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Designing a lot sizing calculator application as a practicum tool for the industrial Engineering Project (PTI) using the Rapid Application Development (RAD) method

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Abstract

An application is a tool designed to perform specific tasks to meet user requirements. Applications can facilitate the learning process in practicums. In the Material Requirement Planning (MRP) module of the Industrial Engineering Project (PTI) practicum, the current tools are inadequate in terms of both theory and process. These deficiencies include incompatible data input, a limited number of methods, the absence of step-by-step solutions, and a lack of output visualization. Such issues can result in suboptimal student understanding. In this study, a lot sizing calculation application was designed specifically for the needs of the PTI MRP module. The application was developed using the Rapid Application Development (RAD) method and implemented via Macro Visual Basic for Application (VBA). The output of this research is an MRP lot sizing calculator application. Verification results show that the application's calculations align with manual theoretical results. Black box testing confirmed that all functional requirements were successfully met. Usability testing yielded an overall satisfaction score of 91.2%, indicating that the application is suitable for user implementation. This application system is expected to enhance student understanding and optimize the Industrial Engineering Project practicum process.

Keywords: Lot sizing; Material Requirement Planning; Macro; Virtual Basic for Application; Rapid Application Development

1. Introduction

In the manufacturing industry, production planning and control aim to optimize the utilization of all resources, including labor, materials, and capacity [1]. Effective production planning and control must be supported by accurate raw material requirement planning. The availability of raw materials is a critical factor in supporting production activities; seamless planning and availability ensure the continuity of the production process [2]. The primary method used for such planning is Material Requirement Planning (MRP). MRP is a vital topic within the field of operations management in industrial engineering [3]. At the Industrial Engineering Department of Diponegoro University, MRP is taught in the Production Planning Control (PPC) course (course code PTID6209) and practiced in the Industrial Engineering Project (PTI) integrated practicum (course code PTID6313). PTI is an integrated laboratory program at Diponegoro University where students design a company based on the theories learned throughout their studies, conducted across six different laboratories. MRP is included in Module 5, "Production Planning and Material Requirements," which is managed by the Production System Laboratory (LSP).

Based on a study of industrial engineering students acting as PTI practitioners, several obstacles were identified during Module 5. These include a lack of conceptual understanding of lot-sizing, difficulty in mapping practicum input data into the application, and inadequate tools to facilitate student comprehension. These constraints can prevent the

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achievement of practicum objectives, specifically the students' ability to master the material requirement planning process. Furthermore, output accuracy is crucial due to the integration between modules, where the output of one module serves as the input for another. The study revealed that 76.1% of students experienced difficulties in practicing MRP lot-sizing calculations in the PTI practicum, with 56.5% stating that the lack of appropriate tools to facilitate practicum needs was a primary challenge.

The tools currently in use are POM QM and Microsoft Excel. POM QM is utilized for calculating the MRP lot-sizing for each part, while Microsoft Excel is used to recapitulate the results of each lot-sizing method for further analysis. Based on feedback from practitioners and laboratory assistants, several deficiencies were identified in POM QM. These include a limited number of methods, the absence of step-by-step solutions (as the application only displays final results), and a lack of visualization for comparing different methods. Given these constraints and deficiencies, it can be concluded that the current tools are inadequate for the requirements of the Industrial Engineering Project practicum. Consequently, there is a need for a dedicated application or tool that aligns with both the theoretical and procedural needs of the practicum. The use of specialized software for MRP lot-sizing calculations is essential. This is consistent with research by Ardika et al. (2022), which suggests that computer-aided applications should be considered to improve the precision and accuracy of MRP calculations for optimal cost efficiency [4]. Furthermore, lot-sizing calculation applications are vital for supporting academic learning, research, and corporate operations [5]. Therefore, the availability of an MRP application in education is highly necessary to enhance student understanding and skills. This aligns with the premise that supporting applications in learning have a positive impact on the quality of education, particularly in engineering disciplines [3].

Several methods can be employed in the design of applications or information systems, such as Waterfall, Prototyping, Rapid Application Development (RAD), and Agile Modeling [6]. This study utilizes the Rapid Application Development (RAD) method. RAD is an application development model that emphasizes short development cycles, offering faster development and higher quality results compared to traditional methods [7]. RAD is suitable for this research as the design process actively involves the users. The application design is implemented using Macro Visual Basic for Applications (VBA), a programming language integrated into the Macro features of Microsoft Excel [8]. Macro VBA was chosen because Microsoft Excel is a software familiar to students, ensuring ease of operation. Following the development process, the application undergoes functional testing and usability testing to determine its feasibility and performance.

2. Research Methodology

2.1. Research Object and Subject

The object of this research is the Department of Industrial Engineering at Diponegoro University. The subjects of the research include faculty members involved in the Industrial Engineering Project (PTI) Module 5 practicum, industrial engineering students at Diponegoro University acting as practitioners, and laboratory assistants from the Production System Laboratory (LSP).

2.2. Research Procedures

Initially, a preliminary study was conducted through literature reviews, surveys, and interviews to gather comprehensive information. The survey involved distributing questionnaires to students as PTI practitioners to identify constraints, difficulties, and user complaints regarding the current system. The subsequent stage involved problem formulation. The central issue addressed in this study is that the current practicum tools for PTI Module 5 are inadequate and do not align with the theoretical and procedural requirements of the practicum. Therefore, this research focuses on designing an MRP application featuring nine lot-sizing methods to support the MRP calculation process within the PTI practicum.

The process then proceeded to the development stage. In the Rapid Application Development (RAD) method, the first phase is requirement planning. During this phase, the functional requirements and application features were identified. This identification was carried out through interviews with industrial engineering students, LSP assistants, and faculty members involved in the PTI Module 5 practicum as the primary users in this study. The second phase of the RAD method is the design workshop. The design process commenced with the creation of application designs using several modeling tools, namely use case diagrams, activity diagrams, and flowcharts. Use case diagrams were utilized to illustrate the functional requirements of the application, while activity diagrams depicted the sequential flow between the user and the system. Flowcharts were used to represent the logical flow of the lot-sizing calculation algorithms.

The resulting designs were subsequently implemented using Visual Basic for Applications (VBA) as the tool for application prototyping. This platform was selected because Microsoft Excel is widely familiar to users, thereby facilitating ease of adaptation and operation. Following this, users provided feedback on the application prototype, which served as input for design refinement. The users involved in this iterative process included three industrial engineering students: one LSP assistant and two PTI practitioners. The final implementation phase involved introducing the new application system to the users. The next stage was testing. The evaluation of the MRP application focused on functional testing, specifically verification and black-box testing. Verification was performed by comparing the calculation results from the MRP lot-sizing application with manual calculations to ensure adherence to theoretical principles. This verification utilized data samples from textbooks and research articles. Black-box testing was conducted by executing all features within the application to ensure they functioned according to the design and were free of errors.

Furthermore, usability testing was conducted to assess user experience and the overall utility of the application. This testing utilized the Computer System Usability Questionnaire (CSUQ) method. The CSUQ is a questionnaire-based usability assessment featuring 16 items and a 7-point response scale. This method was chosen for its suitability in evaluating application usability, its high reliability, and its simplicity. The CSUQ evaluates four categories: System Usefulness (items 1-6), Information Quality (items 7-12), Interface Quality (items 13-15), and Overall Satisfaction (items 1-16). The final stage of this research involved drawing conclusions and providing recommendations. Conclusions were formulated based on the predefined research objectives, while recommendations were provided for future research concerning further application development.

3. Results and discussion

3.1. Current Conditions

Table 1 Outlines the existing challenges identified in the current system.

No.	Problem	Justification
1.	Lack of understanding regarding lot-sizing concepts	• 76.1% of students experienced difficulties in practicing MRP lot-sizing calculations during PTI. • Current applications cannot display step-by-step calculations.
2.	Difficulty in mapping practicum input data into the application	Existing applications do not facilitate inputs for scheduled receipts and the Bill of Materials (BOM)
3.	Inadequate tools to accommodate practicum requirements	• 56.5% of respondents stated that current tools are insufficient. • Lack of data integration between parts due to the absence of BOM input features. • Absence of scheduled receipt inputs requires data to be processed manually before entry. • Limited methods provided do not cover the theoretical requirements of the practicum.

3.2. Identification of Needs

The primary objective of developing the MRP lot-sizing application is to serve as a supportive tool for PTI Module 5 and to improve upon the existing inadequate tools. The target users are industrial engineering students at Diponegoro University (practitioners) and LSP assistants. The development considers the Semester Learning Plan (RPS) of the PPC 1 course (weeks 13 and 14), focusing on MRP input-process-output, BOM structures, MRP stages, and both heuristic and optimization lot-sizing techniques. Additionally, the PTI Practicum RPS for Module 5 (Production Planning and Material Requirements) stipulates that students must be proficient in identifying and applying material requirement planning methods. The necessity for a dedicated MRP lot-sizing calculation tool has been identified since the 2021/2022 PTI practicum cycle.

Table 2 User Story

User	Story
User 1	The system can explain the material requirement planning flow and accommodate report requirements.
User 2	The system can facilitate 9 lot-sizing methods and provide definitions for MRP terminology.
User 3	The system can perform MRP lot-sizing calculations according to theory and present step-by-step calculations.
User 4	The system can facilitate practicum needs and offer ease of use.

Table 3 User Needs

User	Objective	User Needs
User 1	To provide a system that facilitates calculations for 9 lot-sizing methods.	• Users are able to input data into the system. • The application is capable of performing lot-sizing calculations using 9 distinct methods. • The data input menu is designed to be user-friendly and intuitive. • The application can perform MRP lot-sizing calculations accurately and in accordance with established theoretical frameworks.
User 2	To provide a system capable of displaying outputs and step-by-step calculations.	• The application can display MRP output tables for each lot-sizing method. • Users can view both the MRP output tables and the detailed calculation steps for each lot-sizing method. • The output menu is designed for ease of understanding by the user.
User 3	To ensure the system facilitates practicum requirements.	• The application can accommodate material requirement planning processes within the PTI practicum. • Users can input data consistent with the datasets used in the PTI practicum. • The application can generate outputs that meet the specific requirements of the PTI practicum. • The application includes a feature to save calculation results.
User 4	To ensure the system offers ease of use (Usability).	• Users have access to a manual or user guide for operating the application. • The application features a systematic workflow and procedure. • The interface design is intuitive and easily understood by the user. • The application provides a usage demo or tutorial

3.3. Design

At this stage, a "design with user" approach was implemented. This methodology signifies active user involvement throughout the design process, specifically in reviewing and evaluating the design outcomes of each iteration, as illustrated in Figure 1. Following three successive iterations, the final system designs were established, as shown in Figures 2 and 3.

Furthermore, the system design incorporates cognitive aspects. In an educational context, cognitive aspects refer to the thinking processes and mental procedures involved in learning, focusing on how knowledge and understanding are acquired. In this research, the integration of cognitive aspects aims to enhance user comprehension. The specific cognitive elements applied to the design include:

- Systematic Workflow: A structured sequence consisting of input, process, and output phases.
- Curriculum-Based Design: Alignment with the Semester Learning Plan (RPS) to meet theoretical requirements.
- MRP Process Presentation: Detailed visualization of Material Requirements Planning stages, including netting, lotting, offsetting, and exploding.
- Step-by-Step Calculations: Sequential presentation of the computational procedures for each lot-sizing method.
- Procedural Explanations: Provision of supplementary clarifications for every process within the system.
- Output Visualization: Comparative visualization of results to facilitate better data interpretation.

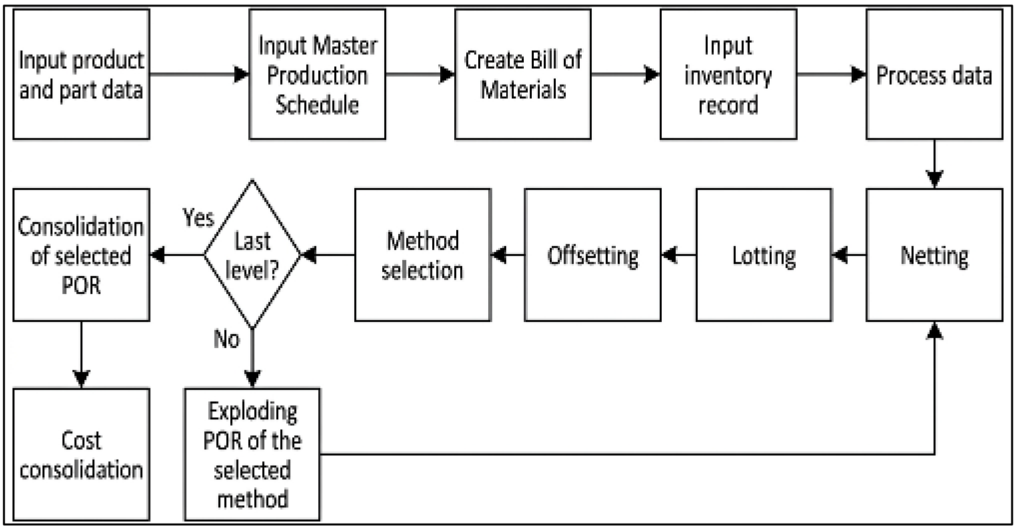

Figure 1 System Flowchart Design

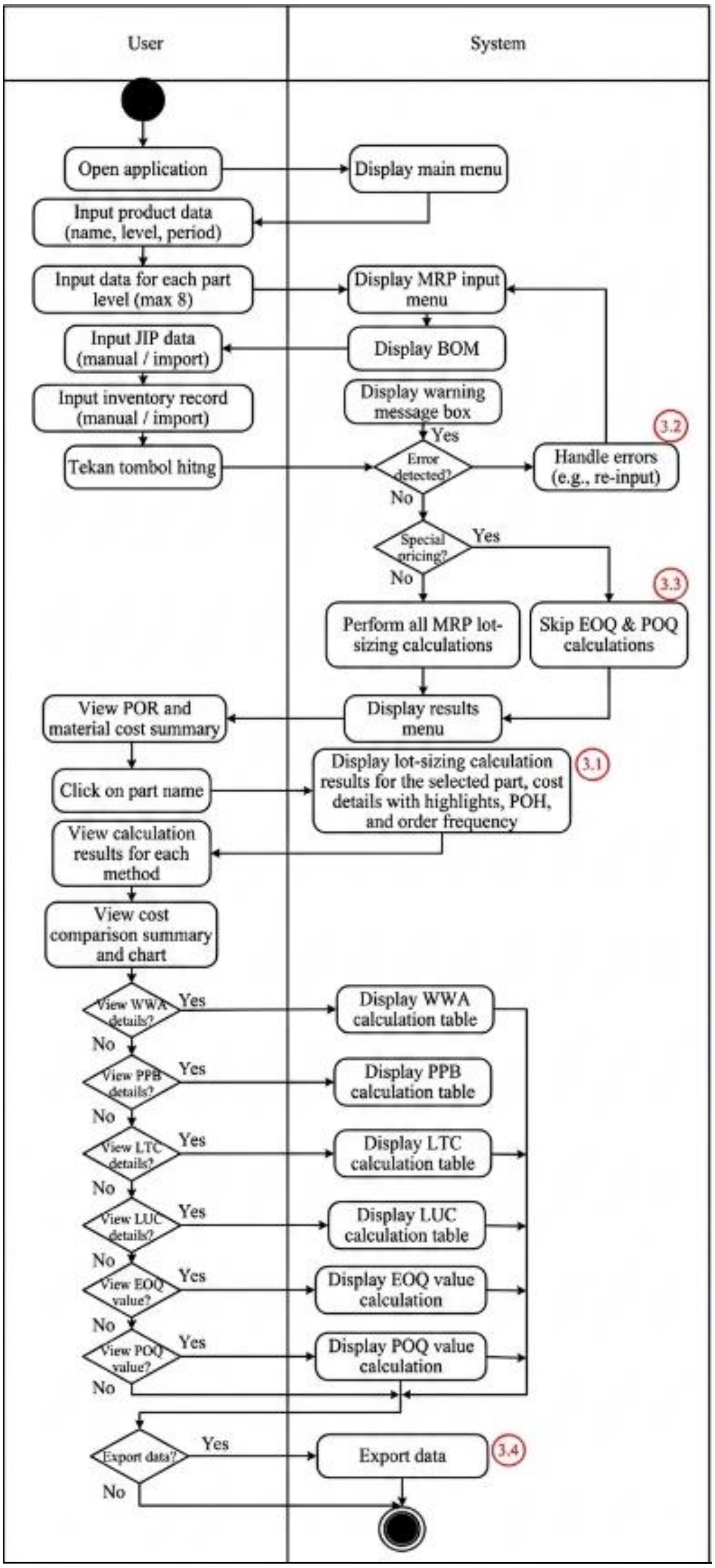

Figure 2 Final Design Activity Diagram

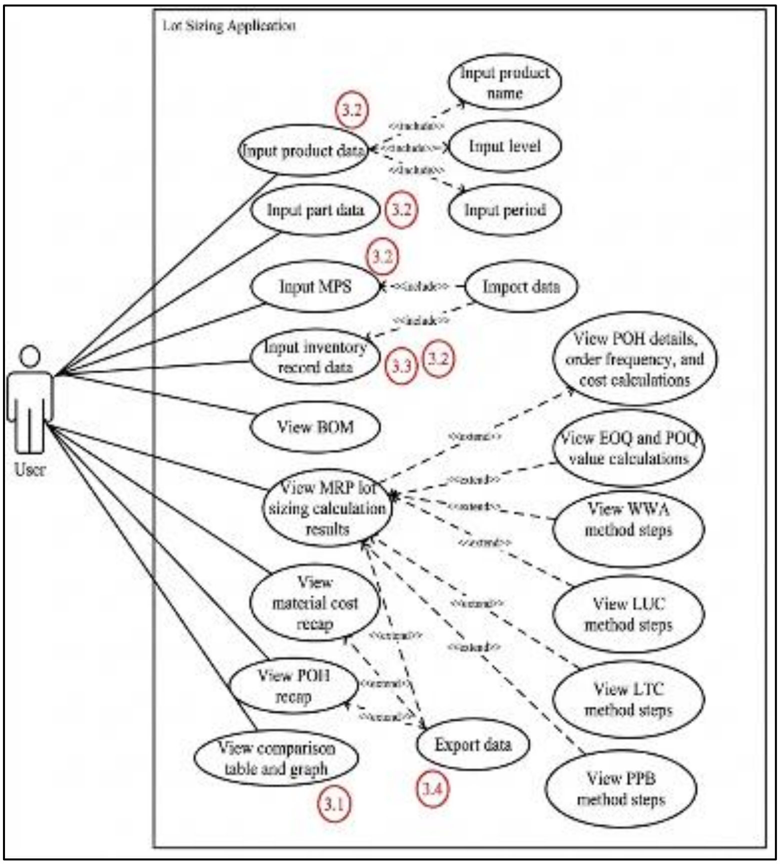

Figure 3 Final Design Use Case Diagram

3.4. Implementation

At this stage, the implementation and its workflow are carried out to introduce the new system to the users. The application design is implemented using Visual Basic for Applications (VBA), which is a feature within Microsoft Excel. Hereinafter in this article, the application will be referred to as the Lot Sizing Application (LOSA)

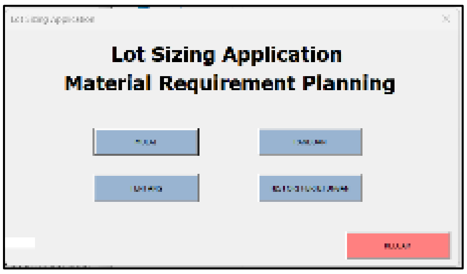

Figure 4 Home Page

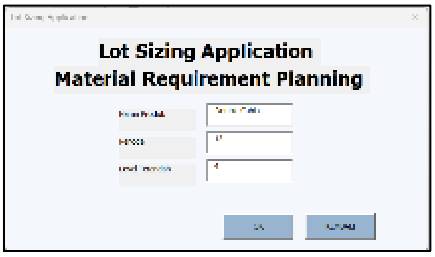

Figure 5 Product Data Input Menu

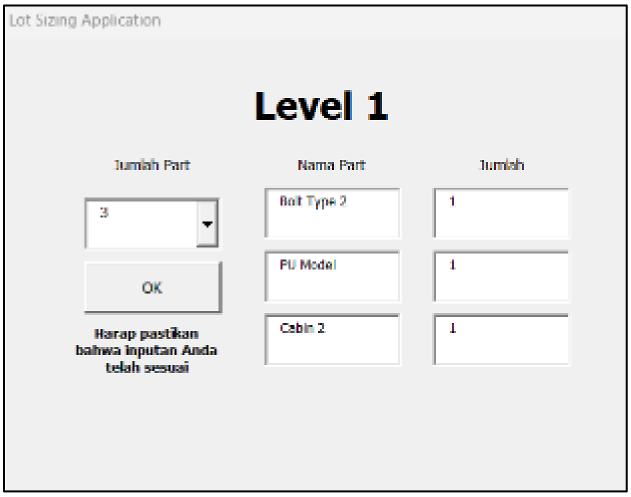

Figure 6 Part per Level Data Input Menu

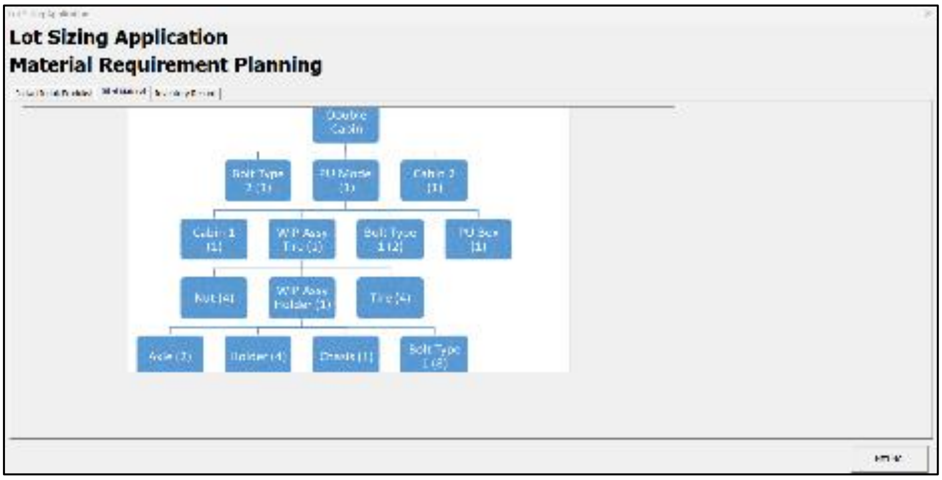

Figure 7 Bill of Materials (BOM) View

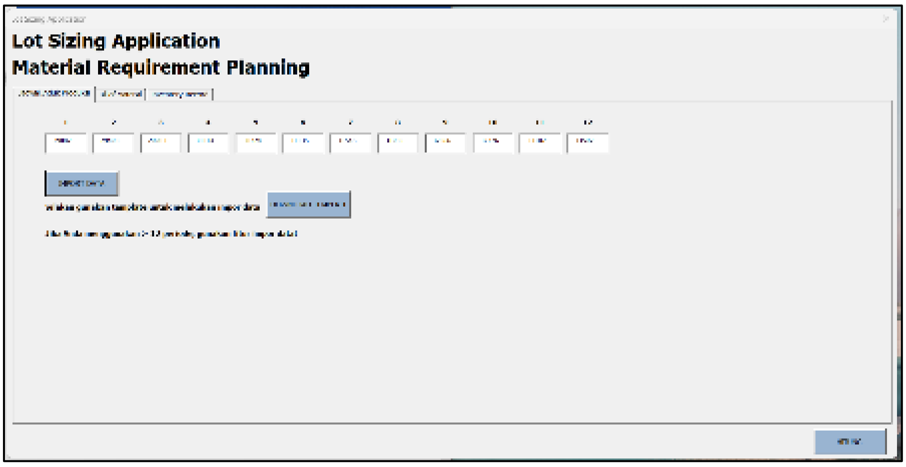

Figure 8 MPS Data Input Menu

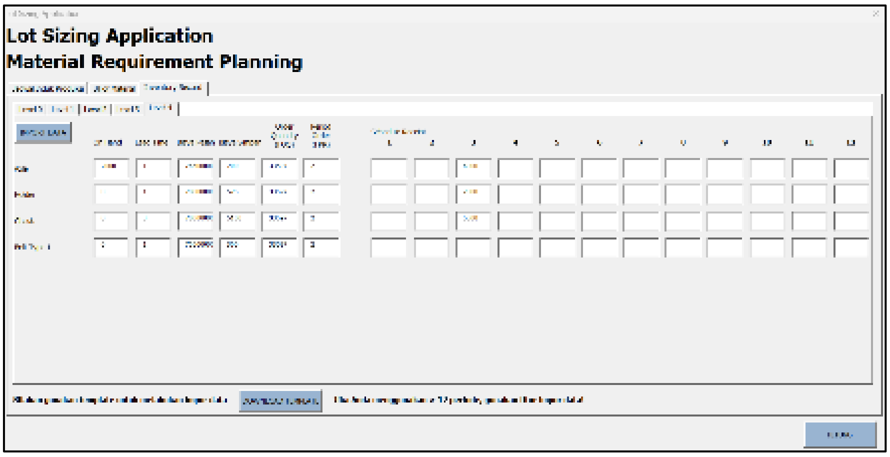

Figure 9 Inventory Record Data Input Menu

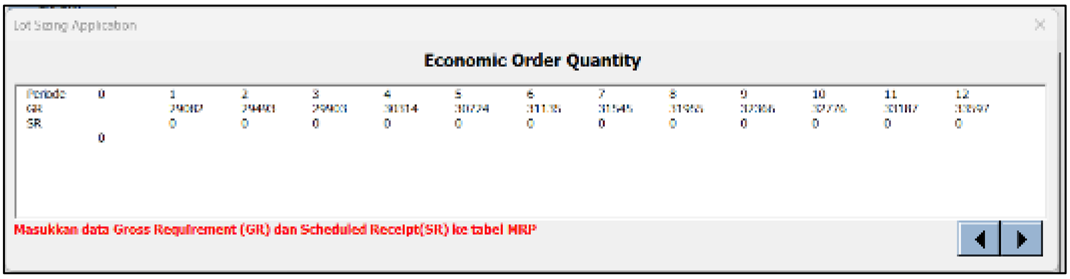

Figure 10 Initial Phase

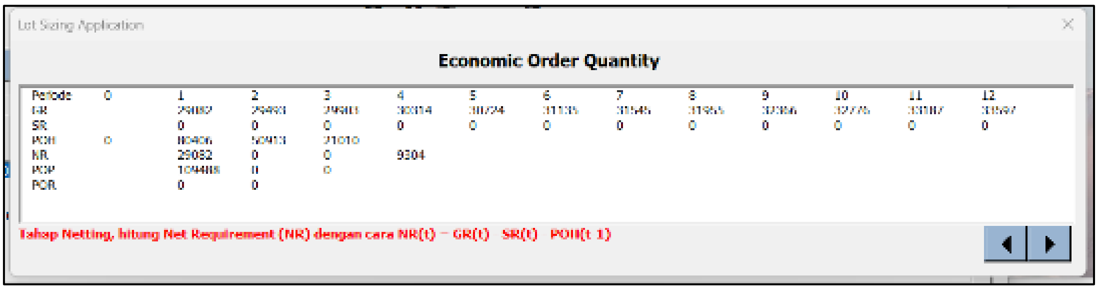

Figure 11 Netting Phase

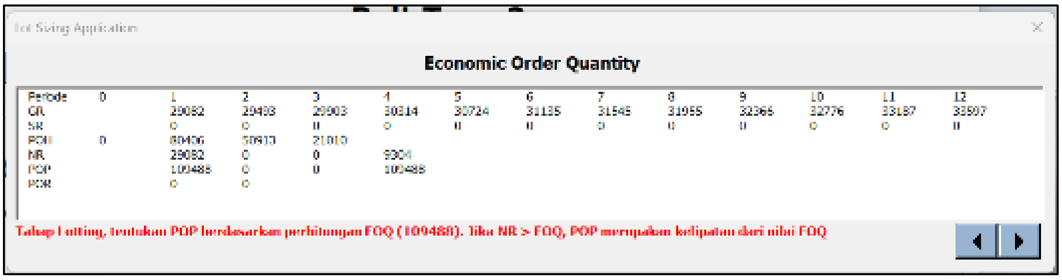

Figure 12 Lotting Phase

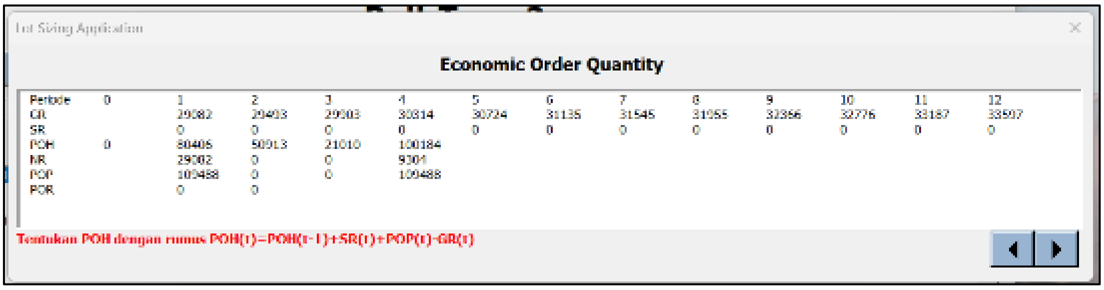

Figure 13 POH Calculation

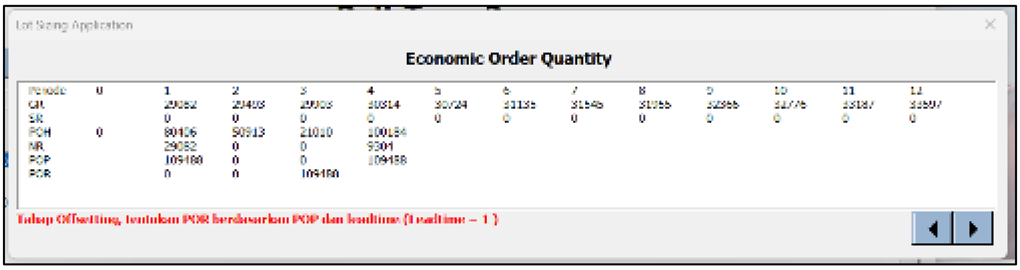

Figure 14 Offsetting Phase

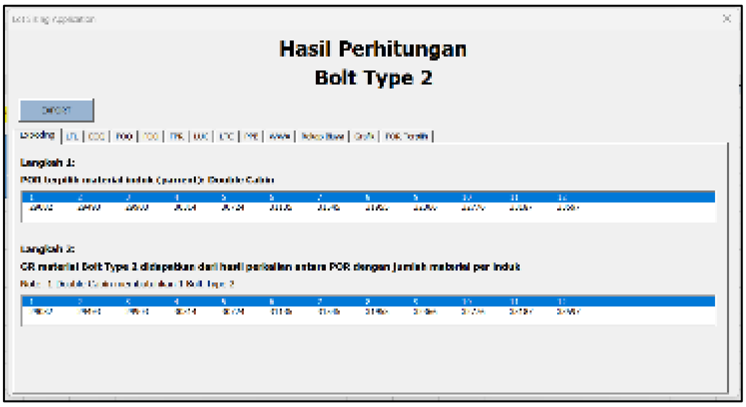

Figure 15 Exploding Process

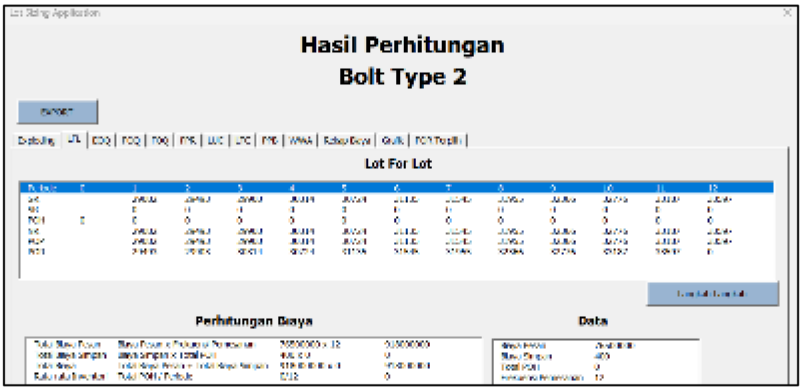

Figure 16 Calculation Results View

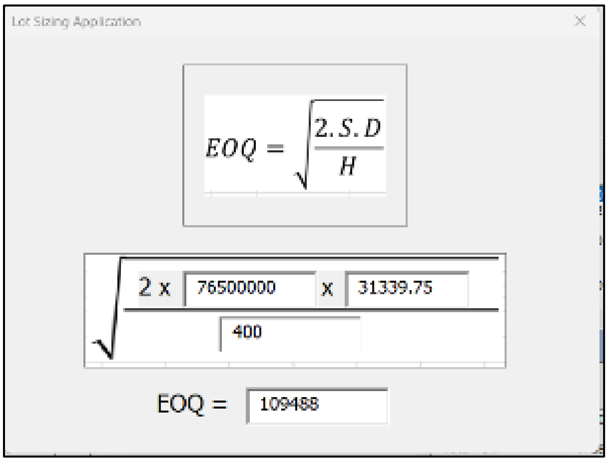

Figure 17 EOQ Calculation View

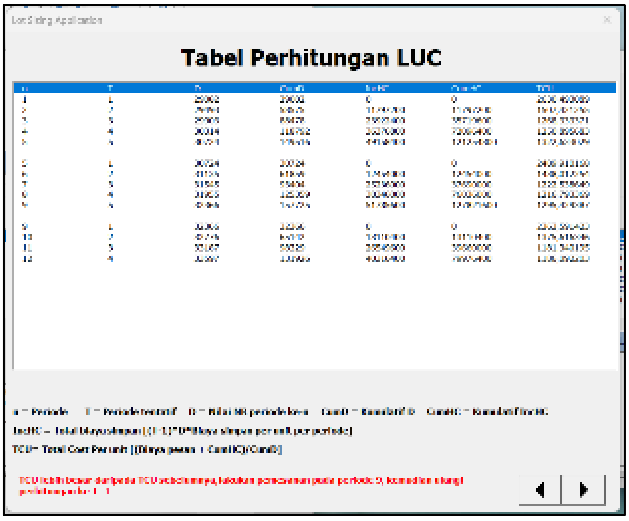

Figure 18 LUC Iteration Table View

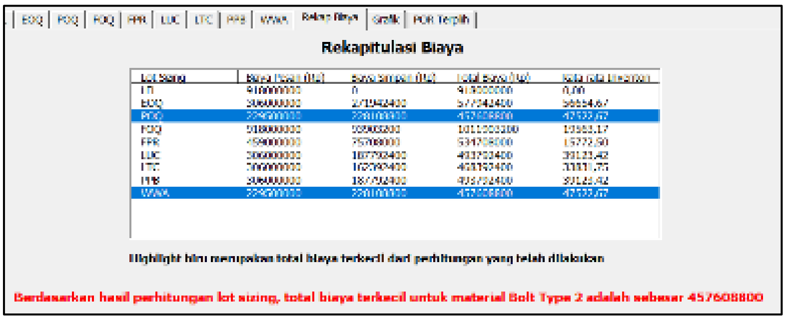

Figure 19 Comparison Table

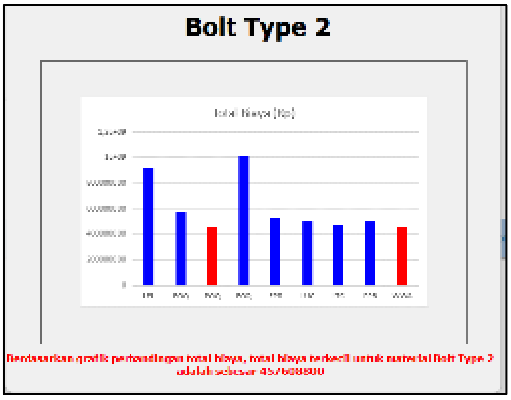

Figure 20 Comparison Graph

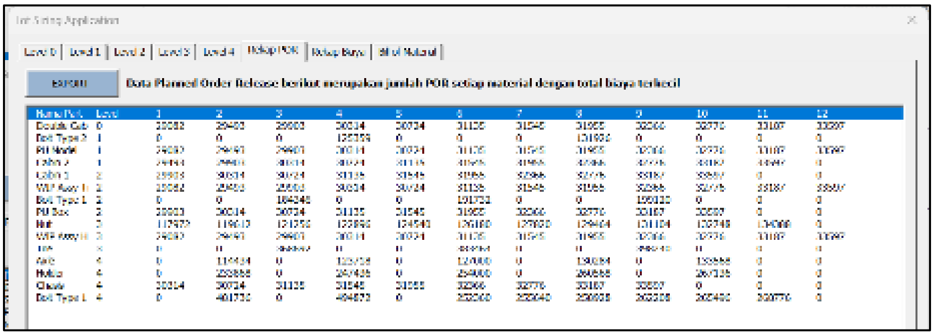

Figure 21 Recapitulation of Selected POR

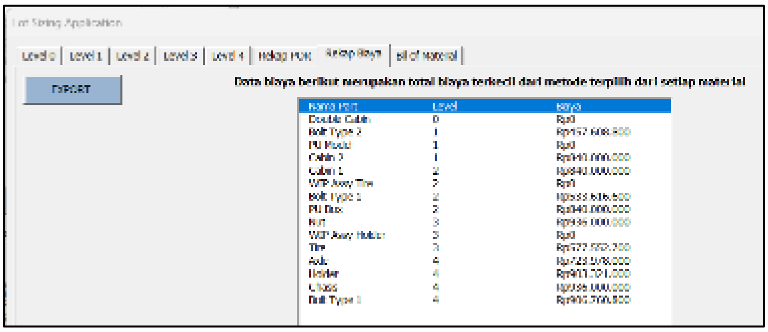

Figure 22 Cost Recapitulation

3.5. Verification

Verification ensures that the calculation results align with theoretical principles. This was conducted by comparing LOSA output with data samples from prominent textbooks and research articles.

Table 1 Verifikation Results

Method	Results	Data Source
LFL	Consistent	[Narashiman et al., 1995]
EOQ	Consistent	[Narashiman et al., 1995]
POQ	Consistent	[Tersine, 1994]
FOQ	Consistent	[Chandradevi & Puspitasari, 2016]
FPR	Consistent	[Chandradevi & Puspitasari, 2016]

LUC	Consistent	[Narashiman et al., 1995]
LTC	Consistent	[Narashiman et al., 1995]
PPB	Consistent	[Tersine, 1994]
WWA	Consistent	[Slamet & Dianti, 2022]

3.6. Black Box Testing

Black-box testing is an evaluation method aimed at demonstrating that the system or application performs its tasks as expected and identifying any errors or defects within the application. This testing focuses on functional requirements and is based on the final design use cases as illustrated in Figure 3.

Table 5 Black Box Testing Results

Functional	Description	Expected Result	Test Result
Product data input	User enters product name, period, and level data accurately	User can successfully input product data	Pass
	User leaves one of the inputs blank	A warning message box appears	Pass
Part data input	User enters part data such as part name, parent, and quantity accurately	User can successfully input part data for each level	Pass
	User leaves one of the inputs blank	A warning message box appears	Pass
View BOM	User views the Bill of Material in the BOM input sub-menu	User can view the BOM corresponding to the previously entered product and part data	Pass
Input JIP	User enters JIP data accurately, either manually or via import	User can successfully input JIP data	Pass
	User downloads the data import template	User successfully downloads the import template	Pass
	User leaves the JIP data blank	A warning message box appears	Pass
Input data inventory record	User enters inventory record data for each part accurately, either manually or via import	User can successfully input inventory record data	Pass
	User leaves one of the holding costs blank	A warning message box appears	Pass
	User enters alphabetic input (letters)	A warning message box appears	Pass
View MRP Lot Sizing Results	User opens the sub-menu for each method	User can view the MRP table results for each lot sizing method	Pass
	User opens the EOQ calculation menu	User can view the EOQ formula	Pass
	User opens the POQ calculation menu	User can view the POQ formula	Pass
	User opens the LUC table menu	User can view the iterations of the LUC method	Pass
	User opens the LTC table menu	User can view the iterations of the LTC method	Pass
	User opens the PPB table menu	User can view the iterations of the PPB method	Pass
	User opens the WWA table menu	User can view the iterations of the WWA method	Pass

View comparison table and graph	User opens the comparison graph sub-menu	User can view the comparison graph of ordering cost, holding cost, total cost, and average inventory for each method	Pass
	User opens the cost summary sub-menu	User can view the comparison table of ordering cost, holding cost, total cost, and average inventory for each method	Pass
View material cost and POR summary	User opens the POR Summary sub-menu	User can view the POR summary table for the selected method of each part	Pass
	User opens the Cost Summary sub-menu	User can view the cost summary table for the selected method of each part	Pass
	User performs data export	User can export the output data in Excel or PDF format	Pass

3.7. Usability Testing

Usability testing was conducted with users, specifically students participating in the Industrial Engineering Project practicum. Initially, the participants were given scenarios or tasks that align with the practicum's requirements. Subsequently, they completed a usability testing questionnaire. The instrument employed for this evaluation was the Computer System Usability Questionnaire (CSUQ), a standardized usability measurement tool.

Table 6 Usability Testing Results

No	Statement	Average
1	Overall, I am satisfied with the ease of use of this application.	6,40
2	The use of this application is simple.	6,66
3	I can complete my tasks more efficiently using this application without needing other applications.	6,66
4	I feel comfortable using this application.	6,34
5	The application is easy to learn.	6,49
6	I am confident that I can be productive using this application.	6,49
7	The application provides clear notifications (error messages) when an error occurs.	6,60
8	When I make a mistake while using the application, I can easily return to the initial state.	6,31
9	The information (MRP results data) presented by the application is clear and understandable.	6,57
10	I can find the information I need.	6,57
11	The information provided is very effective in completing my tasks.	6,57
12	The layout of the information on the application screen (interface) is very clear.	5,89
13	The interface of this application is pleasant to use.	6,00
14	I like the interface of the application.	5,54
15	This application has the functions and capabilities that meet my expectations.	6,51
16	Overall, I am satisfied with this application.	6,54

Table 7 Usability Testing Results by Category

Category	Score	Percentage
System Usefulness	6,50	92,93%
Information Quality	6,42	91,70%
Interface Quality	6,02	85,99%
Overall satisfaction	6,38	91,20%

Based on the results of the usability testing, the Lot Sizing (LOSA) calculation application received scores of 6.50 for system usefulness, 6.42 for information quality, 6.02 for interface quality, and 6.38 for overall user satisfaction. The lowest score, 5.54, was recorded for the statement "I like the interface of this application," primarily because the LOSA application's design remains very simplistic. Nevertheless, a score of 5.54 is equivalent to 79.1%, which falls within the "feasible" category; this indicates that despite the simple interface, users can still easily understand and comfortably use the application, resulting in a positive user experience.

Conversely, the highest score of 6.66 was achieved for both Item 2 ("The use of this application is simple") and Item 3 ("I can complete my tasks more efficiently using this application without needing other software"). The high rating for Item 2 is attributed to the application's simple, sequential, and systematic workflow, which aligns with material requirements planning. Meanwhile, the high score for Item 3 reflects the application's ability to enhance efficiency during practicum activities. Overall, the satisfaction score of 6.38, or 91.2%, indicates that users are highly satisfied with the LOSA application, placing it in the "highly feasible" category.

3.8. System Comparison

The LOSA application designed in this study incorporates several key differences compared to POM-QM, the current tool being utilized. These differences represent improvements over the existing system. Based on the system comparison in Table 8, the proposed system (LOSA) offers several advantages that address the shortcomings of the current tool. Regarding the input aspect, the proposed system is tailored specifically to the requirements of the practicum. In terms of the process aspect, it accommodates nine lot sizing methods in accordance with the university curriculum. Regarding the output aspect, the proposed system provides results tailored to practicum needs and includes output visualization. Furthermore, the proposed system features superior functionalities, such as step-by-step calculation guides, data integration based on product structure, and cognitive learning elements. Considering the input, process, output, and integrated features, the proposed system is deemed adequate as it aligns with both practicum requirements and user needs.

From a cognitive perspective, the design aims to enhance the understanding of practitioners as users. This is intended to resolve the existing system's limitation regarding the lack of conceptual understanding of MRP lot sizing. The cognitive aspects integrated into the proposed system include:

- Systematic Workflow (Input, Process, Output): By providing a systematic flow, users gain a comprehensive overview of the material requirements planning process.
- Design Based on the Semester Lesson Plan (RPS): The material in the system is designed based on the RPS topics to serve as a theoretical reference.
- MRP Processes (Netting, Lotting, Offsetting, Exploding): Each stage of the MRP process is displayed within the system accompanied by brief explanations.
- Step-by-Step Calculation for Each Lot Sizing Method: The system presents detailed, step-by-step calculations for every MRP lot sizing method to ensure users understand the underlying logic.
- Supplementary Explanations for Each Process: Additional explanations are provided throughout the process to reinforce user comprehension.
- Output Comparison Visualization: Visualizations are implemented in the form of charts to facilitate cost comparisons between different lot sizing methods.

Based on the comparison between the current and proposed systems, the LOSA application is expected to enhance practitioner understanding and optimize the execution of the Industrial Engineering Project practicum.

Table 8 System Comparison

Aspects	Current System (POM QM)	Proposed System (LOSA)
Input	Input for demand, lead time, ordering cost, holding cost, and inventory Input does not meet the requirements for practicum and is not aligned with theoretical MRP input requirements.	Input for MPS, parts, product structure, and inventory records (ordering cost, holding cost, scheduled receipts, lead time, and inventory). Input has been customized to meet practicum requirements and aligned with theoretical MRP input
Process	Only accommodates MRP lot sizing calculations for a single part. Only accommodates 5 lot sizing methods (LFL, EOQ, POQ, PPB, WWA).	The application accommodates multi-part and multi-level MRP lot sizing calculations. The application accommodates 9 lot sizing methods according to practicum requirements and the curriculum.
Output	The application provides a cost summary comparison between methods	The application provides a cost summary comparison between methods. The application provides comparison graphs between methods. The application provides a summary of POR and overall material costs as the output of the Material Requirements Planning module.
Calculation Steps	The application does not provide calculation steps or iterations.	The application provides calculation steps/iterations, thereby increasing the validity of the output results.
Data Integration	Data between parts is not integrated because the application only accommodates single-part calculations, requiring repetitive data entry.	Data between parts is integrated according to the product structure, eliminating the need for repetitive data entry.
Data Visualization	Does not provide comparison graphs as output visualization.	Provides comparison graphs as output visualization.
Learning Cognition	Does not consider learning aspects; functions only as a calculation tool.	The application does not only present calculation results but also includes the calculation steps.

4. Conclusion

Based on the research conducted, the following conclusions can be drawn:

- User requirements for the MRP lot sizing application as a supportive tool for the Industrial Engineering Project (PTI) practicum were identified based on the input, process, and output of the material requirements planning module. Additionally, user needs were determined by identifying the shortcomings of current tools, which do not fully accommodate the theoretical and procedural requirements of the PTI practicum. These requirements were developed from user stories, detailed into user needs, and translated into functional requirements, which served as the foundation for the application design. Key requirements include the system's ability to explain the material requirements planning workflow, accommodate reporting needs, facilitate calculations for nine lot sizing methods, provide step-by-step calculation procedures, and ensure ease of use.
- The MRP lot sizing algorithms were transformed into programming code following the specific workflow and logic of each method. These theoretical calculation algorithms were first designed as flowcharts depicting the mathematical logic flow for each method. Based on these flowcharts, the logic was then translated into source code using the Visual Basic for Applications (VBA) programming language.
- The design of the lot sizing calculation application was conducted by considering user identification results and practicum requirements, both theoretically and procedurally. The application was developed using the Rapid Application Development (RAD) method, which incorporates user review and evaluation processes to assess

system prototypes at every iteration. In this study, three iterations were conducted, concluding when no further evaluations were required. The design also integrated cognitive learning aspects. The final design was implemented using Visual Basic for Applications (VBA) macros.

- Testing was conducted using three distinct methods. Verification testing results indicated that the calculations performed by the application are accurate and verified. Black box testing showed that the application system has fulfilled all functional requirements according to the designed use cases. Finally, usability testing yielded an overall satisfaction score of 91.2%, demonstrating that the application is highly feasible for user implementation

Compliance with ethical standards

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Disclosure of conflict of interest

No Conflict of interest to be disclosed.

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