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IMPROVING MATERIAL REQUIREMENTS PLANNING THROUGH WEB-BASED APPLICATION: A CASE STUDY THAILAND SMEs

Abstract

In the small business industry, effective cost control is of paramount importance. A well-functioning Material Requirements Planning (MRP) process plays a vital role in enabling businesses to manage their costs efficiently. This research paper explores the improvement of MRP in the context of small businesses in Thailand through the implementation of a web-based application. The objective was to enhance the MRP process by developing an MRP system using ReactJS, NodeJS, and PostgreSQL. The system was evaluated using heuristic evaluation techniques and the results indicated a positive outcome, the mean value is 0.83. The developed web based MRP system proved beneficial for small businesses, as it effectively reduced stocking costs and facilitated efficient raw material procurement. This research provides valuable insights into the implementation of web based MRP systems, enabling small businesses to optimize inventory management and enhance operational efficiency.

1. INTRODUCTION

The term "materials management" (Bell & Stukhart, 1986; Brown, 1977; Vrat, 2014) refers to a variety of operations management activities involved with selecting the materials required for supply chain and production processes. The control and regulation of material flow is one of these requirements, along with the simultaneous evaluation of factors like demand, price, availability, quality, and delivery schedules. The main components of this strategy, known as material requirements planning (MRP) (Deif, 2011; Jacobs & Chase, 2014; Ptak & Smith, 2011), were forecasting modules and bill-of-materials processors. It is important to remember that traditionally, materials management only applies to tangible goods and products, leaving out services from its purview.

A comprehensive system called MRP was created to simultaneously accomplish three main goals. First and foremost, it seeks to guarantee the availability of goods and materials required for both production procedures and prompt customer delivery. A secondary yet

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crucial objective of the MRP system is to optimize inventory levels, thereby harmonizing the imperative to satisfy demand without accumulating excessive stock, ensuring that raw materials are never out of stock. This balance is vital for maintaining the desired product quality and curbing unnecessary costs (Gola, 2021). Lastly, MRP serves as an instrumental tool for enhancing supply chain integration by meticulously orchestrating production planning. The precision in scheduling deliveries and orchestrating procurement activities under the MRP paradigm plays a quintessential role in bolstering organizational efficiency and optimizing operational performance.

In contemporary times, the utilization of information technology has become pervasive in MRP through the employment of software solutions (Budiac, 2023). However, it is generally acknowledged that the purchase and maintenance of such software entail significant costs, particularly for small and medium sized enterprises (SMEs). As a result, SMEs may incur higher costs when purchasing these software suites. For SMEs, investigating alternative strategies such as developing proprietary MRP software using open-source technology presents a viable option.

Previous studies have presented diverse instances where information technology has been applied to facilitate the management of MRP across various industries. E. Martyani et al. (2019) study and development of a web based MRP information system prototype in a company producing palm oil. D. Kapoor et al. (2022) study and develop a web-based operations management system for micro-manufacturing industries using Enterprise Resource Planning (ERP) concepts. N. Hasanati et al. (2019) develop a web application using PHP programming and Firebird databases and using the MRP method for planning raw material orders in the garment industry. L. Qiang et al. (2001) presents the development of an enterprise application that integrates MRP to a job shop simulator. This system uses Enterprise Java Beans that are deployed in a J2EE-compliant application server to perform B2C transactions and MRP logic. A. Afolabi et al. (2017) presented web-based technologies for planning and control of building materials and develop a framework for effective implementation. This system using database system is designed using MySQL connected to the HTML web interface through a PHP.

In recent years, the field of MRP has witnessed significant advancements due to the integration of information technology (Mabert, 2007; Matías et al., 2008; Rolstadås, 2012). This integration has facilitated the efficient management of resources, production schedules, and inventory levels in various industries. In line with this trend, the study aims to contribute to the existing body of knowledge by focusing on the development of a web-based application for MRP, employing new technologies viz ReactJS, NodeJS, and PostgreSQL database.

The primary objective of research is to assess the feasibility and applicability of the developed MRP system, particularly within the context of SMEs in Thailand (Kesorn & Hanchainao, 2022). SMEs form a crucial segment of the business landscape in Thailand, representing a significant contributor to the country's economy. However, these enterprises often face resource constraints and limited access to advanced technological solutions due to their relatively modest scale.

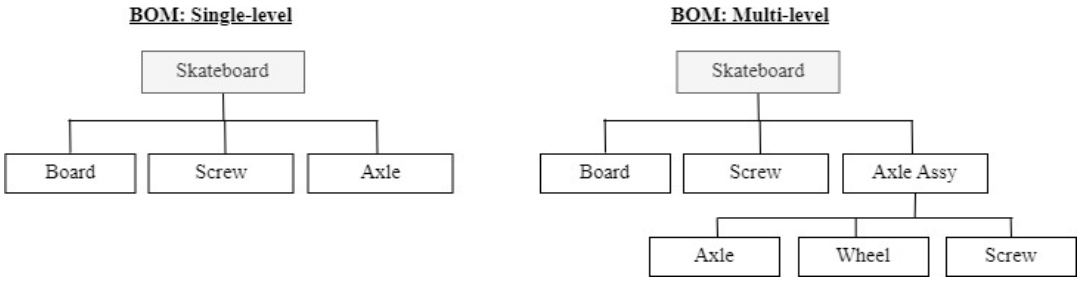
2. LITERATURE REVIEW

2.1 Material Requirement Planning

Material Requirements Planning (MRP) (Deif, 2011; Jacobs & Chase, 2014; Ptak & Smith, 2011) is a systematic approach used in manufacturing to determine the necessary materials and components required for product production. This process involves three key steps: assessing the existing inventory, identifying additional materials needed, and scheduling their production or procurement. By utilizing specialized software, MRP plays a crucial role in optimizing inventory availability, reducing costs, enhancing operational efficiency, and improving overall profitability in manufacturing operations. Moreover, MRP enables manufacturers to respond promptly to increased demand, minimizing production delays and inventory stockouts, thus preventing customer loss and contributing to revenue growth and stability. MRP is an effective methodology that contributes to waste reduction and enhances productivity through the implementation of a Just-in-Time (JIT) (Ho & Chang, 2001; Pheng & Meng, 2018) approach for raw material availability.

2.2 Bill of Materials

A Bill of Materials (BOM) (Jiao et al., 2000) serves as a centralized source of information that outlines the components required and assembly instructions for manufacturing a product. Manufacturers rely on the BOM to initiate the assembly process accurately. The creation of an accurate BOM is crucial as it ensures the availability of parts at the required stages and enhances overall production efficiency. BOM is a hierarchical list that includes all the materials, subassemblies, and other parts that are required to make a product, along with their quantities, and is typically displayed in a parent-child relationship. The parent at the top of the hierarchy is the finished good.



(a) BOM Sigle Level. **(b) BOM Multi Level.**

Fig. 1. Bill of Materials Type.

Figure 1 provides a visual representation of the classification system employed for the BOM, highlighting two primary types: single-level BOM and multi-level BOM. The classification serves as a framework for organizing and categorizing the components within the BOM structure based on their levels of detail and complexity.

2.3 Master Production Schedule

The Master Production Schedule (MPS) (Serrano-Ruiz et al., 2021; Tobon-Valencia et al., 2022) serves as a comprehensive production plan, specifying the products to be manufactured, their quantities, and the corresponding start dates. However, the task of maintaining the MPS is challenging due to the need to balance conflicting objectives. This includes producing enough to fulfil actual customer orders while also generating additional inventory to meet anticipated customer demand.

In conclusion, MRP determines the necessary materials and when they will be needed during the manufacturing process using data from the BOM, inventory data, and the MPS.

3. METHODOLOGY

This research focuses on the development of the MRP system within the context of SMEs in Thailand. Information technology serves as a fundamental component in this research, whereby web applications are designed and developed using ReactJS, NodeJS, and PostgreSQL. The aim is to investigate the feasibility and effectiveness of implementing an MRP system tailored specifically to the needs of SMEs in Thailand. The system design and development process are illustrated in Figure 2, highlighting the various stages involved in creating and implementing the MRP system for the designated case study.

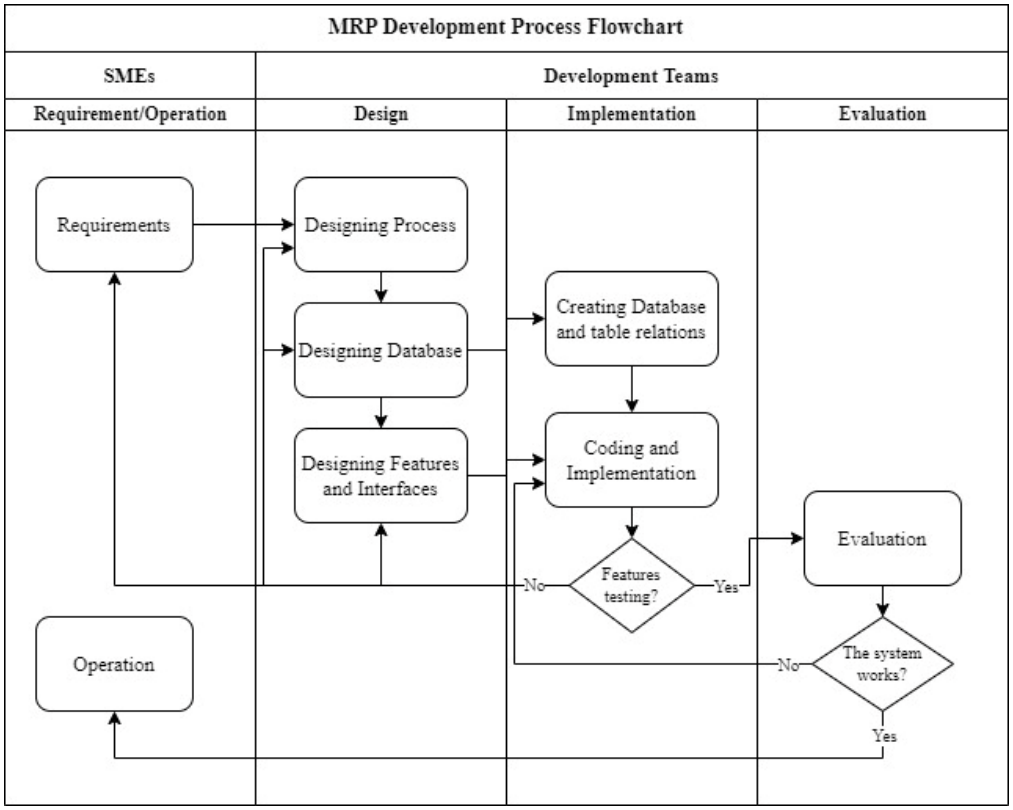


Fig. 2. Development Process Flowchart.

This research project comprises two primary components: the first part focuses on the specific requirements and considerations for SMEs in the case study, while the second part centers on the design and development of the system. Although distinct, these two components are interconnected, with each step contributing to the overall system development process. The following sections provide a detailed description of each step involved in the research.

1. Requirement Analysis: This phase involves a comprehensive examination of the production system requirements within the case study context. The case study revolves around a small business engaged in the production of various types of Thai desserts. Presently, the cooking process relies on the cook's predictions and estimations. This stage aims to identify and understand the specific requirements and challenges faced by the business in terms of optimizing the production system. Through rigorous analysis and assessment, the research seeks to gather pertinent information to inform the subsequent stages of system development.
2. System Design: This phase encompasses the systematic process of designing the proposed system. It involves the development of comprehensive workflows, the design of database systems and their relationships, as well as the design of system functionality. The system design stage is crucial in outlining the structural and functional aspects of the system.
3. Implementation: The implementation phase involves the execution of the system design, encompassing the creation of a database based on the designed specifications and the coding of program modules to incorporate the desired system functionality. Upon completion of the development stages, preliminary functional testing is conducted to assess the system's performance. In this study we utilize a black box testing technique (Rambe et al., 2020). If the system operates correctly and comprehensively, it proceeds to the performance evaluation stage. However, if any issues arise during testing, a thorough examination is conducted, including revisiting the design process and potentially reanalyzing the identified problems. This iterative approach ensures the refinement and enhancement of the system to achieve the desired performance and functionality.
4. Evaluation: Evaluation constitutes a critical step in the software development process as it determines the compatibility of the developed system with the specified requirements and objectives. To assess the system's efficacy, three distinct evaluation methods were employed: performance testing, usability testing and security testing. These evaluation approaches aim to comprehensively gauge the system's performance, user-friendliness, and security aspects. In this study, the usability evaluation was conducted using Nielsen's ten heuristics, which are a set of usability principles established by Jakob Nielsen (1995). These heuristics provide a framework for assessing the usability of a product or system based on factors such as user interface design, navigation, error prevention, and user feedback. Additionally, the heuristic checklist model proposed by Xerox Corporation (Pierotti, 1995) was utilized to complement the evaluation process, providing additional guidelines and criteria for assessing usability aspects specific to the studied context.
5. Operation: The operational phase involves the practical implementation of the designed and developed system within the context of the business case study. At this stage, the focus shifts to importing actual data into the system that has been designed

and developed. This step allows for the system to be utilized in real-world scenarios, enabling users to interact with the system and assess its functionality, effectiveness, and suitability within the operational environment. By importing actual data, the research aims to validate the system's performance, analyze its capabilities in handling real-world data, and assess its overall operational viability in meeting the specific requirements of the business case study.

4. RESULTS AND DISCUSSION

The outcomes of the system design and development process are presented in this section. As previously stated, the objective of this study is to enhance the efficiency of the MRP system within the context of SMEs in Thailand. Through the utilization of web-based technology, the obtained results are displayed and discussed in the following manner.

4.1. Process Design

The design outcomes of the MRP system's operational workflow are presented in Figure 3, showcasing the three primary processes: input, processing, and output. This visual representation provides a comprehensive overview of the system's working process and highlights the key stages involved in its operation.

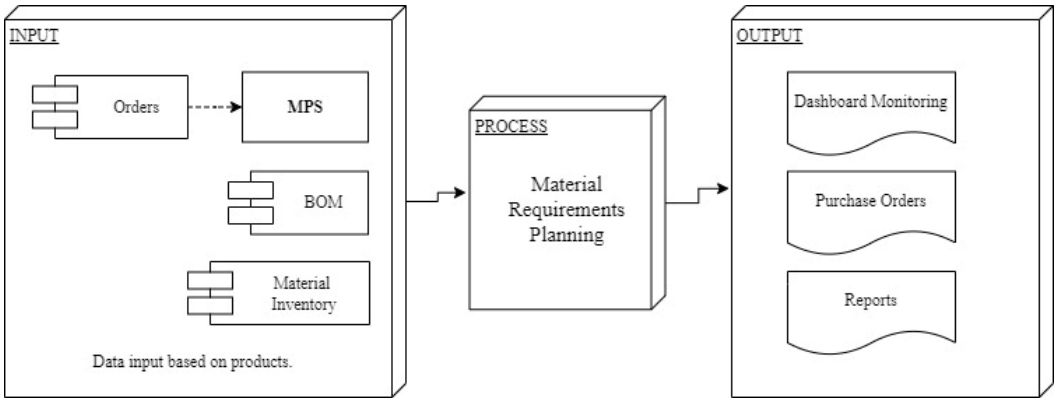


Fig. 3. Process workflow.

The input phase entails the gathering and entry of relevant data into the MRP system. This includes information such as the bill of materials, inventory, master production schedules and customer demand. These inputs serve as crucial data points for the subsequent processing stage.

The processing phase of the MRP encompasses rigorous calculations and analysis of input data within the system. Within the scope of this study, particular attention was given to inventory control, with an emphasis on the application of the Economic Order Quantity (EOQ) (Septiawan & Panday, 2021) concept as shown in Eq. (1). This model plays a vital role in determining the ideal order quantity that minimizes overall inventory costs, comprising both ordering costs and holding costs. By integrating the EOQ model into the

processing phase, the study aims to optimize inventory management and enhance cost-effectiveness within the MRP system.

$$EOQ = \sqrt{\frac{2 \times D \times S}{H}} \quad (1)$$

where: EOQ – The economic order quantity.,
D – The demand or usage of the item in one year period (this study per month).,
S – The ordering or setup cost per order.,
H – The carrying cost per unit per year (this study per month).

The output phase represents the outcomes and outputs of the MRP system's processing stage. This includes comprehensive reports, schedules, and recommendations related to material requirements, production timelines, and procurement activities. The results provide valuable insights and actionable information to guide decision-making processes within the manufacturing environment.

4.2. Database Design

The database system design implemented in this research involved the utilization of ER diagrams as a tool to illustrate and establish relationships among the data tables. By employing ER diagrams, the intricate connections and dependencies between each table were visually represented, facilitating a comprehensive understanding of the database structure. Figure 4 depicts the resulting ER diagram, which provides a visual representation of the relationships and associations between the tables within the database system.

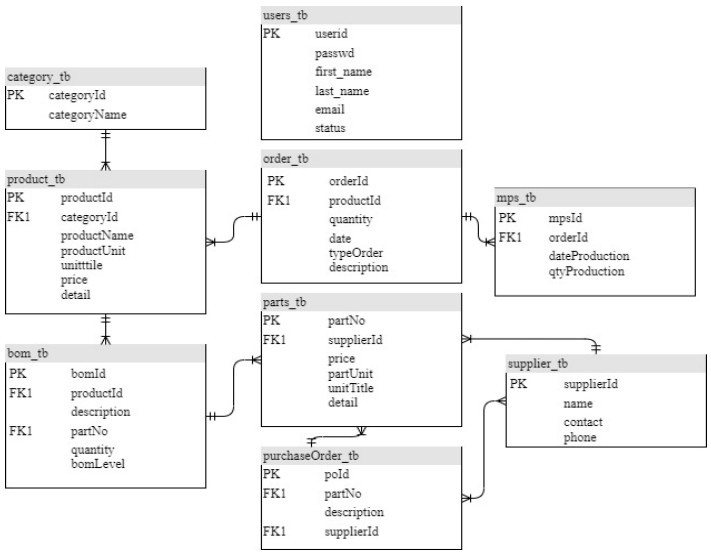


Fig. 4. Database ER Diagrams.

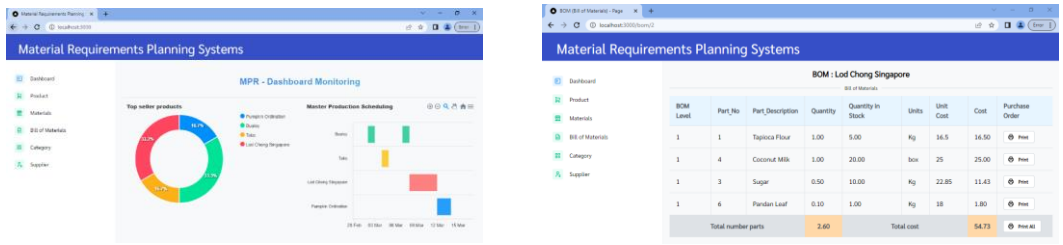
The attributes and characteristics of each table within the database system can be described as follows.

1. Category Table (category_tb): This table stores product category data, providing a classification system for organizing products based on their respective categories.
2. Product Table (product_tb): This table contains information about the products offered by the small business in the case study. It includes details such as product names, descriptions, and other relevant attributes. Examples of products in this context may include Lod Chong Singapore, Banana in Coconut Milk Bua Loy and more.
3. BOM Table (bom_tb): The bill of materials table stores information about the required raw materials and their quantities for each product. It helps in determining the necessary components and quantities for production purposes.
4. Order Table (order_tb): This table stores data related to production orders. It captures information on customer-specific requirements as well as anticipated production needs.
5. MPS Table (mps_tb): The master production schedule table contains information pertaining to the primary production schedule. It utilizes data from the order_tb table for effective production planning and scheduling.
6. Parts Table (parts_tb): The parts table maintains a record of the raw materials required for product manufacturing. It specifies the components needed to produce the final products.
7. Purchase Order Table (purchaseOrder_tb): This table stores information about raw material purchases. It includes details such as order quantities, delivery dates, and supplier information.
8. Supplier Table (supplier_tb): The Supplier table stores information about raw material suppliers. It includes data such as supplier names, contact details, and other relevant information to facilitate effective procurement processes.
9. User Table (users_tb): The User table stores information about authorized system users. It includes details about designated staff members who have access to the MRP system on behalf of the business owner.

4.3. Results of Implementation

In this research, the development of the MRP system was undertaken with a focus on catering to the specific requirements of the Thai dessert business (Kesorn & Hanchainao, 2022). The development process involved the implementation of various program features to support the unique needs of this industry. The MRP system was developed using ReactJS and NodeJS as the primary programming languages, with data storage and management handled through a PostgreSQL database.

The outcome of the system development effort is exemplified in Figure 5, which showcases key components of the developed MRP system. The dashboard page provides users with a comprehensive view of essential statistics and the production schedule for the products. This page offers valuable insights into production performance, allowing stakeholders to monitor and analyze relevant data in real time. Additionally, the BOM page serves as a crucial resource, displaying the material demands associated with each product. This facilitates effective planning and ensures the availability of necessary materials during the production process.



(a) Dashboard Page. **(b) Bill of Materials Page.**

Fig. 5. Web Interface for Material Requirement Planning.

4.4. Evaluation

The evaluation results of the systems developed using heuristic evaluation are presented in this section. The evaluation checklists and rating scores employed in this study were consistent with previous research that evaluated ERP system (Singh & Wesson, 2009). A rating scale ranging from 0 (Not a usability problem) to 4 (A catastrophic usability problem that prohibits users from performing their daily activities) was utilized to assess the systems, allowing for a comprehensive evaluation of their usability.

For the evaluation process, a panel of three assessors was assigned, comprising two specialists in MRP systems and one specialist in information system development. Each assessor brought their expertise and perspectives to the evaluation, ensuring a well-rounded assessment of the developed systems. Following the evaluation, the results were subjected to statistical analysis using measures such as mean, median and mode. These measures provided quantitative insights into the assessment outcomes, facilitating a deeper understanding of the evaluators' opinions and the overall usability of the developed systems. The analysis results, including the calculated mean, median and mode values, are presented in table 1.

Tab. 1. Heuristic evaluation statistical results.

Heuristic	Mean	Median	Mode
Visibility of system status	0.39	0.00	0.00
Match between system and the real world	0.72	1.00	1.00
User control and freedom	0.62	1.00	1.00
Consistency and standards	0.50	0.00	0.00
Help users recognize, diagnose, and recover from errors	0.75	1.00	0.00
Error prevention	1.09	1.00	1.00
Recognition rather than recall	0.89	1.00	1.00
Flexibility and minimalist design	1.81	2.00	2.00
Aesthetic and minimalist design	0.78	1.00	0.00
Help and documentation	0.75	1.00	0.00

The evaluation results indicated that the "visibility of system status" aspect received the most not a usability problem among the evaluated usability criteria, the mean value is 0.39. This suggests that the system effectively communicated its status and provided clear feedback to users, enhancing user understanding and interaction. On the other hand, the

aspect of "flexibility and minimalist design" received the most usability problem, indicating room for improvement in terms of system flexibility and adopting a minimalist design approach, the mean value is 1.81 (Singh & Wesson, 2009). Despite this, the overall assessment of the proposed system is positive, suggesting that it is suitable for the case study at hand. While certain areas may require further refinement, the system demonstrates its capability to meet the specific requirements of the case study.

In addition to the evaluation results, the assessors provided further suggestions to enhance the system's functionality and usability. One notable suggestion was to incorporate customization options for the dashboard page, allowing users to personalize the displayed information according to their specific needs and preferences. Furthermore, the assessors recommended establishing an automatic connection between the dashboard page and the accounting system. This integration would streamline the data exchange process and facilitate real-time updates of financial information. By automating this connection, the system would reduce manual data entry efforts and enhance the accuracy and timeliness of financial data within the MRP system.

5. CONCLUSIONS

This research successfully achieved its objective of improving the MRP process through the development and implementation of a web-based application tailored for small businesses in Thailand. The MRP system, developed using ReactJS, NodeJS and PostgreSQL, demonstrated its effectiveness in reducing product stocking costs and facilitating efficient raw material procurement. The positive results obtained from the heuristic evaluation confirmed the system's quality and usability.

By leveraging the web based MRP application system applied to the small business within the purview of this study, it was discerned that the system significantly augmented efficiency in inventory management. The system aligns inventory levels with the production volume, ensuring optimal stock without superfluous holdings. Additionally, the system facilitates proficient planning for the preemptive procurement of raw materials, synchronizing with the actual production needs. A salient advantage of this system is the comprehensive visibility it offers concerning inventory levels, presenting an avenue for cost reduction and heightened operational efficiency. The outcomes of this study proffer pertinent insights, making a compelling case for the potential application of similar web based MRP systems across various industries and geographical contexts, thereby promoting refined supply chain management practices.

Acknowledgments

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Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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