ISSN: 2037-4445

Augmented Reality in Supply Chains of Indian Micro and Small Enterprises

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Abstract: A supply chain converts unfinished goods into finished goods supplied to customers. It consists of a complex network of enterprises and procedures, including distributors, manufacturers, vendors, and distributors of raw materials. Industry 4.0 has been offering fresh perspectives and creative solutions to issues that supply chains all around the world are facing. This paper analyses how augmented reality may be utilized by micro and small-sized businesses in several areas to create a sustainable supply chain. This review focuses mainly on the qualitative attributes and applications of augmented reality in supply chain bottlenecks that can be useful for Indian Micro and Small Enterprises.

Introduction: Supply Chains have been part of the World economics ecosystem for all levels of enterprises long before the supply chain was even coined. But with the advent of Industry 4.0, it has been noted that many former problems that have been plaguing this ecosystem can now be eliminated by these sustainable solutions. The analysis of qualities of AR use in the supply chain will be done by random sampling of enterprises presently using AR in the respective sphere of quality. Each sampling will be made of one large, medium, small, or micro-enterprise. The use cases will provide evidence of why and how AR can help in building creative and resilient supply chain systems.

Objectives: The research objective of this paper is to investigate and evaluate the implications of incorporating augmented reality (AR) technology into modern supply chains, with a specific focus on understanding how AR can enhance customization and specialization, facilitate flexibility in workplaces, and enable dynamic reconfiguration of operational processes, aiming to provide valuable insights and recommendations for organizations seeking to leverage AR to improve operational efficiency and deliver enhanced customer experiences in the context of supply chain management.

Methods: The design of the study is a descriptive research method. The total number of micro, small, and medium enterprises (MSMEs) from July 2020 to March 2023 in India is 1,47,50,018 respectively, as per the Udyam Registration portal.

Results: This study conducted a systematic literature review (SLR) to explore the potential applications of augmented reality (AR) technology in supply chain management (SCM). The findings revealed that AR has significant potential to enhance various activities along the supply chain and provide value-added solutions. Specific areas within the value chain where AR can be applied were identified, offering improvements in operational optimization and loss minimization. However, more empirical studies are needed to assess the functionality of AR systems in organizational tasks. The study emphasizes the need for practical solutions to organizational, technological, and ergonomic challenges in adopting AR in SCM and logistics. Future research should investigate the interaction between AR and other emerging technologies and explore factors influencing AR acceptance and integration in SCM.

Conclusions: This study aimed to explore the potential applications of augmented reality (AR) technology in supply chain management (SCM). To achieve this, a systematic literature review (SLR) was conducted, which analyzed and categorized 43 relevant studies. The categorization was based

on an adapted version of the value chain model. The findings of this study reveal that AR technology has significant potential in various activities along the supply chain. It was found that AR can provide effective and innovative value-added solutions to support different functions within SCM. By leveraging AR, companies have the opportunity to enhance the overall efficiency of their value chain and address challenges related to planning and scheduling, process integration, and resource utilization.

Keywords: Augmented Reality (AR), Supply Chains, Sustainable, Enterprises.

1. Introduction

Supply Chains have been part of the World economics ecosystem for all levels of enterprises long before the supply chain was even coined. But with the advent of Industry 4.0, it has been noted that many former problems that have been plaguing this ecosystem can now be eliminated by these sustainable solutions. The analysis of qualities of AR use in the supply chain will be done by random sampling of enterprises presently using AR in the respective sphere of quality. Each sampling will be made of one large, medium, small, or micro-enterprise. The use cases will provide evidence of why and how AR can help in building creative and resilient supply chain systems.

1.1. Supply Chain Overview

Supply Chains or specifically digital supply chain has been part of Industry 3.0 also known as Digital Reform which started in the mid-1970s and whose main highlights were using of computers and automation in fabrication. The following are a few of the major technologies that fueled the Industry 3.0 revolution: PLCs, robotics, automated guided vehicles (AGVs), computer-aided design (CAD), and computer-aided manufacturing (CAM) are all examples of technological advancements.

2. Objectives

Technology that combines the real and virtual worlds is frequently referred to as "AR."((Rohacz and Strassburger 2019) [37]. It refers, more particularly, to a real-world environment that is enhanced by visualization and supported by specialized technology and software (Cirulis and Ginters 2013) [16]. When a sophisticated human-computer interface connects real-time simulations and interactions through multi-sensory channels including sight, hearing, touch, smell, and taste, it is called Virtual Reality (VR). In contrast, augmented reality (AR) uses real-time simulations and interactions. Users can build a simulation or an independent universe in a VR environment that is cut off from the actual world. As opposed to this, in an AR environment, the feelings are "augmented" or made to come to life by combining virtual and three-dimensional computer-generated visuals.

Modern supply chains, which have become very complex systems with several levels of locating, projection, multi-sensory systems, and widened information interactions at every step in the chain, can engage augmented reality [11][12][14][15]. Additionally, new business models are being developed, and they feature mass personalization. As a result, operational and manufacturing processes must constantly develop toward a setting that supports specialization and customization. To enable a flexible workplace and ecosystem, this evolution will necessitate dynamic reconfiguration and adjustment activities, including machine and replenishment stock placement and production line layout.

3. Methodology

The design of the study is a descriptive research method. The total number of micro, small, and medium enterprises (MSMEs) from July 2020 to March 2023 in India is 1,47,50,018 respectively, as per the Udyam Registration portal.

3.1. Data Sources

The study is based on the resulting data. The sources of secondary data include annual reports of MSMEs, and various papers and articles. The total no of 43 publications that were used as sources are represented in this report by fig. (1) [3].

3.2. Implements and methods

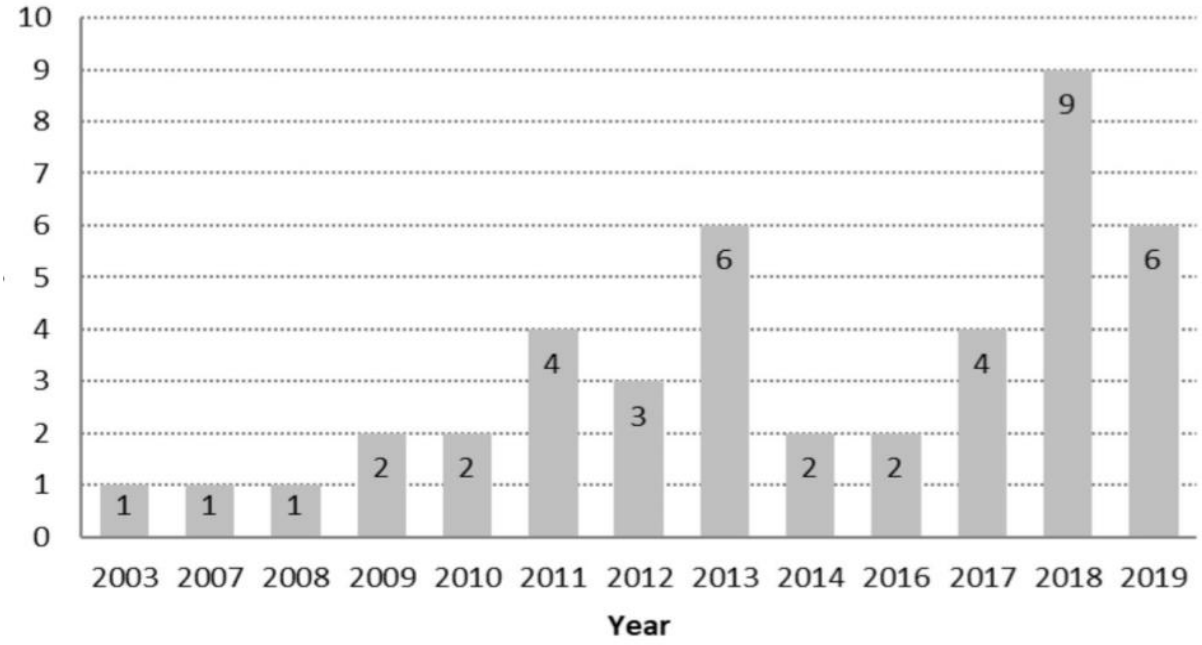
The most applicable research tool like; percentages and indices etc. are used to analyze the effectiveness of AR in Supply Chains for Indian MSEs.

3.3. Theoretical Frame for the Categorization of AR Studies

We categorize the potentials of AR applications in SCM systemically in this research using the conceptual framework (Abdelrahman Rejeb, John G. Keogh, Samuel Fosso Wamba, Horst Treiblmaier, et al., pg. 14)[36]. The adaptability of AR technology supports many activities across the value chain and goes beyond a single organizational function. As a result, Porter (1985)'s value chain model serves as a foundation for our approach. Applications for augmented reality in planning, design, production, sales, and outdoor logistics are among our areas [2].

4. Literature Review

The next subsections describe the respective abilities in order of the sequence of actions, based on the conceptual framework and use cases as examples. The major activities of AR in manufacturing, sales, and outdoor logistics are covered first, and then we go on to the supporting activities linked to planning and design.



4.1. AR in Warehousing

In the supply chain, warehouses play a crucial role in handling and storing inventories. They might be cumbersome to browse due to their size and complexity. This may result in mistakes in inventory management and inefficient order selection. The usage of augmented reality (AR) technology can increase the effectiveness and precision of warehouse operations.

4.2. Order Picking

Raw material, spare components, work-in-progress, or finished goods order picking is a warehouse job that involves locating things from their storage locations to fulfil a specified order picking list and satisfy client demand Tompkins et al. (2010) [40]. There are several order-picking instances where AR may be used. One approach is to utilize augmented reality (AR) glasses or a head-mounted display

(HMD) to show a virtual list of things to choose from in the user's field of vision. The user will then be able to pick each item by scanning its barcode, which will cause the AR system to automatically update the list. There is no longer a need for paper selection lists since they may be misplaced or lost. Utilizing a mobile device, such as a smartphone or tablet, is another option to use AR for order choosing.

Amazon is utilizing augmented reality to make it easier for its pickers to locate things. The business created an AR application that employs computer vision to recognize objects on shelves[1]. The software then shows the item's location on a warehouse map. Pickers may avoid wasting time looking for objects thanks to this. Utilizing augmented reality, Ocado's workers can select orders more safely. The business has created an AR application that utilizes computer vision to locate impediments in the warehouse. The obstructions are then shown on a digital warehouse map via the app. Pickers may avoid hitting barriers because of this.

4.3. AR in Manufacturing

Manufacturing is considered one of the most critical functions in a product-centric firm (McDonald 2009). Companies are experiencing a significant transformation in technology due to the utilization of sophisticated computer and communication tools in the manufacturing sector. These advancements have a remarkable influence on various aspects such as product design, factory automation, cost and quality control, planning, processing, workforce skills, and output management (Ross 2016). The possible applications of augmented reality (AR) technology in manufacturing activities range from planning production processes and assembly to maintaining commercial equipment and robotic systems. Manufacturers may improve their productivity and accuracy by incorporating AR in operations like visualizing and optimizing workflows, enabling real-time collaboration, and giving employees on-the-job training. This game-changing technology has a lot of potentials to boost efficiency and production across the board in the manufacturing sector.

4.3.1. Production Operations

AR technology has found its way into manufacturing processes at General Electric (GE) and Toyota, offering significant benefits in terms of efficiency and training. At GE, AR is implemented to guide workers through complex assembly, maintenance, and repair tasks, resulting in improved productivity and accuracy. The incorporation of AR also enables remote collaboration, allowing experts to provide real-time guidance to technicians on the field, minimizing downtime and enhancing maintenance outcomes. Similarly, Toyota utilizes AR in its manufacturing operations to enhance quality control and optimize processes. By overlaying digital information onto physical components, AR assists workers in swiftly identifying and resolving quality issues, ensuring consistent product excellence. Moreover, it provides immediate feedback on assembly correctness and supports error-proofing measures. Overall, the integration of AR technology in manufacturing brings forth advancements in efficiency, training, quality control, and process improvement for these industry leaders.

4.3.2. Assembly

Siemens integrates augmented reality (AR) into their manufacturing processes to enhance assembly operations. By equipping workers with AR headsets that provide step-by-step instructions, virtual models, and real-time data visualization, Siemens improves complex assembly tasks, reduces errors, and increases overall productivity. This AR-assisted approach enables enhanced design and planning processes, virtual product assembly simulations, and improved monitoring and guidance through virtual instructions, resulting in optimized manufacturing operations.

4.3.3. Maintenance

Boeing, a prominent aerospace manufacturer, incorporates augmented reality (AR) technology in aircraft assembly and maintenance[7]. They utilize AR headsets to guide workers through intricate wiring processes, offering visual instructions and highlighting correct connections. This implementation streamlines assembly tasks reduces errors, and enhances overall efficiency. Furthermore, Boeing leverages AR for maintenance and repair activities, enabling technicians to access digital manuals and visualize instructions while working on aircraft systems. The deployment of AR in manufacturing maintenance plays a crucial role in decreasing the likelihood of machine failures, reducing production costs, and increasing equipment availability, utilization, and reliability.

AR technology in maintenance operations offers improved services by providing relevant information through visual interactions and virtual instructions. It also enhances workflow efficiency, ergonomic comfort, and the ability to visualize the entire repair process. AR technology's applications extend to remote maintenance procedures in harsh environmental conditions, as well as increasing the reliability and operational efficiency of supply chains through predictive maintenance.

4.4. AR in Sales and Outdoor Logistics

4.4.1. Sales

Aside from benefiting businesses, AR technologies allow customers to virtually try, test and interact with different products before their purchasing decision is made (Luh et al. 2013). Such immersive experiences satisfy customer needs and strengthen their willingness to buy products from firms equipped with AR (Poushneh and Vasquez-Parraga 2017). Audi has integrated AR technology into their showrooms, allowing customers to use AR devices to view virtual car models, explore customization options, and visualize vehicles in different settings. Similarly, Volkswagen utilizes AR to provide technicians with virtual guides during vehicle repairs, overlaying step-by-step instructions to streamline the process. AR enhances the shopping experience by enabling customers to visualize products in real-world environments using smartphones or tablets. Additionally, AR facilitates virtual try-on experiences for clothing, eyewear, and cosmetics, helping customers make informed purchasing decisions. Furthermore, AR provides instant access to product information, specifications, features, and customer reviews by scanning product labels or codes. It also assists customers with step-by-step instructions for product assembly, installation, and maintenance by overlaying digital instructions onto physical products, reducing the reliance on complex manuals.

4.4.2. Outdoor Logistics

Outdoor logistics involves all activities necessary for the delivery of products to customers and incorporates all related operations in an outdoor environment. The transportation industry relies heavily on digital data and planning software for optimized load planning and vehicle utilization (DHL 2014). By giving real-time instructions and enhancing travel routes to increase efficiency, it may help workers with navigation and route planning. Logistics staff may obtain information regarding delivery status, package specifics, and handling instructions by using augmented reality (AR) to overlay real-time data onto the physical world. Additionally, it allows for remote support and teamwork, allowing specialists to add comments or directions to field technicians' live video feeds. Real-time visibility of stock quantities and locations provided by AR makes outdoor inventory management easier. While Trimble provides AR solutions for accurate construction execution, UPS uses them to load and sort packages using augmented reality (AR) headsets. Coca-Cola has used AR in marketing to provide customers with engaging experiences by having them scan their items.

4.5. AR in Planning and Design

4.5.1. Layout Design

According to Heizer and Render (2008), one of the key considerations that affect operations' long-term efficiency is facility layout. The creation of a workable layout can guarantee the effective use of smart production and digital manufacturing (Liu et al. 2018), providing greater degrees of flexibility, enhanced efficiency, and improved operations. According to Tompkins et al. (2010), facility planning and material handling account for twenty to fifty percent of operational expenditures, and these costs may be significantly decreased by a well-thought-out layout design.

AR technology plays a significant role in architecture and design by enabling the visualization and presentation of 3D models in real-world environments. Architects and designers can showcase virtual structures overlaid onto physical spaces, providing clients and stakeholders with a better understanding of the design concept and its integration with the surroundings. Additionally, AR allows for real-time design changes and iterations, with digital modifications overlaid onto physical models or existing environments, facilitating on-the-spot adjustments and immediate visualization of the design impact.

Urban planners can utilize AR to create interactive 3D models of cities, enabling visualization of proposed changes and developments within the existing environment. AR also engages the public in the urban planning process, allowing citizens to view and provide input on proposed plans or

developments overlaid in real-world locations. Companies like Autodesk and Bosch utilize AR technology to assist their customers in design and planning processes, allowing them to visualize their designs in the real world before making final decisions or purchases.

4.5.2. Manufacturing Design

AR technology plays a crucial role in product development by enabling the visualization and validation of design concepts. Designers can overlay virtual prototypes onto physical objects or environments, allowing them to assess factors such as form, fit, and functionality in real-world contexts before proceeding to manufacturing[4]. AR also facilitates remote collaboration and communication among design teams, allowing multiple designers to view and interact with the same virtual 3D models simultaneously, enhancing collaboration and expediting the design process.

IKEA utilizes AR to assist customers in planning and designing their homes. With the company's AR system, customers can visualize how different furniture would look in their homes before making a purchase. The use of AR tools enhances customers' perception and understanding of product design and empowers them to actively participate in the value co-creation process. By integrating customers into the supply chain of personalized product manufacturing, AR fosters a new model of value co-creation.

4.5.3. Intralogistics Planning

In supply chain management, intralogistics planning is of utmost importance as it accounts for a significant portion of a product's manufacturing costs and influences production resource efficiency. To illustrate the potential of AR in supporting intralogistics planning, Rohacz and Strassburger (2019) present a case study at Daimler AG where AR technologies, including handheld displays like smartphones or tablets, serve as mobile assistance systems. These AR tools offer convenience and high performance in intralogistics planning, aiding logistics professionals in optimizing processes. Similarly, Trimble utilizes AR to assist customers in surveying and mapping areas. With Trimble's AR system, customers can view the real world overlaid with digital information, such as measurements and distances, enhancing accuracy and efficiency in spatial analysis.

5. Results

This study aimed to explore the potential applications of augmented reality (AR) technology in supply chain management (SCM). To achieve this, a systematic literature review (SLR) was conducted, which analyzed and categorized 43 relevant studies. The categorization was based on an adapted version of the value chain model. The findings of this study reveal that AR technology has significant potential in various activities along the supply chain. It was found that AR can provide effective and innovative value-added solutions to support different functions within SCM. By leveraging AR, companies have the opportunity to enhance the overall efficiency of their value chain and address challenges related to planning and scheduling, process integration, and resource utilization.

Furthermore, the study identified specific areas within the value chain where AR can be applied. These areas include infrastructure development, human resource management, inbound logistics, operations, and marketing and sales. The integration of AR in these functions is expected to bring about improvements such as operational optimization and loss minimization. Overall, the results of the SLR highlight the potential benefits of AR technology in SCM for Micro and Small Enterprises and provide insights into how AR can be strategically implemented within the value chain. AR may enhance a number of value chain processes, including design and development, training of human assets, inbound logistics, factory operations, sales, and outdoor logistics.

The results of this SLR show that, although being developed for several years, augmented reality (AR) technology is still in its infancy. However, as indicated by the rise in scholarly papers in the area, its significance is expanding. More empirical studies are required to assess how well AR systems function in organizational tasks. This report fills a critical knowledge gap by offering a thorough synthesis of AR technologies used in supply chain management (SCM) and logistics. The categorization structure described in this study adds to the body of academic literature by outlining several primary and auxiliary tasks where AR may be used. Future studies will build on this paradigm and concentrate on the effects of AR adoption on processes and its financial ramifications.

The application of AR is presently being pioneered by manufacturing operations by presented by use cases in this paper, and the classification of AR potentials within SCM offers insights into how AR may be efficiently used. It also emphasizes the demand for workable answers to organizational, technological, and ergonomic issues, making AR adoption more practical for SCM and logistics businesses. An intriguing topic for future study is the interaction between AR and other cutting-edge technologies like Blockchain, IoT, Artificial Intelligence, and Big Data Analytics. It is necessary to conduct empirical research that looks into the elements that affect the acceptance of AR in SCM as well as the difficulties in incorporating AR into organizational structures. The suggested classification of augmented reality (AR) applications in SCM and logistics improves industry experts' comprehension of current augmented reality (AR) applications and their future deployment areas. It's crucial to be aware that there can be some overlaps in the categorisation, which reflects the simultaneous influence of AR on several organisational operations.

Due to the changes brought about by AR in the field of SCM, practitioners must investigate the possibilities it offers for internal and external organisational processes. The ability of AR tools and approaches to interface with both current and future technology should be acknowledged by organisations. The research highlights the continuing virtualization of supply chain operations and the demand for better visualisation techniques and supply chain twins, which are digital representations of supply chain operations and goods. The conclusions of this study may not be as generalizable as others because it only synthesises full-length publications from reputable journals, book chapters, and conference papers. Insights from publications like practitioners' magazines may offer extra viewpoints not explored in this study. Additionally, this study seeks to provide a thorough overview of the advancement in AR-related research, which will be helpful to both academic researchers and industry practitioners. This is accomplished by combining the literature on AR with a multidisciplinary research focus.

6. Discussion

In this paper, we provide an overview of the present body of information on AR as a key element of Industry 4.0. Our study, based on a systematic literature review (SLR) of the research paper “The potentials of augmented reality in supply chain management: a state-of-the-art review”, highlights the potentials of augmented reality (AR) technologies in supply chain management (SCM) and logistics for Micro and Small Enterprises. The findings indicate that AR has numerous applications across various activities in the supply chain, offering effective and innovative value-added solutions. By leveraging AR, companies can enhance the efficiency of the value chain and address challenges related to planning, scheduling, process integration, and resource utilization. The implementation of AR can lead to improvements such as optimized operations and minimized losses.

We categorize the potentials of AR into primary and support activities within the value chain, including infrastructure development, human resource management, inbound logistics, operations, and marketing and sales. AR facilitates visualization, navigation, and immersive interaction, bridging the gap between the virtual and real world, simplifying processes, and supporting decision-making. For instance, AR pick-by-vision guidance has been shown to improve task performance and reduce workload. The visualization capabilities enabled by AR enhance operational efficiencies, cost reduction, and responsiveness to changes. AR empowers logistics operators with better control over industrial processes and situational awareness, facilitated by real-time data generation throughout the supply chain.

The framework we propose provides a comprehensive roadmap for implementing AR in companies, adding significant business value. When combined with other technologies like the Internet of Things (IoT), cyber-physical systems, and big data analytics, AR extends firms' capabilities in achieving higher employee efficiencies and improved information accessibility. AR enables a shift towards smarter and more interactive working environments, where integrated and intelligent activities and objects can be managed remotely. In areas such as product visualization, process simulation, and training and maintenance activities, AR holds promise for advancing accuracy, data-driven visualization, and the development of flexible, high-performing, and efficient order-picking systems.

7. Future Challenges and Scope

Augmented reality (AR) technology offers valuable benefits in the planning and design of layout facilities, as well as in enhancing consumer experiences and optimizing outdoor logistics, its adoption in supply chain management (SCM) and logistics still faces several challenges. One major challenge is the need for improved object recognition in AR applications to ensure precise and accurate information display. Additionally, technical limitations such as low-performance AR displays, high computational power requirements, insufficient mobile visualization, energy-intensive applications, and limited battery longevity hinder the effective integration of AR systems in SCM and logistics.

Privacy concerns also pose a barrier to AR adoption, as customers may be hesitant to engage in AR experiences due to potential privacy violations.

The limited industrial applications of AR can be attributed to a lack of awareness and knowledge about the technology, organizational reluctance to change, and uncertainties surrounding the effectiveness and wide-scale adoption of AR solutions for logistics activities. Ergonomics issues, such as headaches, eye strain, and safety risks, remain problematic, posing challenges to the widespread implementation of AR. Additionally, significant financial resources are often required for investing in AR technologies, as some AR apps can be costly to implement. The heavy reliance on AR may also lead to distractions, increased cognitive stress, confusion, and visual fatigue for human operators.

Despite these challenges, the future scope of AR in the supply chain remains promising. Ongoing advancements in AR technology will further enhance its power and versatility, enabling it to solve more problems and improve the overall efficiency and accuracy of SCM and logistics operations. Current real-world examples of AR usage in the supply chain include UPS using AR to assist drivers in finding packages, Amazon utilizing AR headsets to optimize warehouse operations, and Walmart employing AR apps to enhance the customer shopping experience. As AR technology continues to evolve, we can expect to witness even more innovative applications of AR in the supply chain, transforming how SCM and logistics functions are performed and improving overall operational outcomes.

8. Appendix

8.1. Journals and no of papers published on AR

This is a table of Journals that were used for data collection and litratutre review.

Journal	Number of papers	Impact factor (2018)
International Journal of Production Research (IJPR)	4	3.199
Visual Computer (VC)	2	1.415
Business and Information Systems Engineering (BISE)	1	3.6
Expert Systems with Applications (ESA)	1	4.292
Virtual Reality (VR)	1	2.906
The International Journal on Interactive Design and Manufacturing (IJIDM)	1	0.541
International Journal of Advanced Manufacturing Technology (IJAMT)	1	2.750
Journal of Intelligent Manufacturing (JIM)	1	3.355
Computer Graphic Forum (CGF)	1	2.84

Fig (2): Journals and papers published for AR. Graphical table from the potentials of augmented reality in supply chain management: a state-of-the-art review, (Management Review Quarterly 2021), page 849.

8.2. SLR(Systematic Literature review)

A systematic literature review (SLR) is an established research method used to comprehensively identify and evaluate all relevant literature on a particular topic. Its primary objective is to derive meaningful conclusions and insights related to the research question at hand. By undertaking a systematic review, researchers aim to clarify the current state of research and identify gaps or areas that require further investigation.

The process of conducting an SLR follows a formal and methodological approach to minimize biases and enhance the reliability of the literature selected. This involves defining a clear research objective for the review and establishing criteria for including or excluding relevant literature before initiating the search. The search is predominantly conducted in electronic databases of scholarly literature, such as Business Source Complete or Web of Science [39]. Additionally, manual searches, such as reviewing reference lists in relevant sources, and efforts to identify unpublished literature are employed to ensure a comprehensive overview of the research topic. An SLR protocol is a comprehensive document that records all the information and steps involved in conducting a systematic literature review. Its purpose is to ensure transparency and reproducibility in the selection process [38]. The PRISMA flow diagram is commonly used to visually represent the selection process and make it transparent to readers. In an ideal scenario, the input of experts from the relevant research discipline, field experts, and library professionals is sought when determining search terms and strategies. To enhance objectivity in the literature selection, it is recommended to have two or more reviewers independently assess and select the literature. These measures are implemented to increase the reliability and impartiality of the review process. It is important to note that an SLR goes beyond a mere summary of a topic and distinguishes itself from a conventional literature review (Briner & Denyer, 2012) [10]. An SLR involves several process steps, and these steps may be defined differently in the literature (Fink, 2014; Guba, 2008; Tranfield et al., 2003) [24][30][38].

8.3. Country-wise Distribution

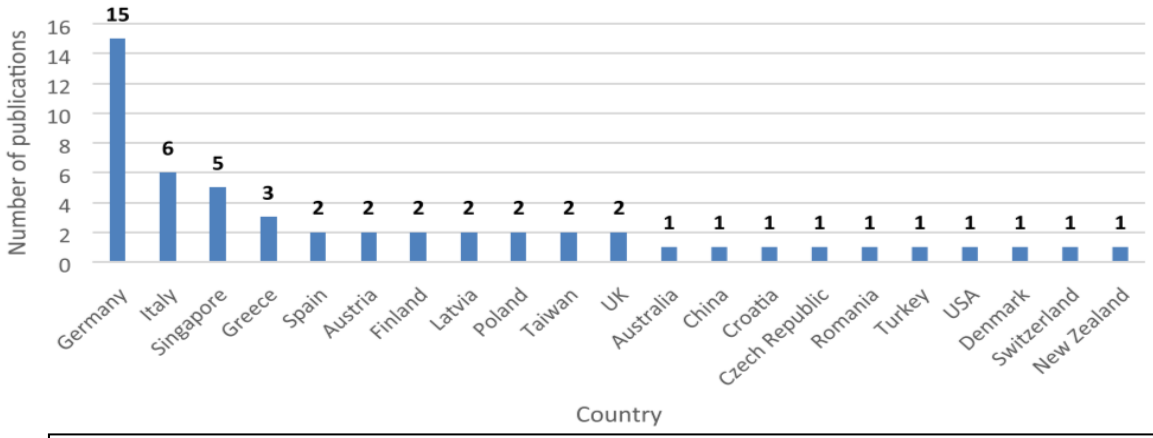


Fig (3): Country-wise distribution of papers publication on AR. Graph from the potentials of augmented reality in supply chain management: a state-of-the-art review, (Management Review Quarterly 2021), page 849.

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