technology (Remondino, 2020).

Technology Trends in the Logistics Industry

Augmented Reaity (AR)

Augmented Reality Technology

According to Ginters and Martin-Gutierrez (2013), Augmented Reality (AR) is a technology that enhances users' perception of the real-world view by overlaying computer-generated visuals, sounds, and other information. AR is an emerging technology that has been gaining increasing interest due to its capability to augment the real-world environment with additional digital elements, such as text, video, and audio, using specialized hardware, software, and peripherals (Reif & Günthner, 2009).

AR is used to modify the real world with virtual visuals, essentially merging virtual and real-world information (Bimber & Raskar, 2005). This technology is often employed in real-time and semantic contexts with ambient factors, providing users an enhanced view of reality (Cirulis & Ginters, 2013). AR devices may include spectacles, tablets, laptops, cell phones, and similar items that display digital layers of information, providing users with an augmented view of reality.

AR technology eliminates boundaries between the digital and physical worlds, providing users with an augmented perspective of reality that incorporates digital information (Radivojević & Milosavljević, 2019). It gives users the appropriate information at the appropriate time and location, making it an effective tool for various applications, including education, healthcare, entertainment, and retail.

AR is a rapidly evolving technology that has the potential to transform the way we interact with the world. It allows us to enhance our real-world experience by superimposing digital information onto our view of reality. Various industries increasingly adopt AR technology, and its potential applications are virtually limitless. Technological advancements and increasing demand for enhanced user experiences drive its adoption. As AR technology continues to evolve, it will likely become an even more integral part of our daily lives.

Application of AR in Logistics

The use of smart goggles in warehouses for picking, sorting, and packaging processes; smart handling of forklifts and trucks; smart delivery of products to the end user utilizing smart goggles and others are all potential AR applications in logistics. Research and development of AR devices, the capability to recognize images, and the connection of devices to software applications will develop the environment for the implementation of AR in all logistics activities (Radivojević & Milosavljević, 2019).

AR may be used in a variety of human-operated applications in logistics where having more information might greatly reducing handling errors. Even though the existing literature is sparse, it is still possible to describe practical scenarios of AR applications in internal logistics, including efficient receiving, storing, picking, delivering, and managing inventory. In addition, numerous value-added activities in logistics can benefit from AR technologies. Regarding augmented reality applications in logistics, order picking is the most researched subject. Considering its operational complexity and economic significance (the picking area accounts for over 50 percent of storage costs), it is also a logistical field with a tremendous process optimization possibility (Wang et al., 2020). According to DHL's "Augmented Reality in Logistics" research, organizations including Knapp, SAP, and Ubimax have attempted to employ AR technologies to merge different tasks, like real-time object identification, barcode reading, navigation system, to achieve fast picking process, free of error and user friendly (Matthias & Kuckelhaus, 2014).

Using AR technology, the 3D model projections and computer-generated visuals can help logistics operations overcome several obstacles (Cirulis & Ginters, 2013). The authors contended that AR has the ability to transform logistics by drawing on successful applications in other industries and initial experimental use cases in warehouse environments. The authors highlighted the importance of three-dimensional spatial instructions, which AR can provide instead of traditional text and image-based guides. (Cirulis & Ginters, 2013) Also suggested that AR has the possibility to improve the working conditions of warehouse employees by eliminating stress-inducing situations and monotonous routines. AR can significantly impact logistics operations by enhancing the quality of work and increasing productivity.

Cirulis and Ginters (2013) stated the potential of AR technology in the logistics industry to improve the quality and value of logistics services. They argued that although Radio Frequency Identification (known as RFID) technology improves the efficiency of logistics item identification, it is not entirely foolproof and can lead to significant losses and damages. Therefore, the authors suggested integrating AR technology could reduce errors by providing additional 3D visualization-based item checks. Specifically, they proposed integrating AR and RFID solutions in a warehouse setting. By combining the two technologies, they observed that it is possible to make logistics item identification more accurate and comprehensive, thereby enhancing the efficacy of logistics operations.

Plakas et al. (2020) provided an overview of augmented reality's potential applications in logistics and manufacturing, followed by a case study detailing the implementation of an AR-Smart Glasses application at a distribution warehouse operated by a major telecommunications provider to improve order fulfillment. The authors highlighted the specific features and functional takeaways from the pilot installation of the created AR system.

According to the authors, augmented reality technology can enhance order processing in warehouse logistics, which is otherwise a laborious and error-prone activity. They also emphasized that the AR system was deployed in real-world manufacturing scenarios and integrated into the delivery center's ordering process, suggesting the viability and potential of this technology in logistics.

Benefits and Opportunities

AR technology has emerged as a valuable tool for logistics-related processes such as packing, processing, storage, and shipping. Incorporating AR technology can simplify these processes and make them more user-friendly by reducing the risk of errors in object selection and decision-making duration. Furthermore, AR can help address various logistical challenges, including difficult circumstances and repetitive warehouse worker tasks (Cirulis & Ginters, 2013). The successful implementation of AR in various businesses and warehouse-based experiments demonstrate the potential and prospects of AR in logistics, making it an industry-wide development in logistics that can improve the effectiveness and efficiency of logistical procedures.

According to a study by (Cirulis & Ginters, 2013), the benefits and opportunities of adopting augmented reality in logistics, particularly in order fulfillment, are significant. The authors claimed that by providing workers with additional data to assist in item localization, AR technology could reduce the risk of errors. They also noted several logistical applications for augmented reality, including game creation and pathfinding methods. The study describes how AR technology can provide workers with additional information to locate objects more quickly. Using content production and pathfinding tools to locate and visualize goods in virtual warehouses was promoted as streamlining and enhancing logistical operations. Augmented reality is becoming increasingly popular in various industries and professions because it can enhance human perceptions and capabilities by integrating virtual data with the real world.

Augmented reality technology is a system that combines both real and virtual objects by integrating technological devices into the existing perspective of the real world. For AR technology to function, a sensor that captures live images and a screen showing both the actual world and the virtual world (Jagtap et al., 2020). When applied in commercial processes, Industrial Augmented Reality (IAR) technology has shown numerous significant benefits in logistics. To integrate AR technology in an industrial setting, technological considerations, and organizational characteristics are two essential factors for success. IAR has already shown promise in logistics by lowering the risk of errors, increasing flexibility, boosting dependability, and enhancing employee safety. The use of IAR processes in the logistics sector offers several opportunities, such as improving worker safety, facilitating maintenance, enabling training, enhancing quality assurance, optimizing design and layout, strengthening information exchange, fostering location-based work activities, supplying language translation, and identifying products close to their expiry date (Jagtap et al., 2020).

Augmented reality technology in the logistics industry offers various benefits and opportunities. AR technology can streamline and simplify logistical processes, reduce the risk of errors, and enhance employee safety. Integrating AR technology in logistics offers new opportunities to improve quality assurance, optimize design and layout, strengthen information exchange, and improve training methods. As such, AR technology represents a significant development in logistics that has the potential to enhance efficiency and effectiveness in the industry.

Costs and Risks

The implementation of AR in logistics poses several challenges that require addressing. One of the main obstacles is the high cost associated with deploying AR technology in a business environment, which includes the expense of expensive equipment and the need for employee training (Jagtap et al., 2020). Integrating AR technology with current systems and procedures can also be difficult, requiring technological adaptation and staff training.

Inaccuracy and time-consuming algorithms are two other issues that impede the effective use of AR technology in logistics. Although efforts have been made to improve alignment accuracy and reduce algorithm complexity, further progress is needed to achieve the desired effect of AR applications (Masood & Egger, 2020).

Privacy is also a primary challenge with AR in logistics, as the technology may collect and store sensitive data in the cloud, posing a risk of breach and data theft (Rejeb, 2019). Customers may also have concerns about privacy related to AR-based service enhancements. Moreover, hardware and software limitations impact the speed and efficiency of AR systems, particularly in outdoor logistics contexts that require processing power to handle complex simulated scenes and display motion in variable environments (Rejeb, 2019).

Therefore, implementing AR in logistics presents significant risks and costs, including the need for employee training, expensive equipment, technological adaptation, privacy concerns, and hardware and software limitations. To fully leverage the potential benefits of AR technology in logistics, it is imperative to address these challenges.

Internet of Things (IoT)

Internet of Things Technology

The Internet of Things (IoT) has emerged as a transformative technology reshaping how society and the economy operate. IoT enables connected devices to share data about their state and surroundings, providing new opportunities for logistics applications through sensors, smart processors, and wireless communication systems (Tadejko, 2015). RFID has been the most commonly used identifying device for IoT applications in logistics due to its widespread availability and affordability. However, recent developments in beacon technology can potentially transform the industry and expand RFID's application (Radivojević et al., 2017).

Each IoT device must be tagged with a unique digital identifier to ensure the compatibility and functioning of devices from different manufacturers. The IoT is a system that relies on advanced data and communication methods to enable the labeling, recognition, communication, and procedural knowledge of objects, creating a digital representation of the real world that offers a range of services to consumers (Radivojević et al., 2017). The features of IoT include embedded security and confidentiality methods, scalability, wireless broadband sharing, energy-optimized alternatives, tracking item capabilities, and self-organization capacities, which are critical to its effectiveness in logistics (Radivojević et al., 2017).

IoT is a revolutionary technology that has several advantages for logistics operations, such as improved efficiency, transparency, and accessibility. However, the implementation of IoT in logistics also poses challenges, including compatibility issues and the need for unique digital identifiers for each device. It is essential to address these challenges and leverage IoT's advanced data and communication methods to generate smart apps and services that can enhance logistics operations and maximize the benefits of IoT in logistics.

Application of IoT in Logistics

The application of IoT technology in logistics helps boost the efficacy and efficiency of managing freight transportation (Jianli, 2012). To handle product details, vehicle direction, and data transmission, a system that integrates RFID, GPS, and GPRS innovations was suggested by one of the studies. A vehicle-mounted processor controls each properly functioning module, and the system allows GPRS to transfer the data it gathers to a remotely controlled management center. According to the author, this method can efficiently handle cargo loading, enhance vehicle alignment, and reduce the time needed to manage cargo transit.

The IoT has several practical implications for every global logistics supply chain phase, from manufacturing to retailing, by enhancing visibility, enabling real-time delivery tracking, boosting data integrity, and accelerating exception monitoring. With applications like real-time cargo tracking, warehouse management, proactive asset maintenance, and enhanced last-mile transportation, the logistics sector outperforms other industries using data-driven IoT technology (Tadejko, 2015). Beacon technology is also a viable solution for boosting the retail customer experience via IoT. Beacons use Bluetooth to communicate with customers' cell phones and deliver relevant and customized information. Customers may specify their interests and receive pertinent information when entering a store. Machine-to-Machine (M2M) communication is an essential component of IoT, initiating a transformation in this field. New IoT networks effectively tackle market issues from an M2M viewpoint to M2M solutions, mostly found on vertical portals and exclusively serve one particular vertical platform.

There is four-layer designs for the IoT idea, comprising of the Perception, Network, Middleware, and Applications levels as suggested by (Radivojević et al., 2017). The Perception layer includes physical items outfitted with identifying technologies, including RFID, GPS, and WSN. Among smart objects and the systems that process them, comprising networking devices like PAN, LAN, MAN, and WAN, data and information are transmitted more easily thanks to the network layer. The Middleware layer comprises information systems that employ hardware and software components for data collection and processing in the context of Big Data to generate consumer services. The application layer comprises several services offered to consumers in different industries. The authors claim that logistics is one industry where IoT technology can be actively employed. It may support fast and high-quality decision-making in the logistics industry using the present status of the items, systems, and environment. Companies can employ IoT devices to maintain and track the flow of products, streamline distribution networks, and enhance the general efficacy and efficiency of logistical operations. It may offer in-the-moment insights into the logistics process by gathering and interpreting data from physical things, allowing businesses to make the right choices, cut costs, and improve customer satisfaction (Radivojević et al., 2017).

Benefits and Opportunities

Applying IoT technology in logistics can present several advantages and prospects (Jianli, 2012). A cargo transportation management system may be created to develop the effectiveness of managing cargo transit by integrating RFID, GPS, and

GPRS technologies. The system employs GPRS for data communication, GPS for vehicle orientation, and RFID to keep track of the commodities. According to the authors, this combination of systems provides efficient control of the delivery of products and the direction of the truck, as well as the capability to identify and correct faults in real time. They assert that this increased efficiency results in less time expenses and better overall logistical data management. Data gathered by an IoT system may also be transmitted to a remotely controlled monitoring center, increasing the visibility and openness of logistical operations.

Logistics is one of the first industries to adopt IoT technology due to its reliance on a robust logistical network, communication between supply chain participants, fast and accurate information, and real-time data (Radivojević et al., 2017). The real-time surveillance of shipping and replenishment equipment, logistical units, cargo, and people is made possible by implementing IoT in logistics. It makes optimizing people, systems, and resources possible while assessing resource performance and arranging logistically controlling operations and processes, analyzing all relevant data, and automating business operations. IoT ideas in logistics could examine the most significant impacts on quality improvement, cost reduction, and enhanced efficiency at the point of logistics activities, players in the distribution network, and on a global scale (Radivojević et al., 2017). IoT enables linking numerous resource-constrained connected systems, objects, and people via the Internet protocol, enabling constant data transfer and complete visibility and openness in logistical operations. Smart services and apps that may enhance logistics operations and general efficacy can be developed using the helpful information retrieved from IoT data (Tran-Dang et al., 2020).

Implementing advanced tracking and monitoring systems enabled by IoT significantly improved compliance in the logistics industry (DHL, 2015). According to

DHL, IoT-based tracking systems have led to a 10-15% increase in compliance in the logistics industry. This enhanced compliance helps companies avoid costly fines and penalties but also helps to build trust with customers, ultimately improving the overall quality of service.

Costs and Risks

Enforcing the IoT in logistics has resulted in several advantages and opportunities, but it also brings risks and costs. One of the main concerns of IoT in logistics is security, as using multiple connected devices and systems can create vulnerabilities and increase the risk of cyberattacks (Botta et al., 2016). Moreover, IoT implementation requires significant hardware, software, and network infrastructure investments, which may pose challenges for small and medium-sized logistics companies (Hakim et al., 2023).

The widespread adoption of connected devices threatens data privacy and security, necessitating effective governance of IoT (Tadejko, 2015). As the number of connected devices transmitting information or data regarding a user's local environment increases, the risk of unauthorized access or hacking increases. As a result, it is critical to implement modifications to protect data privacy and security fundamentals. Another main challenge is the requirement for scalable applications to store and analyze the vast amount of data generated by IoT devices. In addition, designing IoT system architecture that allows the connectivity of millions of connected devices is a challenging technological and scientific task (Tadejko, 2015).

IoT architecture for logistics requires guidelines for network-enabled objects. Conventional transport methods such as Wi-Fi and GSM 3G/LTE systems cannot adequately satisfy the needs of IoT sensor systems. Additionally, there is a need for ubiquity and regulation of methods for device detection, reporting systems, and authentication, as well as the requirement for every IoT device to communicate with any software or service. Several protocols, including MQTT, XMPP, CoAP, DDS, and proprietary, are required for IoT.

In addition, managing and interpreting the substantial volume of real-time data in data centers gives rise to additional concerns about security, storage, and analysis. As a result, applying data mining methods such as Machine Learning or deep learning is crucial to uncover concealed details that can be employed to enhance service value and effectiveness (Tadejko, 2015).

Cryptographic security services for resource-constrained IoT systems require further research to guarantee the confidentiality, reliability, validity, and integrity verification of exchanges between various parties (Hussein, 2019). In commercial interactions, it is critical to keep smart objects from providing competitors with access to sensitive data that they can exploit maliciously. There are challenges in managing and analyzing data in IoT, particularly when utilizing AI and machine learning techniques. Energy-efficient sensors and transmission methods are required to implement intelligent IoT capabilities. The transport layer is one of the most critical IoT challenges to assure end-to-end dependability and manage capacity. Several protocols' inability to offer enough end-to-end dependability is a risk factor for the successful application of IoT in logistics (Hussein, 2019).

Robotics and Automation (R&A)

Robotics and Automation Technology

Automation involves the employment of various computerized technologies, whereas robotics is the design and usage of robots to carry out specified tasks. In the e-commerce logistics industry, robotics and automation are vital technologies that combine efficiency, scale, and adaptability (Huang et al., 2015). Automation through automated storage and retrieval system can provide significant efficiency while being constrained in adaptability when contending with order inequalities in size, form, weight, and mechanical characteristics. By combining the strengths of automation with the supplementary capabilities of robotics, robots can result in a major paradigm change in logistics business applications.

Automation is a solution to labor scarcity in the contractual logistics sector, and logistics firms have difficulties adjusting to the expansion of e-commerce (Lizzio et al., 2019). R&A may cause some individuals to lose their employment. However, they may also contribute to establishing new positions that include working with and retaining automated machines and software. Automation might require considerable modifications to personnel and the entire logistics sector.

Robotics and Automation are two components of Industry 4.0's first pillar. Robots may be designed to move items and perform jobs reliably and constantly in various combinations. Although robots were first primarily utilized in packing and palletizing, their usage has now spread to other areas of the food logistics sector. On the other hand, automation is described as the use of several kinds of automated technologies. Automation primarily boosts efficiency by reducing the time needed to complete jobs, improving production and profit. For example, it helps businesses to free workers from risky working conditions, such as loading and offloading large objects or driving forklifts in awkward places (Jagtap et al., 2020). The reduction of expenses, the increase in production, and the improvement of productivity are the primary drivers behind implementing R&A in a business.

Robotic process automation (RPA) is a software technology that uses artificial intelligence and machine learning capabilities to automate routine tasks, allowing employees to focus on more complex and strategic tasks (Willcocks et al., 2017). RPA systems can imitate human actions, such as navigating computer systems, copying and pasting data, and filling out forms, to complete tasks with accuracy and speed. The use of RPA in supply chain management has gained significant consideration in recent years due to its potential to improve efficiency and reduce operational costs. RPA has become increasingly important across industries, with a survey revealing that 52% of companies have invested more than $10 million in RPA technology (KPMG, 2019). Furthermore, it can improve data accuracy and quality and enable real-time tracking and monitoring of supply chain processes, leading to better decision-making and improved customer satisfaction.

Application of Robotics and Automation in Logistics

Due to its potential to completely transform logistics operations, incorporating robots and automation technologies into the logistics industry has recently attracted much interest. R&A have a major effect on the logistics sector and possess the ability to alter the current methods for storing and retrieving items (Huang et al., 2015). The studies also covered the ideas of robotics grid warehousing and cellular warehouse management as cutting-edge approaches to automated retrieval and storage solutions. In their paper, a Logistics Automation Service System (LASS) corporate concept is also suggested by (Huang et al., 2015). In this approach, key players may concentrate on their core strengths while enhancing one another's knowledge and exchanging risks and rewards. This concept demonstrates the possibility for shared investments in robotic logistics systems by leveraging the recently developed idea of the Product Service System (PSS).

Robotics and automation are revolutionizing logistics (Lizzio et al., 2019). These innovations have various applications, such as computerized ports, automated air and sea freight, and autonomous transportation. The implications of autonomous trucking on highways, railroads, and ports were discussed in the first part of the sequence (Lizzio et al., 2019). Although ports are speeding up the deployment of R&A, companies still need to cover their expenses, and performance is still decreasing. Port managers may take several actions to optimize the advantages of automation. Advancements in automation technologies have led to the release of new products by companies such as Ocado Retail, Common-Sense Robotics, Grey-Orange, and XPO Logistics. As per the forecasts, by 2030, AI technology will enable the automation of several logistics-related processes. For instance, managers and supervisors will utilize virtual reality goggles to synchronize both human and robotic systems and real-time inventory tracking will be provided via logistics management systems (Lizzio et al., 2019). Logistics businesses are engaging cautiously despite the prospect of automation and robotics for five reasons: e-commerce and technical advancements, purchasing issues, the possibility of a shift in the omnichannel logistics system, and the hazards of temporary contracts. Finally, robots and automation are transforming the logistics industry, and there are many applications of these innovations, notably autonomous trucking, port mechanization, and automation in maritime and air freight lines (Lizzio et al., 2019). Nevertheless, development in automation technologies is very slowly increasing, and logistics firms are leery of the dangers these technologies provide.

The relevance of Robotics and Automation in the logistics sector is highlighted by (Jagtap et al., 2020) as a critical component of Industry 4.0. Robots and automation in the agricultural logistics industry are motivated by the need to lower costs, boost output, and enhance productivity and working conditions. Robots, in various forms, can perform tasks continuously and consistently, and their use in agricultural logistics enables complete monitoring and transparency across the supply chain. The authors also highlight how automating operations may increase productivity by reducing job time requirements and enhancing accuracy while eliminating workers from dangerous working settings. Employing automated guided vehicles (AGV) in inventory logistics is a way to boost productivity, maximize flexibility, and reduce labor and operational costs. The employment of swarm robots for moving, transporting, sorting, packing, and delivering products, together with sensor arrays and detection systems, to assure environmental safety (Jagtap et al., 2020). Despite the positive outcomes, many businesses are reluctant to implement these technologies owing to a lack of information about the technology and worries about the expense of upkeep and maintenance. The authors emphasize the significance of spreading knowledge about the advantages of R&A in the logistics industry.

Benefits and Opportunities

Applying R&A in logistics presents various advantages and prospects (Huang et al., 2015). One of the key benefits of automation is its capacity to boost the efficiency and effectiveness of e-commerce logistics operations, resulting in improved client satisfaction by ensuring quick delivery. In addition, in digital commerce logistics operations, robots offer a balance between adaptability, effectiveness, and flexibility by employing mobile robot picking techniques. Moreover, the concept of robotics grid warehouses and cellular warehouses (CW) can potentially revolutionize the operations of automated logistics systems for e-commerce, making them more competent and adaptable. The business strategy LASS (Logistics Automation Service System) allows stakeholders share risks and gains while concentrating on their core competencies (Huang et al., 2015). With this concept, investors can invest in robotic e-commerce logistics and share the benefits of using R&A.

In the logistics industry, using robots and automation has several advantages and potential (Jagtap et al., 2020). Firstly, deploying robots and automation reduces costs and increases output volume and velocity, resulting in higher productivity and a better work environment. Secondly, R&A provide manufacturing flexibility, especially when immediate modifications are necessary to meet customer demands. The consistency and repeatability of robotic operations make them ideal for logistics tasks such as packing and stacking pallets. Additionally, integrating automation and robotics in logistics processes provides end-to-end surveillance and traceability across the distribution network, which is crucial for handling essential commodities. The authors highlight that the optimal application of robots in logistics is to optimize product handling and transportation by combining robotics with sensor systems and imaging technology (Jagtap et al., 2020). Automating these processes improves the work environment by enabling the distribution of workers more consistently. Logistics operations such as arrival, initial processing, quality control, packing, and palletizing will increasingly become automated.

The deployment of automation and robotics in logistics also enhances productivity by reducing the time required to complete tasks, improving product quality, and increasing revenue. Furthermore, automation reduces defects, meets production requirements, minimizes waste, and increases profits. The deployment of R&A also positions a company as innovative, boosting its competitive edge. For instance, autonomous guided vehicles (AGVs) can facilitate the transfer of items, providing essential mechanization for warehouse logistics (Jagtap et al., 2020). AGVs enhance productivity, reduce labor and operational costs, and allow for facility reorganization. In warehouses, companies utilize R&A to actively move swarms of objects on rails and carry out tasks such as transportation, packing, and shipping. They deploy proximity sensors and detection systems to ensure a safe work environment for human workers.

Technology has also played a crucial role in reducing defects in the logistics industry. By deploying R&A, companies can significantly reduce errors caused by manual processes such as picking and packing. According to a DHL study, robotics in warehouse operations can reduce errors by up to 50% (DHL, 2016). This reduction in defects leads to a higher quality of service and helps companies reduce costs associated with returns, rework, and related activities.

Costs and Risks

Prior to implementation, it is essential to thoroughly examine the costs and risks associated with incorporating Robotics and Automation in the logistics sector. According to Lizzio et al. (2019), utilizing robots and automation in logistics involves potential risks and expenses. The implementation of automation technology requires substantial investment, which may be deemed costly by contractual logistics businesses. Moreover, the current technology may still need to be improved to perform certain value-added activities, such as unpacking and assessing the condition of returned items. As technology advances, the logistics sector must assess the advantages and disadvantages of automation, evaluate the costs and risks involved, and determine if the technology aligns with its specific needs (Lizzio et al., 2019). The tasks that involve delivering value-added services, which often necessitate a human touch, currently need more support from automation. Unless there are advancements in automation technology, these tasks will continue to be carried out by human employees.

Implementing R&A in logistics entails risks and expenses, as highlighted by Radivojević and Milosavljević (2019). The increased need for technological, managerial, and financial strategies, similar to the use of R&A, contributes to these costs and hazards in the logistics field. Organizations adopting R&A in logistics must modify their management framework and operational structure to align with the new paradigm of smart logistics. The requirement for substantial investment in hardware infrastructure further adds to the high initial costs. Applying R&A innovation in logistics may introduce risks regarding the necessity for process-oriented management practices and the associated high operational costs. Due to the complexity and challenges associated with R&A technology, staff members may require additional training and intellectual resource innovation (Radivojević & Milosavljević, 2019). Therefore, effective execution, commitment from all levels of the organization, and employee enthusiasm for continuous training and education are suggested as critical solutions to address these challenges.

Big Data

Big Data Technology

"Big Data" refers to extremely large and complex datasets that cannot be quickly processed or analyzed using traditional methods (Mikavica et al., 2015). While there is no single definition of Big Data, it is generally characterized by the 3Vs paradigm, which emphasizes its enormous Volume, Velocity, and Variety (Sagiroglu & Sinanc, 2013). More recently, two additional attributes, Value and Veracity, have been recognized as essential features of Big Data (Elhoseny et al., 2015).

Big Data represents a significant opportunity for organizations to gain new insights and improve decision-making, particularly when combined with business intelligence tools and techniques (Wang et al., 2016). As such, combining Big Data and business intelligence is often called Big Data Business Analytics (BDBA), which has become a critical capability for many businesses. BDBA has been applied in various contexts, including supply chain management and logistics, where it can help organizations optimize their operations by forecasting demand, managing inventory, and improving overall performance.

To effectively manage Big Data, specialized tools, and techniques are required to process and analyze these massive and complex datasets (Lekić et al., 2019). The size of Big Data sets can vary significantly among businesses, with some working with terabytes or petabytes of data every day. The 3Vs of Big Data (Volume, Velocity, and Variety) highlight the key challenges of managing and processing such datasets. The Value and Veracity of Big Data represent essential factors in determining the usefulness and reliability of the insights gained from Big Data analysis.

Big Data is a rapidly growing field that offers significant opportunities for businesses and organizations to gain new insights and improve their operations. Businesses can gain a competitive advantage and improve their performance by leveraging specialized tools and techniques, such as BDBA. However, managing and processing Big Data requires careful consideration of its unique characteristics, including its enormous Volume, Velocity, and Variety, as well as its Value and Veracity.

Application of Big Data in Logistics

Big Data has emerged as a powerful tool within the logistics industry, providing diverse applications for extracting crucial insights from extensive and intricate datasets (Mikavica et al., 2015; Wang et al., 2016; Lekić et al., 2019). These interdisciplinary studies have explored various methodologies and tools to harness the potential of Big Data. One significant application identified is predictive analysis, which employs machine learning algorithms to anticipate potential patterns and trends by analyzing historical data (Mikavica et al., 2015); this enables firms to enhance supply chain efficiency, expedite deliveries, and reduce costs by forecasting demand for specific items and effectively managing inventories (Mikavica et al., 2015).

Another promising application of Big Data in logistics is route optimization.

That entails identifying the most efficient delivery vehicle routes by considering traffic conditions, road surfaces, and delivery schedules. Analyzing large volumes of data encompassing these variables using Big Data techniques allows for determining optimal routes. The best routes can be identified by leveraging social network analysis and current traffic information, thereby improving efficiency (Mikavica et al., 2015). Additionally, Big Data can be leveraged for real-time delivery vehicle tracking, enabling the monitoring of critical metrics such as vehicle position, speed, and efficiency. This facilitates expedited deliveries, reduced fuel consumption, and operational efficiency enhancements (Mikavica et al., 2015).

(Wang et al., 2016) stated that big data business analytics (BDBA) has the potential to significantly reduce costs and enable more focused strategic decisions in logistics and supply chain management (LSCM) by offering valuable insights into industry trends, consumer purchasing patterns, and maintenance phases. Real-time information access and exchange among governmental organizations is another possible application of Big Data in the logistics industry, enabling better decision-making, emergency service intervention, openness, and traceability throughout the logistics system, which generates value (Wamba et al., 2015). The ongoing assessment of organizational-wide plans and operations is another area where BDBA can help gain knowledge and direct business strategy (Wang et al., 2015). Business analytics (BA) is the examination of the abilities, tools, and procedures used to continually assess a company's plans and procedures.

(Lekić et al., 2019) highlighted the potential of Big Data to transform the logistics industry. Despite generating important data from the daily monitoring of billions of shipments, the industry does not adequately utilize this data to enhance operational effectiveness and customer satisfaction. The logistics industry can gain an edge over its competitors by utilizing five features of big data, including network infrastructure, synchronization with business, tangible products, tangible customers, and core optimization (Lekić et al., 2019). The last-mile optimization is one of the scenarios for the logistics industry's usage of big data. Companies can utilize Big Data approaches to optimize last-mile deliveries, often representing the costliest step in the logistics cycle. By analyzing data, it is possible to maximize the performance of a typical delivery ship and effectively manage a brand-new last-mile delivery model. Real-time data processing is critical in speeding delivery via last-mile route planning (Lekić et al., 2019). The article also discusses the application case of strategic network planning, where significant data approaches can help with network layout and optimization by examining extensive historical capacities and ordering usage patterns, leading to improved planning with longer projection timeframes, lowering the risk associated with long-term infrastructure expenditures, and boosting overall sales.

Benefits and Opportunities

According to (Mikavica et al., 2015), Big Data has the potential to enhance operational effectiveness and customer satisfaction and create innovative business models in the logistics industry. The adoption of Big Data projects may bring a variety of benefits and opportunities. The initial phase involves establishing accountability and duties for collecting and analyzing data to derive value from big data. This requires identifying the sources of essential business data, such as social networking sites, machine instruments, and information systems inputs, and exploring new data-gathering techniques like sentiment analysis and video analytics. Big data projects should be initiated in company areas with high potential for success, such as advertising, customer support, supply-chain management, and financial services. Additionally, they emphasize the importance of aligning Big Data projects with complementary business tasks and evaluating the complexity, objectives, and technological architecture accordingly. The authors also highlight the significance of having a diverse team of business and technical specialists to ensure success in Big Data projects (Mikavica et al., 2015).

Logistics organizations possess access to an extensive volume of data generated from managing item flow, encompassing shipment particulars such as origin, destination, size, weight, contents, and location. Big data analytics confers a competitive advantage by controlling last-mile deliveries, real-time route planning, and resource allocation (Mikavica et al., 2015). By implementing enhanced regression and case modeling approaches, logistics organizations can effectively employ a more extensive and diverse dataset to enhance the reliability of resource planning and utilization, thereby reducing the risks associated with long-term infrastructure investments and dependence on external contractual capacity. Furthermore, acquiring customer insights through big data analytics assumes a significant role, providing crucial information pertinent to managing customer relationships and evaluating client satisfaction. By integrating multiple detailed data resources, a logistics company can comprehensively depict customer relationships and operational success, thereby ensuring satisfaction for both the recipient and the sender. The application of big data analytics facilitates inventory management, real-time capacity management, supplier and client relationship cultivation, and standard delivery forecasting, empowering supply chain planning organizations to generate economic value by recognizing data as a critical asset (Mikavica et al., 2015).

The logistics industry has the potential to benefit greatly from advancements in Big Data technologies and methods. Logistics companies track billions of shipments daily, resulting in vast amounts of data that need to be more utilized. Last-mile optimization is a potential application of Big Data technology in logistics. Processing large amounts of real-time data can enhance transportation networks and improve last-mile efficiency, reducing shipping costs and time savings (Lekić et al., 2019). Strategic network planning is another promising application of Big Data analytics. By evaluating large volumes of past data on capacity and usage, Big Data approaches can forecast future demands and improve distribution system architecture and capacities, thereby minimizing the risks associated with transportation and warehousing capacity investments (Lekić et al., 2019).

Costs and Risks

Logistics organizations face several data acquisition, storage, retrieval, and communication, evaluation, and visualization issues. Moreover, the system architecture poses a challenge as the large volume of data and capacity constraints of storage devices and CPUs create significant difficulties for real-time data extraction from Big Data. Proper pre-processing techniques are necessary to address the challenges of inconsistent data, incomplete information, and privacy concerns.

In addition, there are financial implications of big data on data storage and processing. The development of Big Data significantly influences storage architecture and database access mechanisms, and strengthening data access is essential for improving the efficiency of data-intensive systems (Mikavica et al., 2015). Data curation, which includes data identification, retrieval, quality control, and storage, is also necessary, as well as communication bandwidth capacity as a limitation in cloud and distributed applications. Data safety and privacy concerns exist as the increase in data volume exposes sensitive logistics information to cybercriminals, posing risks to intellectual property, individual privacy, confidential business information, and financial details.

The complexity of the vast number of data that must be processed is one of the difficulties of employing big data in logistics. The intricacy of the data makes it challenging to gather and analyze, which raises the cost. The risk of fraud in a setting where cybersecurity is not frequently used is another concern, which may result in significant financial losses for the corporation. The decreased privacy and legal concerns associated with the implementation of big data also pose a risk, as data leakage may lead to severe repercussions for the firm, including damage to its reputation and legal repercussions. It is, therefore, crucial to implement sufficient privacy and security safeguards to reduce the hazards connected with big data (Mikavica et al., 2015).

CHAPTER 3: PROPOSED MODEL

Multiple-Criteria Decision-Making Overview

Mathematical models known as multi-criteria decision-making (MCDM) techniques are utilized to facilitate decision-making in circumstances where the potential outcomes are judged according to several criteria that directly oppose one another (Ceballos et al., 2016). MCDM is among the most broadly utilized decision techniques in science, commerce, and government. It is based on the concept of a complicated world and thus can help enhance decision quality by making decisions more specific, reasonable, and effective (Zavadskas & Turskis, 2011). A decision-maker in the real world must first comprehend and understand the situation. Numerous multi-criteria techniques aim to address various types of problems. Each technique has advantages and disadvantages and different levels of usefulness. MCDM methods tend to be chosen randomly; sometimes, the analyst is already acquainted with a process, other times, a technique is created ad hoc, and sometimes a technique is selected simply because the software supporting it is accessible (Kornyshova & Salinesi, 2007). They added that each situation requires a unique MCDM approach. The effect of technique selection on critical decisions is also widely recognized, as are the impacts of poor decisions.

The solution may vary depending on the MCDM method employed, mainly when the alternatives are comparable. The long-term objective is to develop guidelines to aid the decision-maker in choosing which MCDM method to employ (Ceballos et al., 2016). There are several methods of MCDM, and few of the most popular ones are:

- The Weighted Sum Model (WSM)
- The Analytical Hierarchy Process (AHP)
- The Analytical Network Process (ANP)

- The Weighted Product Model (WPM)
- The ELECTRE
- The TOPSIS

The weighted sum model (WSM) is the initial and most utilized method. The weighted product model (WPM) is a variant of the WSM that has been introduced to address some of its shortcomings. The analytic hierarchy process (AHP) and Analytic Network Process (ANP), introduced by Saaty, is a recent development that has lately gained popularity. The ELECTRE and TOPSIS techniques are other commonly used methods (Triantaphyllou & Triantaphyllou, 2000). In multi-objective problems, the Weighted Sum Model (WSM) is the most frequently used. It incorporates the various associated objectives and weights to generate a singular number for each option to make them comparable (Helff & Gruenwald & d'Orazio, 2016).

The analytic hierarchy process (AHP) is an MCDM method that assists decision-makers with complicated problems involving multiple subjective and conflicting criteria. AHP provides a hierarchical structure, allowing the analyst to concentrate more on particular criterion and sub-criteria while assigning weights (Ishizaka & Labib, 2011). ANP generates complicated connections between decision components by substituting a network structure for a hierarchical structure. ANP offers all the advantageous characteristics of AHP, such as simplicity, agility, the ability to employ both quantitative and qualitative aspects simultaneously, and the capacity to assess judgmental consistency. ANP examines each problem in the context of a network of criteria, sub-criteria, and alternatives. All network's components can interact with one another in any manner (Kheybari & Rezaie & Farazmand, 2020).

In this study, we will use the ANP model with BOCR analysis for prioritization of the technology tools in the logistics industry.

Proposed Models

ANP Model

Decision-making is an indistinct human process that frequently happens in every individual's presence when two or more options are available. Multiple, incommensurable, and contradictory criteria make the decision challenging (Gölcük & Baykasoğlu, 2016). Multiple criteria decision-making (MCDM) is a developed set of concepts, methods, and procedures that aids decision-makers in making complex decisions more systematically. Saaty proposed this model, initially an analytic hierarchy process (AHP) using the multi-criteria decision analysis (Saaty, 1996). Analytic Network Process (ANP) is a generalized method of the Analytic Hierarchy Process (AHP) designed for more complicated problems with element interconnections. In the ANP technique, the hierarchical structure of the Analytic hierarchy process that flows from an objective through criteria, sub-criteria, and alternatives becomes a network. All network elements, divided into clusters, are interconnected via feedback and interdependence connections within and among clusters (Govindan & Sarkis & Palaniappan, 2013). According to Saaty, a network system allows feedback between clusters when forming an issue with functional dependency. Saaty recommended utilizing the AHP to address the issue of independence on alternatives or criteria. In contrast, the ANP was proposed as a solution to address the issue of dependence among alternatives or criteria (Saaty, 2005).

Using the ANP decision analysis framework was based on several motivations. The alternatives can be calculated in determining the effect of technology on the logistics sector (Tesfamariam & Lindberg, 2005). Instead of arbitrary scales, decision-opinion makers can prioritize the criteria based on pair-comparison rates (Saaty, 2004). The feedback enables the logistics sector to understand the complicated implications of technology better and provides the uncertainty and risks involved when using such technology (Jayant, 2016). When applying the ANP model, the opportunities, benefits of the strategy, cost incurred, and potential risks are assessed and weighted based on the strategic criteria developed. Applying this method ensures that the criteria priorities are assessed using pair-comparison rates and evaluated (Tesfamariam & Lindberg, 2005). The qualitative values are transformed into numerical values, considering that the respondents' views on the effect of technology on logistics can be qualitative; this can be essential when providing comparative analysis. The interdependence of the variables and the feedback generated from the ANP helps in determining the appropriate technology to be used in assessing the technology used in the logistics industry.

Although ANP has demonstrated its effectiveness in the decision-making process, many researchers have used the ANP method in different research studies. (Jayant, 2016) applied ANP in evaluating green supply chain management and determining sustainable development. (Tesfamariam & Lindberg, 2005) Assessed the relevance of the ANP and system dynamics in determining the aggregate analysis of the different manufacturing systems. (Jayant, 2015) utilized the ANP method to evaluate the used cell phones' management and disposal alternatives. From these studies, the assessment is to determine the alternatives to the multi-criteria decisions, which helps influence the researcher's opinion on the different technologies and the alternatives available.

Benefits-Opportunities-Costs-Risks (BOCR) Analysis

The key challenges facing the ANP method are relying heavily on the judgment of the experts and using a large number of factors leading to the development of the model (Jayant, 2015). Therefore, significance has been placed on using the BOCR analysis method, which allows a few elements to be selected when developing the model and conducting the analysis (Peker et al., 2016). Where there are many elements, the participants often face the challenge of determining the appropriate decision, but using BOCR analysis makes it easier when conducting the analysis. However, the researcher can use the ANP method and BOCR analysis to improve the study outcome. In the case of BOCR analysis, the decision analysis starts with defining the objectives, then the potential alternatives and attributes for the problem.

The objectives of the analysis are supported by the attribute where the variation of the objective is positively correlated with the variation of the attributes. The attributes and objectives are considered mutually neutral where they are negatively correlated. Also, in the BOCR analysis, the benefit (B) attributes and cost (C) attributes are not subjected to uncertainty when achieving the objective of the analysis. However, opportunity (O) and risk (R) attributes are still being determined when analyzing the alternatives and achieving the goal and objectives. In this case, the clustered weights of the benefits attributed to the technology trend, their costs, opportunities, and risks are added.

The analysis combines the outcomes of the benefits, costs, opportunities, and risks, which is provided in the additive formula given below:

$$P = bB + oO + c(1 + C)normalized + (1/R)normalized$$

Where, b, o and c are considered the normalized weights for the decision criteria developed.

A detailed analysis of the decision problem can be made in four scenarios:

Additive

$$P = bB + oO + c(1 + C)normalized + (1/R)normalized$$

Subtractive

$$P = bB + oO + c(1 + C)normalized - (1/R)normalized$$

Multiplicative with different priority powers

$$P = BbOo[(1 + C)normalized]c[(1/R)normalized]r$$

Multiplicative

$$P = BO/CR$$

CHAPTER 4: METHODOLOGY (ANALYSIS)

The proposed model is given below for analyzing the technology trends in the logistics industry and assessing benefits, opportunities, costs and risks associated with each trend:

Step 1: Set up a team of specialists that will investigate and analyze the possible alternatives available for the current study.

Step 2: Establishing control hierarchy and strategic criteria.

Step 3: The team assesses the sub-elements (benefits, opportunities, costs, and risk) of the BOCR model

Step 4: The team sets the weights for the strategic criteria.

Step 5: The team establishes the weights of BOCR concerning the strategic criteria.

Step 6: Evaluating the BOCR weights.

Step 7: Determining priorities of technology tools in the logistics industry.t significant potential for improving their operations, competitiveness, and sustainability. Adopting these technologies presents several challenges to logistics firms, including complex decision-making processes.

Application of the Model in the Logistics Industry

Step 1: Formation of a Specialist Team: In the initial phase of the proposed model, a team comprising five specialists in logistics and technology is assembled. The team members are provided a comprehensive overview of the study's objectives. Three professionals with extensive experience in logistics operations, gained from serving in prominent international logistics providers, and two technology and innovation experts who have worked in various innovation centers contribute their expertise. The specialists collaborate to establish criteria and interdependencies, create a pairwise comparison matrix, and analyze the resultant outcomes.

Step 2: Establishment of Control Hierarchy and Strategic Criteria: The control hierarchy of the Analytic Network Process (ANP) model is depicted in Figure 1. At the hierarchy's outset, the model's purpose, which is the prioritization of technology tools in the logistics industry, is positioned. Subsequently, strategic criteria and subnetworks are incorporated. In conjunction with relevant literature insights, the expert team identifies the strategic criteria as Efficiency & Productivity, Security & Safety, and Resource Investments. The first strategic criterion encompasses ease of use, staff productivity, service quality, and time management. The second criterion contains encryption, employee safety, and data privacy. The third strategic criterion includes necessary training, system integration, maintenance, and accessibility of the tools.

Step 3: Subnetwork Establishment: In this stage, the subnetworks, precisely the Benefits, Opportunities, Costs, and Risks (BOCR) clusters, are established, as depicted in Figure 2. Within each cluster, nodes represent various sub-criteria, exhibiting unidirectional and bidirectional relationships denoted by unidirectional and bidirectional arrows, respectively. The Benefits criteria encompass the subnetworks of technology efficiency, enhanced quality, and time-saving. The Opportunities criteria encompass the subnetworks of enhanced collaboration, innovation and competitiveness, and new market expansion. The Costs criteria contain the subnetworks of implementation cost, maintenance costs, and staff training. The Risk criteria encompass data quality, governance, and scalability risk subnetworks. By assigning weights to each subnetwork, the prioritization of emerging technological trends impacting the logistics sector is assessed. Figure 3 exemplifies one of the benefits sub-criteria exhibiting a two-way relationship with each alternative.

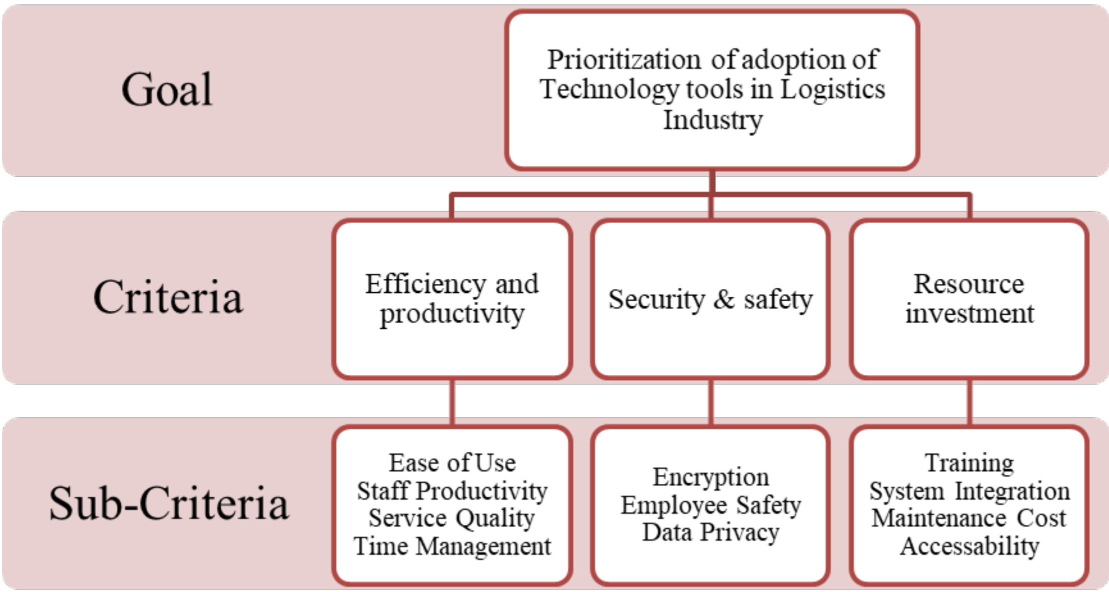

Figure 1. The hierarchical structure of ANP.

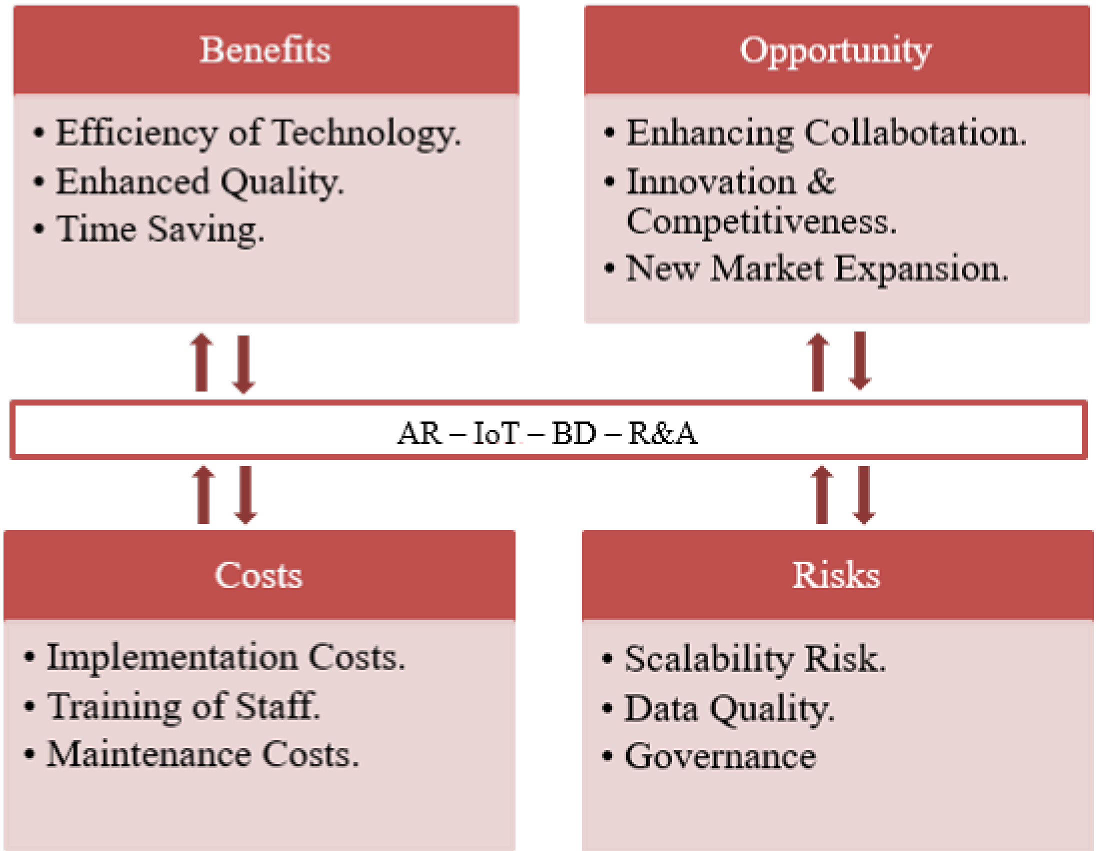

Figure 2. The BOCR subnetworks.

Step 4: Determination of Weights for Strategic Criteria: In this phase, the weights for the strategic criteria are established through the utilization of pairwise comparison matrices. The expert team members evaluated the strategic criteria in accordance with the goal of "prioritizing technology tools in logistics" and created individual matrices for conducting pairwise comparisons. The final pairwise comparison matrix was obtained by calculating the geometric average of these matrices, as presented in Table 1. The calculated inconsistency value of 0.03703, which is less than 1, is deemed acceptable. The inconsistency measure is an effective tool for spotting potential contradictions and errors of judgement throughout the decision-making process. It enables the detection of logical inconsistencies in the relationships among various decision elements. It is essential to ensure that the inconsistency ratio does not exceed 0.1. Consequently, the inconsistency measure is considered at each stage of the pairwise comparison process (Saaty, 2005).

The results indicate that the expert team members' primary concern regarding the strategic criteria is Security & Safety, assigned a weight of 0.64. Efficiency & Productivity follows with a weight of 0.26, while Resource Investment is given a weight of 0.10. These results highlight the team's recognition of the importance of security and safety considerations in adopting technology tools within the logistics industry. Consequently, the criteria associated with security and safety should be thoroughly analyzed while evaluating alternative solutions. Tables 2, 3, and 4 present the assigned weights for each strategic criterion derived from the same calculations.

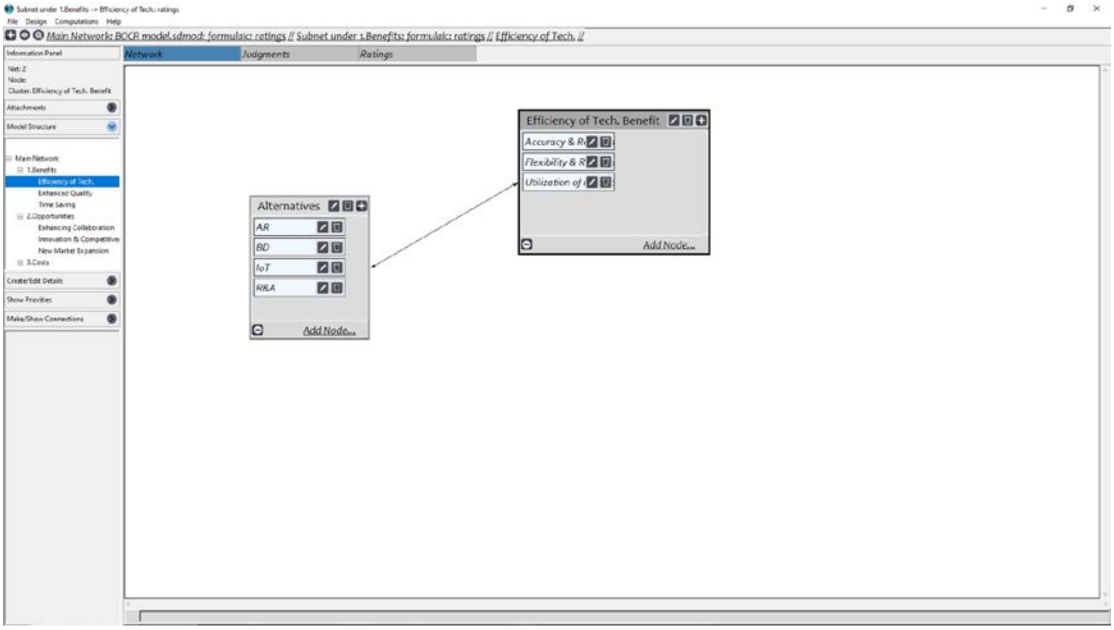

Figure 3. Subnetwork of benefit subnet.

Table 1. Pairwise Evaluation Matrix for Strategic Criteria and Weight Allocation

	Efficiency & Productivity	Resource Investment	Security & Safety	Weights
Efficiency & Productivity	1	3	1/3	0.26
Resource Investment	1/3	1	1/5	0.10
Security & Safety	3	5	1	0.64

Table 2. Pairwise Evaluation Matrix for Efficiency & Productivity sub-criteria

	Ease of Use	Service Quality	Staff Productivity	Time Management	Weights
Ease of Use	1	1/4	1/5	1/2	0.080
Service Quality	4	1	3	3	0.500
Staff Productivity	5	1/3	1	2	0.273
Time Management	2	1/3	1/2	1	0.147

Table 3. Pairwise Evaluation Matrix for Resource Investment sub-criteria

	Accessibility	Maintenance	System Integration	Training	Weights
Accessibility	1	3	1/3	2	0.247
Maintenance	1/3	1	1/3	1/3	0.094
System Integration	3	3	1	3	0.483
Training	1/2	3	1/3	1	0.176

Table 4. Pairwise Evaluation Matrix for Security & Safety sub-criteria

	Data Privacy	Employee Safety	Encryption	Weights
Data Privacy	1	1/3	3	0.258
Employee Safety	3	1	5	0.637
Encryption	1/3	1/5	1	0.105

Step 5: Determination of Weights for BOCR with Respect to Strategic Criteria: Following the establishment of weights for the strategic criteria, the subsequent step involves deriving the weights for BOCR (Benefits, Opportunities, Costs, and Risks) as they do not carry equal levels of importance in the prioritization of technology tools within the logistics industry. In this phase, the expert team uses the linguistic values provided in Table 5 to analyze BOCR with respect to each strategic sub-criterion. Each expert team member is individually posed with questions about the assessment of BOCR in alignment with the strategic sub-criteria. Numeric values corresponding to the linguistic values are assigned for each evaluation, and arithmetic averages are computed. The outcomes of these evaluations are presented in Table 6 for further

analysis. To calculate the weights of BOCR, the initial step involves multiplying these values with the weights of the strategic sub-criteria. By normalizing these values, the weights of BOCR are derived and listed in the last column of Table 6. The approximate weights of BOCR, based on the calculations, are 0.31 (Benefits), 0.24 (Opportunities), 0.20 (Costs), and 0.25 (Risks).

Step 6: Evaluation of BOCR Weights: In this phase, the weights for the BOCR subnetwork criteria are evaluated. Similar to the previous phases, the expert team members construct pair-wise comparison matrices, and the use the geometric average to determine the final matrices. Using Super Decisions software, a supermatrix illustrating the relative weights is generated, as presented in Table 7. The analysis reveals that the most significant criteria are "Enhanced Quality" within the Benefits subnetwork, "Innovation & Competitiveness" within the Opportunities subnetwork, and “Maintenance Cost" within the Costs subnetwork, and "Governance" within the Risks subnetwork.

Table 5. Linguistic Values

Linguistic Values	Average Numbers
Very High	1
High	0.75
Medium	0.5
Low	0.25
Very Low	0

Table 6. Strategic Criteria BOCR ranks

Weights	Efficiency & Productivity 0.26			
	Ease of Use	Service Quality	Staff Prod.	Time Management
Weights	0.080	0.500	0.273	0.147
Global Weights	0.021	0.129	0.07	0.038
Benefits	Very High	Very High	Very High	Very High
Opportunities	High	Very High	Very High	High
Costs	Low	Medium	Medium	High
Risks	Low	Medium	Medium	Low

Resource Investment 0.10			
Accessibility	Maintenance	System Integration	Training
0.247	0.094	0.483	0.176
0.026	0.01	0.051	0.018
High	Medium	Very High	High
Medium	Medium	Medium	Low
Very High	Very High	High	Very High
Medium	High	Medium	Very Low

Security & Safety 0.64			Totals	Normalized
Data Privacy	Employee Safety	Encryption		
0.258	0.637	0.105		
0.165	0.406	0.067		
Very High	Very High	High	0.97	0.31
High	High	Medium	0.75	0.24
High	Medium	Very High	0.62	0.20
Very High	Very High	High	0.78	0.25

Step 7: Determination of Priorities for Technology Tools in the Logistics Industry: In this phase, the priorities of technology tools are established. Matrices are constructed to compare the alternatives with the subnetworks (BOCR), resulting in 85 matrices. An example of such a matrix, comparing the "Product Innovation" node within the "Innovation & Competitiveness" subnetwork of the Opportunities

subnetwork, is depicted in Figure 4. The inconsistency value for this specific example is calculated as 0.0441, which falls below the acceptable threshold of 1. Table 8 displays the prioritization of different alternatives through various formulas. The first column of Table 8 illustrates the four technology tool alternatives (Augmented Reality, Big Data, IoT, and Robotics & Automation), followed by four columns presenting the priorities based on Benefits, Opportunities, Costs, and Risks. Subsequently, the last three columns show the logistics industry's rankings of technology tools according to three distinct formulas. These calculations were performed utilizing the Super Decisions software, which offers results in various formulas and formats (e.g., graphical and textual). We modified the Additive formula in the software for the cost and risk subnetworks to obtain positive factors instead of negative results, thus inverting the formula using the following approach:

Costs Formula

$NormalNet(ImplementationCost)*($SmartInvAlt(ImplementationCost))+ $NormalNet(MaintenanceCost)*($SmartInvAlt(MaintenanceCost))+$NormalNet(StaffTraining)*$SmartInvAlt(Staff Training)

Risks Formula

$NormalNet(DataQuality)*$SmartInvAlt(DataQuality)+ $NormalNet(Governance)*$SmartInvAlt(Governance)+$NormalNet(Scalability Risk)*$SmartInvAlt(Scalability Risk)

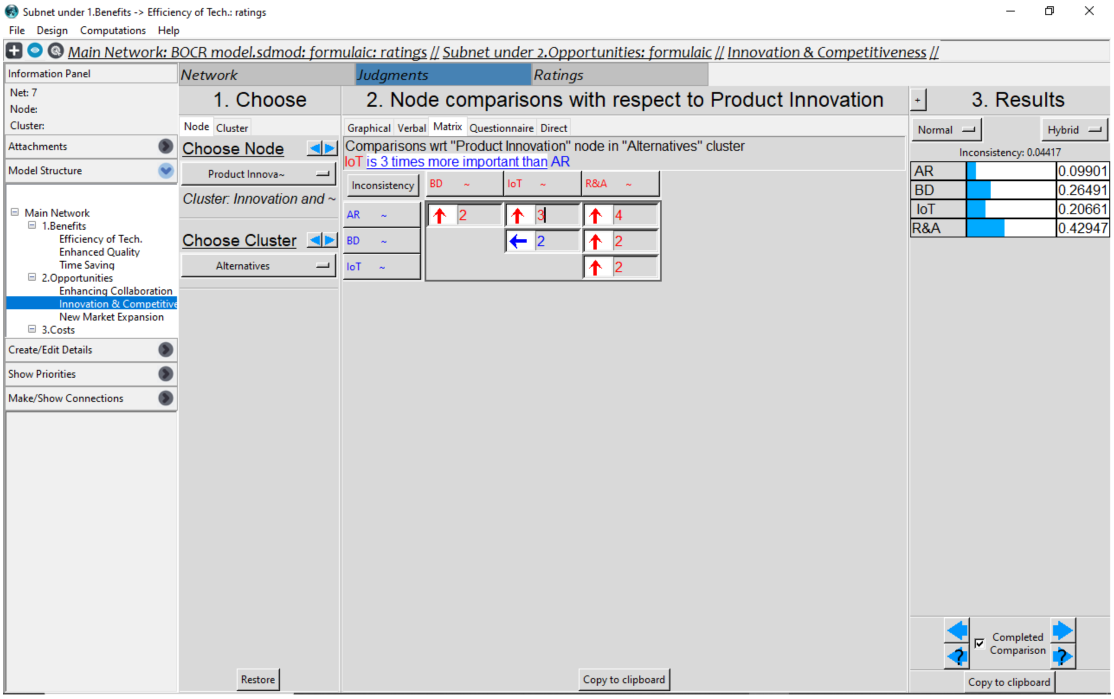

Figure 4. Comparison of alternatives according to sub-criteria.

According to Table 8, Big Data shows excellent results in Benefits and Opportunities, with scores of 0.4023 and 0.3571, respectively. It also has the highest cost effectiveness with a result of 0.3686. This shows that BD has a higher potential for providing benefits than the other three technology tools, but also has higher risks than the other tools. Although AR has high priority in terms of cost and risks, however the benefits and opportunities of this tool are very poor. IoT comes in the second place in the ranking using the additive (subtractive) and additive (probabilistic) formulas and in the first place in the multiplicative formula.

Table 7. BOCR Subnetworks Criteria Final Relative Weights

BOCR		Criteria	Final Relative Weights
	B1	Efficiency of Tech.	0.249
Benefits	B2	Enhanced Quality	0.594
	B3	Time Saving	0.157
	O1	Enhancing Collaboration	0.230
Opportunities	O2	Innovation & Competitiveness	0.648
	O3	New Market Expansion	0.122
	C1	Implementation Cost	0.295
Costs	C2	Maintenance Cost	0.511
	C3	Staff Training	0.194
	R1	Data Quality	0.314
Risks	R2	Governance	0.482
	R3	Scalability Risk	0.204

Table 8. Strategic Criteria BOCR ranks

					Rank		
Tech.	B	O	C	R	Additive	Additive	Multipli
Tools	0.310	0.241	0.198	0.250	Negative	Probabilistic	cative
AR	0.1012	0.1026	0.3369	0.3893	0.1224	0.0827	0.0118
BD	0.4023	0.3571	0.3686	0.1820	0.3188	0.3328	0.3201
IoT	0.2956	0.2789	0.1723	0.1708	0.3008	0.3198	0.4189
R&A	0.2010	0.2614	0.1223	0.2579	0.2579	0.2647	0.2492

Sensitivity Analysis

Sensitivity analysis is a critical component of the ANP-BOCR model, allowing decision-makers to evaluate the robustness and stability of their results. Sensitivity analysis involves fluctuating the weights assigned to criteria and alternatives to assess the impact on the overall rankings and decision outcomes. This helps decision-makers recognize the model's sensitivity to different parameter values and provides insights into the reliability of the results. Sensitivity analysis is vital in addressing the uncertainties and biases inherent in decision-making processes, and it helps in identifying the most critical criteria and alternatives that significantly influence the decision outcomes (Saaty, 2013).

The sensitivity analysis in this study was performed using super decision software. First, we applied the analysis to the benefits subnet. Figure 5 shows that Big Data has the highest priority when the benefit is at its original value of 0.31, followed by IoT, R&A, and AR. However, the priority of BD diminishes when the importance of Benefits is reduced to 0.1 or lower, and the IoT becomes the best performer. The second analysis was done on the Opportunities subnet, as shown in Figure 6; the results indicate an advantage of the Big Data technology over all other alternatives across all importance levels assigned to the Opportunities subnet. These findings suggest that Big Data is better suited to meeting the identified Opportunities than the other three technologies considered in the study. The observed performance advantage of the BD underscores its potential for improving decision-making and creating value for organizations aiming to leverage technology for competitive advantage.

Further studies can be conducted to explore the aspects underlying this observed performance advantage of Big Data technology. The sensitivity analysis of the cost criteria in the BOCR analysis undertaken in this study involved varying the cost data to assess its impact on the overall rankings of the four technology alternatives. The findings in Figure 7 indicate that AR technology is the best performer in the cost subnet, outperforming the other alternatives until the importance of cost reaches 0.8. At this level of importance, Big Data (BD) technology is the top priority regarding cost efficiency. Notably, when the importance of cost is less than 0.1027, the BD technology is ranked the worst performer in terms of cost, followed by the Internet of Things (IoT), Robotics and Automation (R&A), and AR. Between 0.1027 and 0.2, IoT technology becomes the worst performer in terms of cost. When the importance level of cost is above 0.2, AR technology is ranked the best performer, with BD emerging as the second-best performer.

These findings highlight the performance of the different technologies under varying levels of importance assigned to the cost criterion. They can help inform decision-making in technology selection for optimal cost-benefit outcomes. In the sensitivity analysis of the risk subnet, the risk data was varied to assess the effect on the overall rankings of the alternatives. The results in Figure 8 showed that the AR technology had the highest performance in terms of risk on all levels of risk importance. Following AR, the R&A technology ranked second, while the IoT and BD technologies ranked third and fourth. Notably, BD was one of the lowest priorities in terms of risk across all levels of risk importance. However, when the risk importance reached 0.44, the IoT technology became riskier than BD. These findings suggest that AR technology is the most robust option in terms of risk and that the important level of risk should be carefully considered when selecting an alternative.

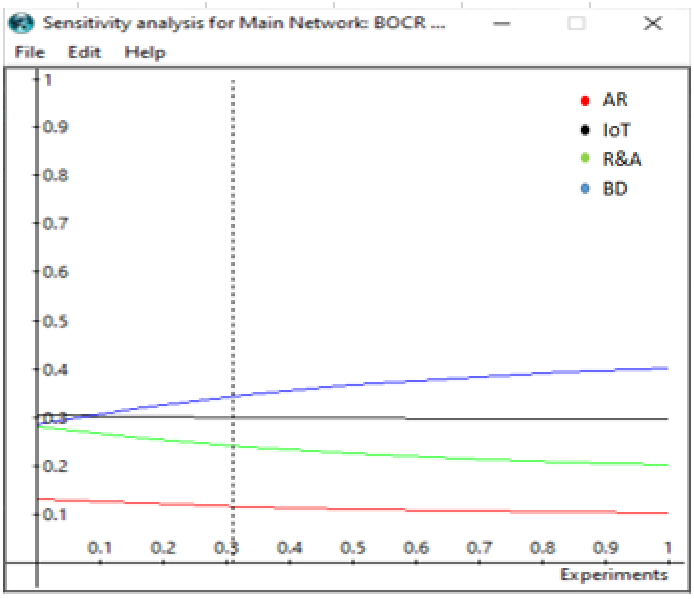

Figure 5. Sensitivity analysis for benefits.

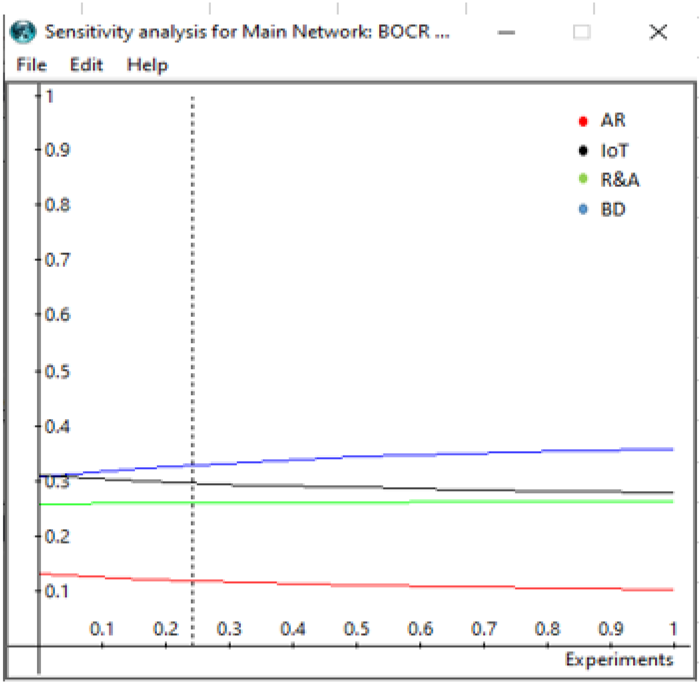

Figure 6 Sensitivity analysis for opportunities.

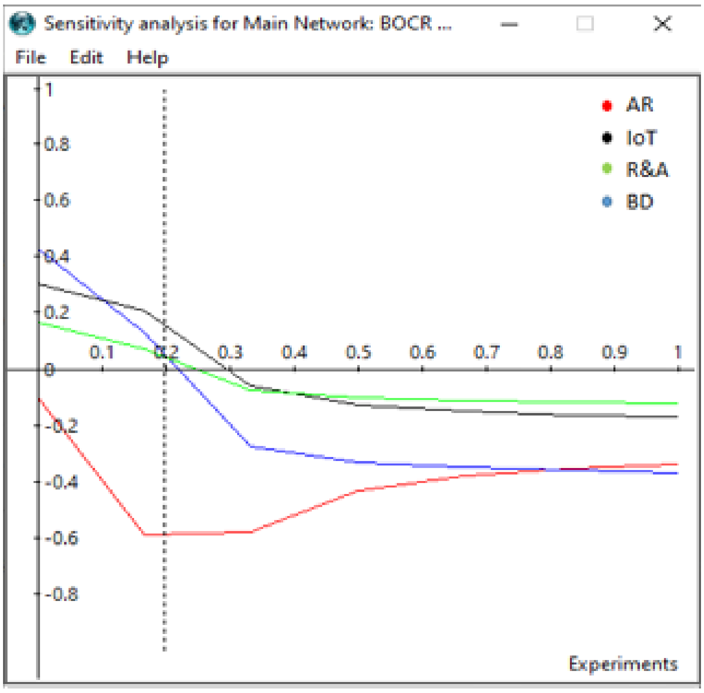

Figure 7 Sensitivity analysis for costs.

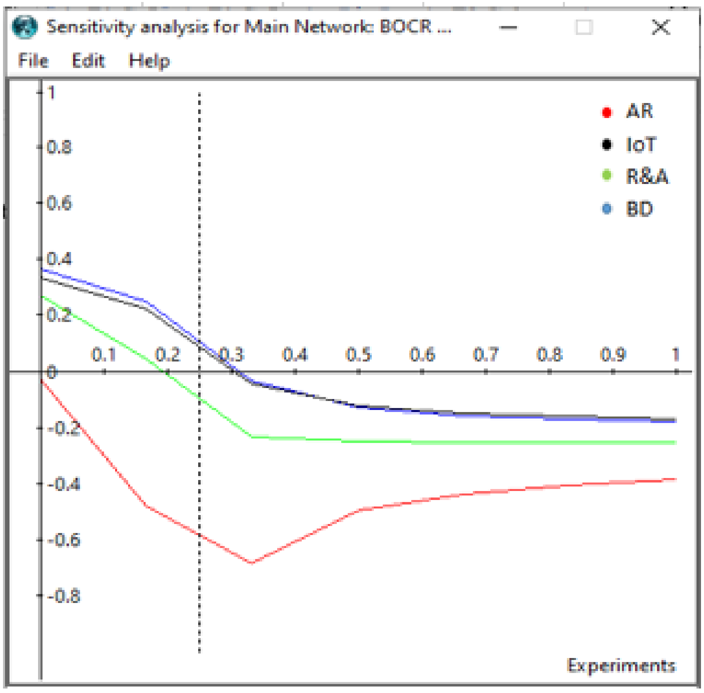

Figure 8. Sensitivity analysis for risks.

Discussion

The study investigated the adoption of emerging technologies in the logistics industry and prioritized them using ANP and BOCR analysis. The research study focused on four technologies that have gained significant attention in the logistics industry. The technologies are Augmented Reality, Internet of Things, Big Data and Robotics and Automation. A mixture of quantitative and qualitative data gathering and analysis methodologies were used in the study. The data was gathered through semi-structured interviews with logistics specialists. The experts collaborated to establish criteria and interdependencies, create pairwise comparison matrices, and analyze the results.

The study's findings suggested that Big Data had a higher potential for providing benefits than the other three technology tools, but it also had higher risks than the other tools. Although AR had a high priority regarding cost and risks, its benefits and opportunities were very poor. IoT ranked second in the additive (subtractive) and additive (probabilistic) formulas and first in the multiplicative formula. Sensitivity analysis is a critical component of the ANP-BOCR model, allowing decision-makers to evaluate the robustness and stability of their results. The sensitivity analysis in this study was performed using super decision software.

The sensitivity analysis revealed that Big Data was better suited for meeting the identified benefits than the other three technologies considered in the study. The observed performance advantage of the BD underscores its potential for improving decision-making and creating value for organizations aiming to leverage technology for competitive advantage. The study's recommendations are expected to inform logistics firms' technology adoption strategies, enabling them to identify and prioritize technologies with the most significant potential for improving their operations, competitiveness, and sustainability. Adopting these technologies presents several challenges to logistics firms, including complex decision-making processes. The use of ANP and BOCR methods provides a structured approach for prioritizing these technologies, considering their benefits, opportunities, costs, and risks. The study's findings are expected to contribute to understanding the decision-making process for adopting emerging technologies in the logistics industry.

The study highlighted the importance of emerging technologies in the logistics industry and the need for logistics firms to adopt a strategic approach in selecting and prioritizing technologies. The ANP-BOCR model provided a structured approach for prioritizing technologies, considering their benefits, opportunities, costs, and risks. The study's recommendations are expected to inform logistics firms' technology adoption strategies, enabling them to identify and prioritize technologies with the most significant potential for improving their operations, competitiveness, and sustainability. Further studies can be conducted to explore the aspects underlying the observed performance advantage of the Big Data technology and to identify potential areas for improvement in the ANP-BOCR model.

CONCLUSION, LIMITATIONS AND FURTHER RESEARCH DIRECTIONS

The logistics industry is transforming rapidly with the adoption of technology tools. Adopting these technologies presents significant challenges to logistics firms, including complex decision-making processes. This study aimed to prioritize these technological tools and assess their effects on the logistics sector by employing the ANP and the BOCR technique. The study used a MCDM methods comprising both qualitative and quantitative data collection and analysis techniques. Semi-structured interviews with logistics experts and practitioners were conducted, and the data collected was analyzed using ANP and BOCR.

The study's findings contribute to understanding the decision-making process for adopting these technologies in the logistics industry. The use of ANP and BOCR methods provides a structured approach for prioritizing these technologies, considering their benefits, opportunities, costs, and risks. The study's recommendations inform logistics firms' technology adoption strategies, enabling them to identify and prioritize technologies with the most significant potential for improving their operations, competitiveness, and sustainability.

The results indicate that the primary concern for the expert team members regarding strategic criteria is Security & Safety, which was given the highest weight. Efficiency & Productivity came next, followed by Resource Investment. This highlights that the team views the security & safety aspect as the most significant factor for adopting technology tools in the logistics industry. Therefore, the criteria associated with security and safety should be analyzed carefully while providing such alternatives.

Limitations

Future researches can address several limitations which were encountered in this study. The study's sample size was relatively small, comprising only five specialists in logistics and technology. Future research can form a larger sample size and a wider range of participants, including logistics firms from different regions and sectors. Additionally, the study focused on only four technologies; future research can explore other technologies and their impact on the logistics industry. Furthermore, the study used ANP and BOCR methods to prioritize the technologies. They can also use different techniques to confirm the study's results, such as fuzzy logic and the Analytic Hierarchy Process (AHP).

Future Research Directions

The study identified several areas for future research in the logistics industry's adoption of emerging technologies. Firstly, future studies could focus on the barriers and challenges facing logistics firms in adopting technology tools. These studies could provide insights into the factors that hinder technology adoption and inform strategies for overcoming these barriers. Secondly, future studies could investigate the impact of technologies on the logistics industry's sustainability and environmental performance. This research could help logistics firms understand the potential benefits of these technologies in reducing carbon emissions, improving energy efficiency, and promoting sustainable operations. Thirdly, future studies could explore the role of technologies in enhancing logistics firms' customer service and satisfaction. This research could provide insights into the impact of these technologies on customer experience, loyalty, and retention. Fourthly, future studies could investigate the impact of the technologies on the workforce and human resource management in the logistics industry. This research could help logistics firms understand the implications of these technologies on their workforce, identify potential skill gaps and training needs, and develop strategies for managing the workforce transition to the digital era. Finally, future studies could compare the effectiveness of different prioritization methods for technology tools in the logistics industry. This research could provide insights into the strengths and limitations of other methods and help logistics firms select the most appropriate method for their specific context and needs.

In conclusion, this study has contributed to understanding the adoption of technology tools in the logistics industry and provided insights into the prioritization of these technologies using ANP and BOCR methods. The study's findings have practical implications for logistics firms seeking to leverage technology tools for competitive advantage and sustainability. Future research paths suggested in this report might improve awareness of how technology impacts the logistics sector and provide methods for successful adoption and deployment.

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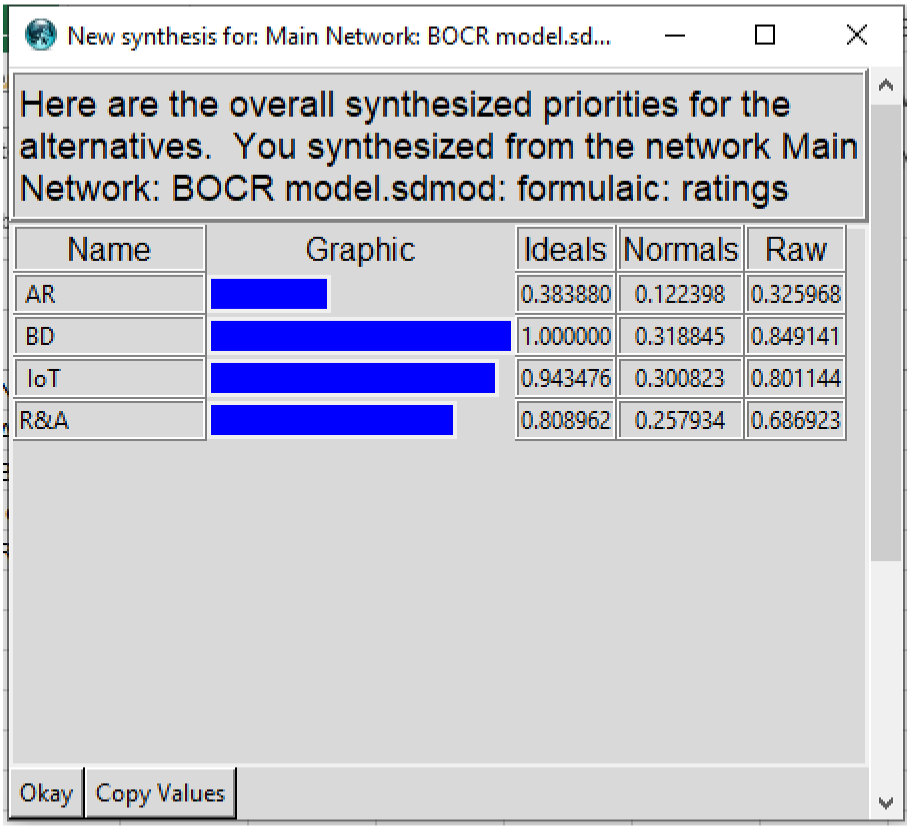
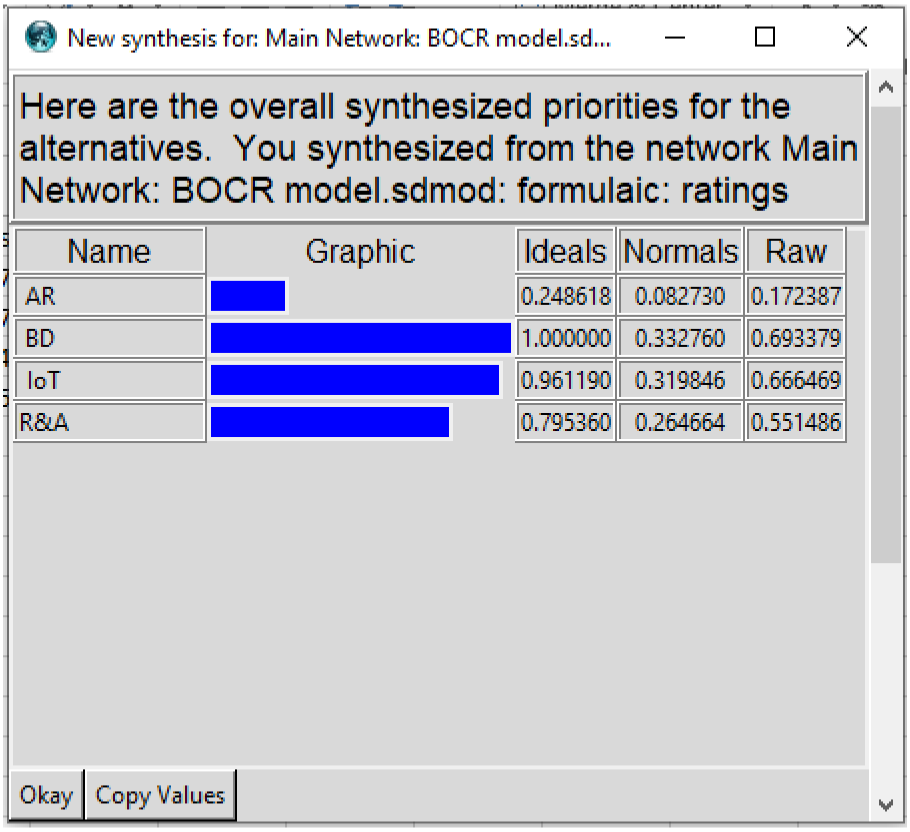
APPENDIX

Appendix 1: Priorities using additive (negative) formula.

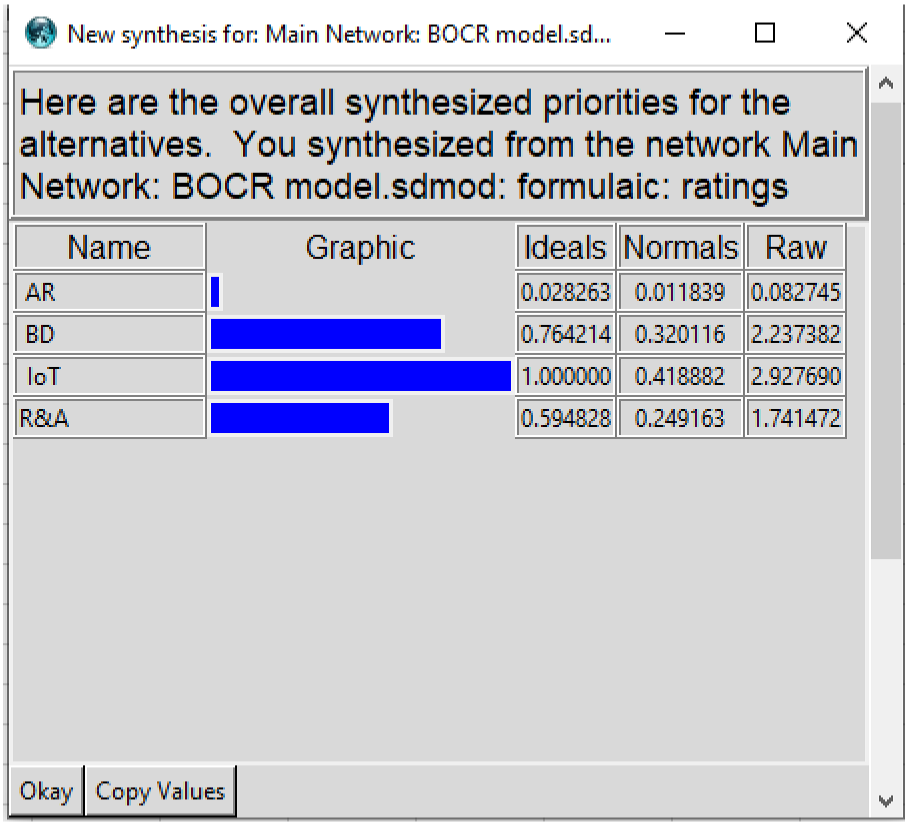


Appendix 2: Priorities using additive (Probabilistic) formula.



Name	Graphic	Ideals	Normals	Raw
AR		0.248618	0.082730	0.172387
BD		1.000000	0.332760	0.693379
IoT		0.961190	0.319846	0.666469
R&A		0.795360	0.264664	0.551486

Appendix 3: Priorities using multiplicative formula.



Name	Graphic	Ideals	Normals	Raw
AR		0.028263	0.011839	0.082745
BD		0.764214	0.320116	2.237382
IoT		1.000000	0.418882	2.927690
R&A		0.594828	0.249163	1.741472

Appendix 4: Inconsistency and weights for criteria of benefits.

Inconsistency: 0.05156

Efficienc~	0.24931
Enhanced ~	0.59363
Time Savi~	0.15706

Appendix 5: Inconsistency and weights for criteria of opportunities.

Inconsistency: 0.00355

Enhancing~	0.22965
Innovatio~	0.64833
New Marke~	0.12202

Appendix 6: Inconsistency and weights for criteria of costs.

Inconsistency: 0.02039

Implement~	0.29527
Maintenan~	0.51059
Staff Tra~	0.19414

Appendix 7: Inconsistency and weights for criteria of risks.

Inconsistency: 0.05156

Data Qual~	0.31081
Governance	0.49339
Scalabili~	0.19580