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A SYSTEMATIC LITERATURE REVIEW ON RFID APPLICATION IN MANUFACTURING AND SUPPLY CHAIN MANAGEMENT

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Abstract

Radio Frequency Identification (RFID) is an intelligent object tracking system having exponential applications in various industries. In recent years, academicians and practitioners from manufacturing and supply chain industries are showing significant interest in adopting RFID technology. RFID technology is primarily applicable in product traceability throughout manufacturing and supply chain which results in improved efficiency and economic benefits. In this paper, authors have systematically reviewed the selected literature on applications of RFID in manufacturing and supply chain management. The selected literature was broadly classified into two categories based on potential areas of research and methodologies used in research on application of RFID in manufacturing and supply chain management. This paper tries to bridge a gap between theoretical research and practitioners implementing RFID technology by properly analysing selected literature and offering future opportunities for research.

KEYWORDS: *RFID, manufacturing, supply chain management, Literature review*

1. INTRODUCTION

RFID (Radio Frequency Identification) is a promising technology with exponential applications in various industries. As per RFID Journal, "Radio frequency identification (RFID) is a generic term that is used to describe a system that transmits the identity of an object or person wirelessly in the form of a unique serial number, using radio waves. It has grouped under the broad category of automatic identification technologies" [1]. RFID systems are comprised of the tag, the reader, and the RFID middleware [2]. Tags are affixed on objects in which product information is stored [3]. Tags are of two types namely 'active' tags which work on their power source and 'passive' tags react by capturing power from the incoming radio frequency [4]. The function of RFID reader is to capture data stored in the tags even without line of sight and deliver the information to backend database for further processing. The middleware processes RFID data read by the reader to remove incomplete or multiple reads generated from the same tags [5]. Finally, after filtering, classifying and normalising data, middleware forwards only the meaningful information to the business applications [1].

The RFID technology has wide range of application in various disciplines namely transportation sector, healthcare sector, sports sector and so on. There has been exponential increase in academic research on RFID technologies, and it is expected to grow continuously in future [6]. In recent years, academicians and practitioners from manufacturing and supply chain industries are showing significant interest in adopting RFID technology. RFID is becoming popular due to its low-cost sensing and identification characteristics [7]. It is more advantageous than traditional barcodes in the area of supply chain management as barcodes can only be used to detect the same code present on the same type of items, whereas RFID is used to identify various products as well as to trace it throughout production processes and other activities [8]. Also, it provides several

advantages such as greater product visibility and traceability [9], improved inventory management [10], improved business and control processes [11], and enhanced supply management efficiency [12]. In this paper, an attempt has been made to review the selected existing literature on applications of RFID in manufacturing and supply chain management (SCM). The first objective of the present study is to explore selected existing literature on RFID application in manufacturing and SCM sector.

Further, to enlist future research opportunities by identifying research gaps from the literature review and to provide valuable insights for academicians and practitioners is second objective of the study. Based on these research objectives, following research questions were formulated for the study.

RQ1: What is the current state-of-art of literature on the application of RFID in manufacturing and supply chain management?

RQ2: What are the possible future trends in the area of RFID adoption and implementation in manufacturing and supply chain management?

To answer these questions, this study aimed at exploring existing literature on RFID application in manufacturing and SCM sector. In this paper, the author reviews literature on RFID and segregates the selected literature based on applications of RFID in the area of manufacturing and supply chain management. By critically analysing the selected literature, author provides valuable insights for all the academicians and practitioners working in this domain. This paper tries to bridge a gap between theoretical research and practitioners implementing RFID technology by properly analysing selected literature and offering future opportunities for research. Section 2 discusses the methodology adopted for selecting articles for literature review. It further outlines the classification scheme for selected literature. Section 3 systematically reviews the potential areas of research and section 4 reviews different methodologies used

in research on RFID application in manufacturing and SCM sector. Finally, section 5 concludes with discussion and future directions.

2. REVIEW METHODOLOGY

In the present study, we followed a systematic approach to review the selected literature on the application of RFID in manufacturing and supply chain management. Firstly, the search using the combination of key terms: ‘Radiofrequency Identification/RFID’ AND ‘Manufacturing Industry/Sector’ AND ‘Supply Chain Management’ was performed. The open-source database was used to collect the research articles by applying inclusion and exclusion criteria. We excluded white papers, theses, book chapters, conference proceedings and websites and only articles published in peer-reviewed journal were included in this review. Also, only articles published in English language were included in this study.

Further, by reviewing the title and abstract of selected research articles, we have excluded those articles which were not di-

rectly relevant to our study. In addition to the above-selected articles, few more articles were selected by backward reference searching method. Fig. 1 shows the article selection methodology used in present study and based on these criteria, 35 research articles were shortlisted for our study.

2.1 Distribution of Articles based on year of publications

The distribution of research articles published between the years 2006 to 2016 on RFID and its application in manufacturing and supply chain management sector is as shown in Fig. 2. As we can see, there is exponential increase in number of publications between 2006 and 2008, from one publication to six. The sudden increase in number of publications shows that researchers acquired more interest in RFID during that period. Then, number of publications fluctuated between two to five after year 2010 till 2016. Earlier studies till 2010, mainly focus on identifying factor influencing RFID adoption whereas articles published later are more focused on impact of RFID on process management or performance improvement in manufacturing and supply chain activities.

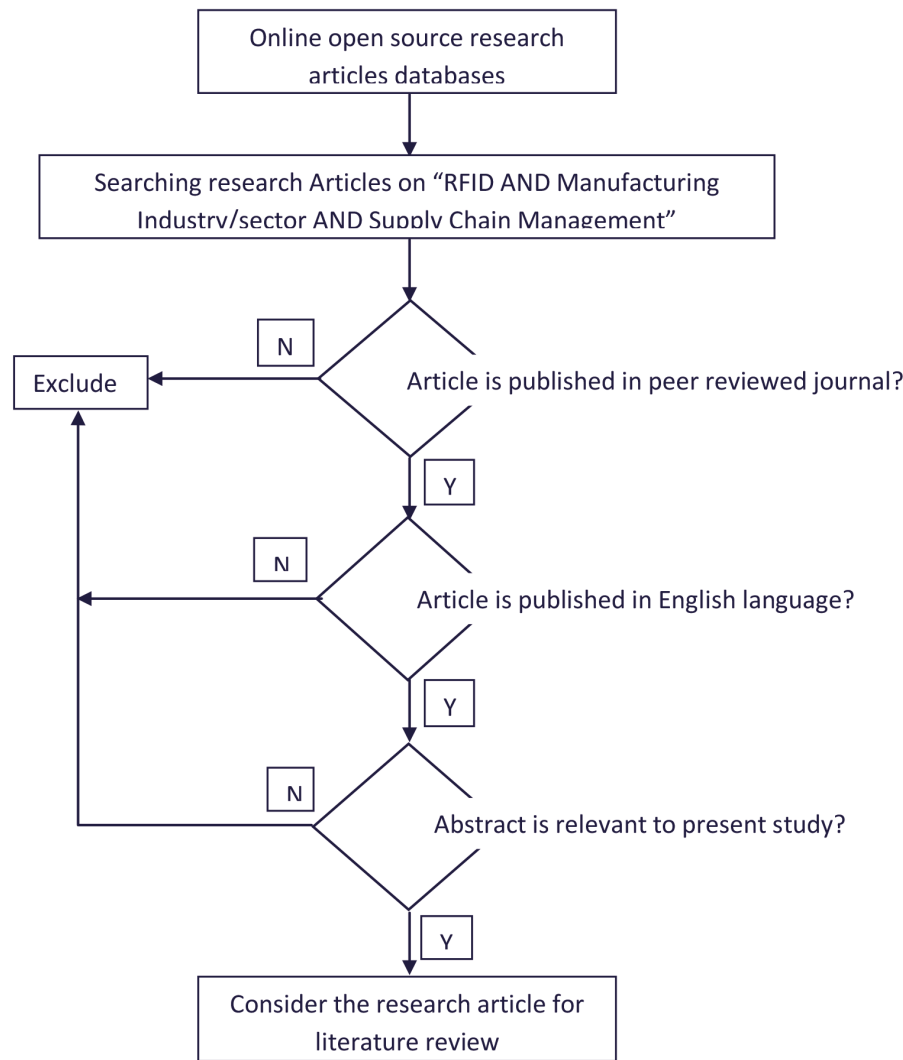


Fig.1 Article selection methodology (Source: Musa and Dabo, 2016)

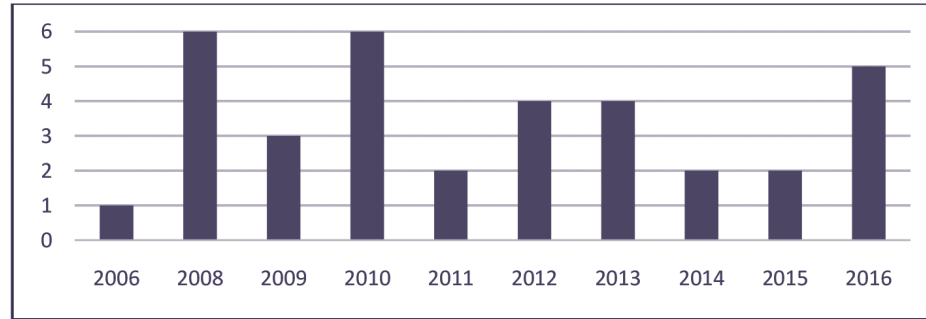


Fig. 2 Distribution of research articles by year of publication

2.2 Distribution of Articles based on Journal

The literature review yielded 35 research articles from 23 journals published between the years 2006 to 2016 on RFID application in manufacturing and SCM sector. The distribution of research articles in 23 journals is as shown in Fig. 3. These 23 journals are from various disciplines like manufacturing, logistics, supply chain management, production and operations management. Four journals namely ‘International Journal of Production Economics’, ‘International Journal of Advanced

Manufacturing Technology’, ‘International Journal of Production Research’ and ‘Industrial Management & Data Systems’ are contributing to 40% of research articles selected in the present study. ‘International Journal of Production Economics’ has highest number of research articles published with 15% of publications, during ‘International Journal of Adv. Manufacturing Technology’, ‘International Journal of Production Research’ and ‘Industrial Management & Data Systems’ have published 8% of publications each.

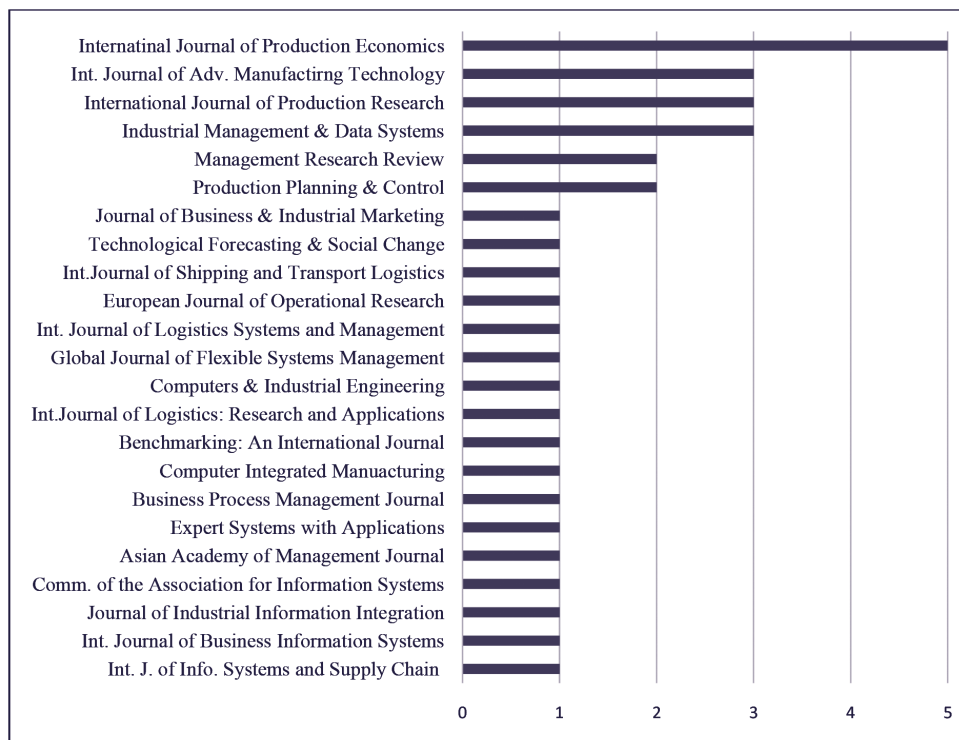


Fig. 3 Distribution of research articles by Journal

By reviewing the selected literature, we observe that researchers have majorly worked upon identification of RFID Adoption factors in manufacturing and supply chain management [12-14]; application of RFID in warehousing and inventory management [6],[15],[16]; application of RFID in logistics and supply chain management [9],[17],[18] and impact of RFID on performance improvement [10],[19],[20]. Also, Empirical

approach, analytical approach, simulation approach and theoretical approach are four major research approaches that were used in the selected existing literature to examine the RFID application in manufacturing and SCM sector. Based on this survey, the selected literature for present study was broadly classified under two categories namely ‘content-based’ and ‘research methodology based’, as shown in Fig. 3. Authors

divided the selected literature into four subcategories under 'research methodology' category namely analytical research, simulation-based research, empirical research and theoretical research. They have also divided the selected literature based on its content into four subcategories under 'content' category

namely RFID adoption factors, Warehousing and Inventory management, Logistics & Supply Chain Management and Performance improvement. The subcategories under content category are overlapping, and they indicate different areas of research on RFID application in manufacturing and SCM sector.

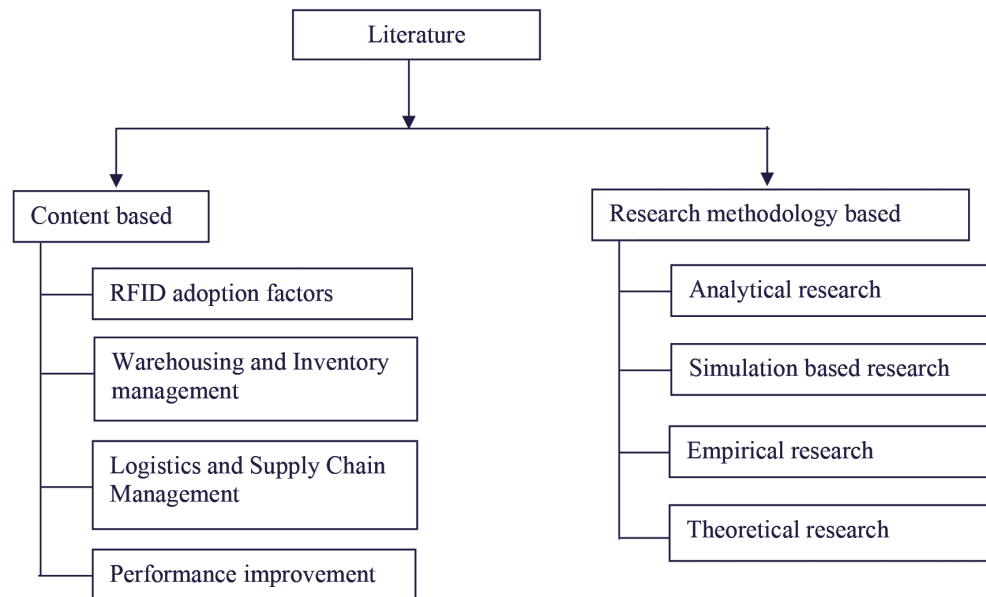


Fig. 4 Literature classification scheme

3. POTENTIAL AREAS OF RESEARCH ON RFID APPLICATION IN MANUFACTURING AND SCM

Many academicians have done much research on RFID application in various sectors. In this paper, we are focusing on reviewing the papers which are related to RFID application in manufacturing and supply chain management. As stated above, broadly classified under two categories namely content-based and research methodology based. In this section, we will discuss selected literature by categorising it under first category 'content-based'. Authors have further classified the literature in four subcategories namely RFID adoption factors, Warehousing and Inventory management, Logistics & Supply Chain Management and Performance improvement.

3.1 RFID adoption factors

RFID is a new technology which can drastically transform manufacturing and SCM sector, but its adoption rate is still low [6]. Hence, researchers have focused on identifying the critical factors specific to the manufacturing sector influencing RFID adoption. Chang et al. [21] and Lin L.C. [22] conducted an empirical study to assess the key factors influencing RFID adoption in Taiwanese logistics industry. Reyes et al. [13] also conducted similar research for logistics industry across the globe. Wang et al. (2010) surveyed to discuss potential barriers to adopt RFID in Taiwanese manufacturing firms. Chuang and Shaw [2] surveyed to identify critical factors influencing RFID implementation and other enterprise resource management systems. Bose and Lam [1] discussed the barriers for management of massive amount of data generated by RFID technologies and

suggested various solutions for the successful RFID implementation. The factors identified based on the survey conducted in large organisations cannot be directly applied for small or medium scale industries (SMEs) as challenges faced by them will be different. Therefore, some researchers have focused on potential challenges faced by SMEs to RFID adoption. Chen and Papazafeiropoulou [8] conducted a survey-based study to identify critical factors influencing RFID adoption decision in Taiwanese IT manufacturing SMEs. Similar studies were conducted by Pool et al. [23] for Iranian manufacturing SMEs and Fossowamba et al. [14] for SMEs in USA, UK, Australia and India.

3.2 Warehousing and Inventory management

Inventory management is a part of the warehousing process. In inventory management, the company can keep track of raw materials, Work-in-process goods and finished goods. Inventory management can only be helpful to check the availability of the exact physical number of stocks present in the warehouse, whereas warehousing involves all the movements from inward movement of raw materials to outbound movement of finished products. Lim et al. [6] conducted a literature review of articles published between year 1995 to 2010 related to RFID and its impact on warehousing operations and presented its applications, benefits and obstacles to RFID adoption in warehousing. Huang et al. [15] presented an advanced manufacturing technology namely RFID based wireless manufacturing to manage job shop work-in-process inventories and for improving shop floor efficiency. Chen et al. [24] applied value stream mapping to analyse and identify inefficient operations in warehousing

and lean management, and RFID technology was introduced to improve efficiency of warehouse management. Alyahya et al. [25] developed an optimisation algorithm for selection and transportation of in house item for proposed RFID based inventory management and warehousing system. Fan et al. [16] developed newsvendor models to study how RFID technology adoption affects policies of inventory control and supply chain benefits. The value of RFID technology in supply chain of maintenance companies was examined by few researchers. Ngai et al. [26] developed an RFID based model to reduce the costs associated with tracking processes of supply chain of aircraft maintenance and by performing a case study proved that RFID technology is advantageous for aircraft maintenance. Similar research was done by Ramudhin et al. [27] who developed a generic framework for designing an RFID based tracking and control system and applied that framework to an aircraft engine maintenance, repair and overhaul (MRO) activities.

3.3 Logistics and Supply Chain Management

Logistics management deals with meeting customer demands by planning and controlling the movement of goods from suppliers to consumer and information from end-user to suppliers whereas Supply chain management is a broader term which involves all the activities from procurement of raw materials till finished goods delivered to end customer. Logistics management is a part of supply chain management. Logistics management focuses on maximising customer satisfaction while supply chain management seeks to achieve overall competitive advantage. Many researchers have worked on application of RFID in supply chain management. Sarac et al. [17] conducted a literature review by focusing on impact of RFID technology on reducing the cost and business value of RFID for supply chain management. They have also presented return on investment analysis for deployment of RFID in supply chain management. Musa and Dabo [5] also conducted an exhaustive literature review of 1187 articles published between years 2000 to 2015 on RFID in SCM and provided useful insights for future researchers. Shamsuzzoha et al. [28] presented an evaluation methodology to compare the performance of different tracking and tracing technologies namely barcodes, QR codes and RFID concerning logistics and supply chain management. Zhou et al. [29] developed an RFID based remote monitoring system to get real-time information flow of supply chain which will drastically improve productivity. Lee and Park [7] proposed a unique dynamic tracing task model (DTTM) to get the end to end traceability along the supply chain. Kwok et al. [30] presented an EPC and RFID enabled supply chain network to enhance the tracking and tracing of product movement and

anti-counterfeiting within the supply chain. Similarly, Azuara et al. [9] developed a system based on RFID technology to ensure product traceability and to detect counterfeited products inside the supply chain. Afsharian et al. [3] evaluated the advantages of RFID and performed empirical study to show that RFID implementation is beneficial for supply chain of manufacturing firms. Dai et al. [18] performed a case study in small engine valve manufacturing firm to showcase how adoption of RFID is beneficial for SMEs in logistics management. Chen et al. [31] applied value stream mapping to analyse and identify inefficient operations in supply chain and lean management, and RFID technology was introduced to improve efficiency of supply chain management. Ustungdag Alp [32] performed research on valuation of RFID investments by calculating the net present value (NPV) of an RFID investment on a three-echelon supply chain. Nativi et al. [33] investigated the impact of introducing real-time monitoring of inventory using RFID technology in decentralized supply chain with closed-loop logistics and concluded that it helps in achieving higher environmental and economic performance.

3.4 Performance Improvement

The aim of performance improvement is to increase the efficiency of various processes. In manufacturing and supply chain management, many researchers have assessed the effect of using RFID technology on performance improvement. Zelbst et al. [4] studied how RFID implementation has positive effect on operational performance within the manufacturing sector. Zelbst et al. [34] also evaluated the effect of RFID and information sharing on supply chain performance. Zelbst et al. [35] further assessed the effects of RFID technology adoption and information sharing within a manufacturing facility on the just-in-time (JIT) and total quality management (TQM) practices and its subsequent impact on operational performance of manufacturing firms. Lee et al. [10] investigated the impact of RFID on inventory performance of a supply chain through simulation modelling of a representative manufacturer-retailer supply chain. Kumar and Chan [20] have utilised RFID technology to improve inventory and warehouse operations at reverse facilities in closed-loop logistics. Johansson and Pals-son [11] performed an empirical study in Swedish manufacturing firms to conclude that better logistics performance can be achieved using RFID technology. Zhang et al. [19] proposed a Smart Gateway Technology to capture real-time data from various manufacturing resources connected by multiple types of RFID devices. Authors claim that it improves data identification performance and in turn increases product quality.

Table 1 Classification of literature

Classification of literature	Research Methodology			
	Analytical	Simulation	Empirical	Theoretical
RFID adoption factors			Chang et al. [21]; Chen and Papazafeiropoulou [8]; Chuang and Shaw [2]; Pool et al. [23]; Fossowamba et al. [14]; Lin L.C. [22]; Reyes et al. [13]; Wang et al. [12]	Bose and Lam [1]

Warehouse and Inventory Management	Fan et al. [16]	Alyahya et al. [25]	Ngai et al. [26]; Ramudhin et al. [27]; Chen et al. [24]	Lim et al. [6]; Huang et al. [15]
Logistics and Supply Chain Management	Lee and Park [7]; Nativi et al. [33]	Ustungdag Alp [32]; Shamsuzzoha et al. [28]	Afsharian et al. [3]; Kwok et al. [30]; Azuara et al. [9]; Dai et al. [18]; Chen et al. [31]	Sarac et al. [17]; Musa and Dabo [5]; Zhou et al. [29]
Performance Improvement		Lee et al. [10]; Kumar and Chan [20]	Zelbst et al. [4],[34],[35]; Johansson and Palsson [11]	Zhang et al. [19]

4. METHODOLOGIES USED IN RESEARCH ON RFID APPLICATION IN MANUFACTURING AND SCM

In the second category of selected literature, namely ‘research methodology’, authors have subcategorised literature based on approach used in research namely analytical research, simulation-based research, empirical research and theoretical research. As shown in Table 1, the selected literature is classified as per content subcategories and as per research methodology used. It is evident in the present study that most of the researchers have conducted empirical studies. In this section, we will review in detail all four approaches used for research on RFID application in manufacturing and SCM sector.

4.1 Analytical Research

In analytical research, researchers develop and propose a new model and try them using existing software. Performing simulation study can be a part of this approach. In this subsection, we will review the articles in which analytical approach was used to conduct research on the application of RFID in manufacturing and supply chain management. Fan et al. [16] developed newsvendor models to study how RFID technology adoption affects policies of inventory control and supply chain benefits. Nativi et al. [33] proposed a model to investigate the impact of introducing real-time monitoring of inventory using RFID technology in decentralized supply chain with closed-loop logistics and by performing simulation they concluded that it helps in achieving higher environmental and economic performance. Lee and Park [7] conceptualized a unique dynamic tracing task model (DTTM) to get the end to end traceability along the supply chain. However, all these models mentioned above are based on certain assumptions or hypotheses. Hence, the results of these analytical models have certain inaccuracies involved. Simulation approach can provide better results as compared to analytical model. In the next subsection, we will review the articles in which simulation approach was used to conduct research on RFID application in manufacturing and SCM sector.

4.2 Simulation Research

In the simulation approach, researchers conduct study by performing various runs in artificial environment. This approach gives more realistic results as a research model can be tested over a period considering all dynamics of the system. Ustungdag Alp [32] developed a simulation model to calculate the net present value (NPV) of an RFID investment on a three-echelon

supply chain. Lee et al. [10] investigated effect of RFID on inventory performance of a supply chain through simulation modelling of a representative manufacturer–retailer supply chain. Shamsuzzoha et al. [28] developed an experimental set up with 30 dummy model runs to compare the performance of different tracking and tracing technologies namely barcodes, QR codes and RFID concerning logistics and supply chain management. Alyahya et al. [25] conducted a simulation study based on optimisation algorithm developed for selection and transportation of in house item for proposed RFID based inventory management and warehousing system. However, Simulation approach has certain disadvantages. Results of the simulation depends upon research model and any invalid model may result in wrong results. Also, this approach is time consuming and expensive. Most accurate results can be incurred by experiments or case studies. In the next subsection, we will review the articles in which empirical approach was used to conduct research on RFID application in manufacturing and SCM sector.

4.3 Empirical Research

Empirical research is based on investigations done through measurement or observation phenomena and drawing conclusions based on collected evidence. This research have several subtypes namely experimental study, case study, focus group interview method, questionnaires, surveys, correlational study and longitudinal study. In the present study, numerous researchers have used questionnaire or survey-based approach for conducting empirical research. Afsharian et al. [3] performed an empirical study to show that RFID implementation is beneficial for supply chain of manufacturing firms. Wang et al. [12] surveyed to discuss potential barriers to adopt RFID in Taiwanese manufacturing firms. Chen and Papazafeiropoulou [8] conducted a survey-based study to identify critical factors influencing RFID adoption decision in Taiwanese IT manufacturing SMEs. Similar studies were conducted by Pool et al. [23] for Iranian manufacturing SMEs and Fossowamba et al. [14] for SMEs in USA, UK, Australia and India. Chang et al. [21] and Lin L.C. [22] surveyed to assess the key factors influencing RFID adoption in Taiwanese logistics industry. Reyes et al. [13] also conducted similar research for logistics industry across the globe. Chuang and Shaw [2] surveyed to identify critical factors influencing RFID implementation and other enterprise resource management systems. Zelbst et al. [4],[34],[35] performed survey-based empirical studies to investigate the impact of RFID implementation on operational performance and supply chain

performance within manufacturing sector. Johansson and Pals-son [11] surveyed Swedish manufacturing firms to conclude that better logistics performance can be achieved using RFID technology.

Many researchers have also used a case study approach in which empirical investigation is done by observational phenomenon in real-life context. Ngai et al. [26] and Ramudhin et al. [27] performed a case study and proved that RFID technology is advantageous for aircraft maintenance. Kwok et al. [30] and Azuara et al. [9] developed a system based on RFID technology to ensure product traceability and performed case studies to detect counterfeited products inside the supply chain. Dai et al. [18] performed a case study in small engine valve manufacturing firm to showcase how adoption of RFID is beneficial for SMEs in logistics management. Chen et al. [24],[31] performed case studies to showcase improved efficiency of warehouse management and supply chain management by introducing lean management and RFID technology. In the next subsection, we will review the articles in which theoretical approach was used to conduct research on RFID application in manufacturing and SCM sector.

4.4 Theoretical Research

Theoretical studies include articles on theory building, articles proposing conceptual frameworks and articles discussing literature review. In this type of research, authors support his or her claim without verifying the proposed models using any empirical data. Few researchers have conducted systematic review of literature. Lim et al. [6] conducted a literature review of articles published between year 1995 to 2010 on RFID technology and its impact on warehousing operations whereas, Sarac et al. [17] systematically reviewed existing literature by focusing on effect of RFID technology on reducing the cost and value creation for supply chain management. Musa and Dabo [5] also conducted an exhaustive literature review of 1187 articles published between years 2000 to 2015 on RFID in SCM and provided useful insights for future researchers. Bose and Lam [1] discussed the barriers for management of huge amount of data generated by RFID technologies and suggested various solutions for the successful RFID implementation. Zhou et al. [29] developed an RFID based remote monitoring system to get real-time information flow of supply chain; Huang et al. [15] presented an advanced manufacturing technology namely RFID based wireless manufacturing to manage job shop work-in-process inventories and for improving shop floor efficiency. Zhang et al. [19] proposed a Smart Gateway Technology to capture real-time data from various manufacturing resources connected by multiple types of RFID devices.

5. DISCUSSION AND FUTURE DIRECTIONS

In the present study, selected literature on RFID application in manufacturing and SCM sector has been systematically reviewed. Total 35 research articles shortlisted for the present study were broadly categorised into two categories namely 'content-based' and 'research methodology based' To the best of author's knowledge, this categorization approach is unique than previous existing literature in the stated research area. The literature review study reveals that benefits of RFID, applica-

tions of RFID and key factors influencing RFID adoption are widely discussed in the literature. Also, many researchers conducted research on application of RFID in inventory management to reduce inventory inaccuracies, product counterfeiting and to improve inventory efficiency. The research have also been conducted on application of RFID in logistics and supply chain management to improve traceability across supply chain. Studies also show that adoption of RFID technology can lead to enhancement of operational performance, supply chain performance, logistics performance and competitiveness. The review offers useful insights on current state-of-art of literature on application of RFID in manufacturing and supply chain management. Firstly, the review states that RFID adoption is beneficial in manufacturing and supply chain management. The main advantages of implementation of RFID technology in manufacturing and supply chains are:

- Improvement in product traceability throughout the supply chain [7-9]
- Improvement in quality and transparency of data across the supply chain [9],[19]
- Increase in efficiency of processes through real-time tracking [15],[29],[33]
- Reduction in inventory inaccuracies and product counterfeiting [9],[30]
- Reduction in required manpower due to process automation [3]

Despite all these advantages, adoption rate of RFID technologies is still low [6]. It is mainly because of its high initial investment cost. Many existing identification technologies are much cheaper than RFID technologies. However, from the literature review, we understood that RFID technologies not only helps in product identification but also helps in significantly increasing operational performance which in turn increases business benefits.

The main contribution of this paper is to identify future research opportunities by exploring research gaps from the reviewed literature. The following discussion may help researchers in the field of manufacturing and supply chain to identify new research areas for future research. From reviewed papers, we have identified following limitations of existing literature which will be directive for future research.

- Many academicians have discussed challenges in the adoption of RFID technology or factors affecting RFID adoption, but most of the studies are conducted in developed countries.
- There is a lack of study on return on investments in RFID technology against high initial implementation cost.
- Even though many researchers have done an empirical study on factors affecting RFID adoption decision focusing on manufacturing sector, role of government in RFID adoption is still less explored.
- Future research can be conducted to reduce the cost of RFID technologies for higher adoption.

- There is no industry-specific technical and financial guideline for practitioners to choose and implement RFID system.
- Most of the studies in the existing literature have analysed simplified supply chain for a specific period which lacks in consideration of the dynamics of the system.
- There is a lack of study which specifies changes required in business models for adoption of RFID in manufacturing and supply chain management.
- With increasing awareness about environmental safety, more studies to be performed on the application of RFID in reverse logistics and its impact on environment and business benefits.

The literature analysis performed in the present study is useful for practising managers in manufacturing and supply chain sector. We hope that this survey will be helpful for them to acknowledge the enormous potential of RFID technology. As this study discusses numerous articles on critical factors influencing RFID adoption in manufacturing sector, it might serve as a guide for adoption and implementation of RFID in the stated area. Finally, our research also has few limitations. Authors have only considered research papers from open source databases. Also, authors did not take any research paper from languages other than English which may result in ignoring any important research paper related to stated area of research. Despite these limitations, this paper tries to bridge a gap between theoretical research and practitioners implementing RFID technology by systematically analysing selected literature and offering future opportunities for research in RFID application in manufacturing and supply chain setup.

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