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An Online Tool for Learning Material Requirements Planning in a Computer Integrated Manufacturing Course – A Case Study*

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Material Requirements Planning (MRP) is a commonly used method and system for production and procurement planning in manufacturing companies. In practice, MRP functionalities are provided as a core module of the Enterprise Resource Planning (ERP) systems, but can also be offered via software tools. As MRP competencies are vital for several engineering roles, their attainment is one of the operations management and industrial engineering education goals. Accordingly, in this work, the possibilities and effectiveness of a new online MRP learning tool are assessed. The new MRP module from web-based OPR-MAN software was chosen following a customized selection procedure aiming to identify the most suitable MRP educational software for the Computer Integrated Manufacturing (CIM) course at the Faculty of Organizational Sciences, the University of Belgrade. The chosen module was subsequently applied when teaching several generations of students attending the CIM course. Its effectiveness was assessed both quantitatively (considering students' test scores as a measure of individual performance) and qualitatively (using online questionnaire probing students' overall satisfaction with this tool). A total of 145 students participated in the evaluation and the results showed that students acquired advanced MRP competencies and were very satisfied with the use of this new online tool for learning MRP.

Keywords: Material Requirements Planning; MRP; educational software; OPR-MAN, POM-QM for Windows; evaluation

1. Introduction

In engineering classroom traditional lectures should be supported with some suitable software, tools, applications, simulations, games, case studies, and/or quizzes [1, 2]. In that way students will have an opportunity to take an active role during class time besides only listening and taking notes. That's play an important role in acquiring appropriate engineering, professional and foundational competencies.

The Material Requirements Planning (MRP) competencies are very important for several job positions such as operations manager, material manager, industrial engineer, manufacturing manager, logistics manager, production planner, and inventory manager. The candidates for these positions should have the knowledge and skills to explain MRP logic, understand the MRP gross-to-net explosion, use the bill of materials (BOM), make real master production schedule (MPS), use different types of order policies, manage with safety stock, evaluate the MRP calculations, calculate inventory costs, work with pegged requirements, understand the various MRP reports, and perform order rescheduling [3]. They also need to know how MRP can be integrated with other systems i.e. capacity requirements planning (CRP), manufacturing execution system (MES), distribution requirements planning (DRP) and enterprise resource planning (ERP). Accordingly, the topic of MRP is needed across all study programs within the fields of operations management and industrial engineering.

At the Faculty of Organizational Sciences (FOS) one program of undergraduate studies is Operations Management. Within this program there are two courses where topic of MRP is studied. First, the students learn the basics of MRP and how to manually calculate MRP plan in the Logistics course in the third year. Here, traditional way of teaching is supplemented with one topic-related Quizlet game. Then, the students enhance their MRP knowledge and skills with the help of new MRP module from OPR-MAN software in the Computer Integrated Manufacturing (CIM) course in the fourth year of study. This work is just primarily focused on functionalities, possibilities and advantages of application this new web-based educational tool in CIM classroom.

2. Theoretical Background

MRP dates back to the early 1960s and the most deserving for its development is Orlicky [4]. In 1959 Bosch was developed the first MRP system for

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calculating material requirements with the process of regenerative data processing [5]. Three years later Case was developed the first MRP system with the net change approach [5]. During 1970s the association American Production and Inventory Control Society (APICS; now known as the Association for Supply Chain Management ASCM) has made efforts for wider application of MRP. In 1975 Martin was developed the method of distribution requirements planning (DRP) which uses the logic of MRP. Throughout the years, the limitations of MRP have been noted in practice, such as disregarding production capacity constraints and assuming deterministic demand and lead time [6]. In 1980 Wight introduced method of effective planning of all resources of a company i.e. manufacturing resource planning (MRPII). MRP II enables organization of the system so that output data is used to reconcile MPS and functioning of MRP system with feedback loop. Further, in 1990s MRP systems evolved into ERP systems [7]. ERP systems represent a class of software products developed to integrate the internal and external business processes of an organization. The core of ERP is MRP system which has been widely used in manufacturing industry [8]. One of the most famous ERP solution providers SAP (e.g. [9-11]) provides the planning tool MRP in order to enable companies to manage with whole supply chain, "from forecasting and production planning through purchasing, manufacturing, and finished goods delivery to the customer" [12].

The demand for MRP software is increasing due to the growing need for automation in manufacturing processes, the importance of tracking the data in real-time, and the increasing use of advanced Industry 4.0 technologies in production environment [13]. According to the Dataintelo Consulting [13], in 2023 the global MRP software market size was valued at USD 7.5 billion and the predicted value for 2032 is USD 14.8 billion, growing at a CAGR of 7.2% during the forecast period. One previous study showed that the MRP module was purchased and implemented by 79% of companies which purchased ERP systems [4]. The revenue in the ERP software market is projected to attain USD 55.88 billion by 2025 and it is anticipated to have reached of USD 65.29 billion by 2029, growing at a CAGR of 3.97% during the forecast period, according to the Statista Market Insights [14].

2.1 MRP: Basics

MRP is a commonly used method for production and procurement planning in manufacturing companies. The main reason for using MRP is to accurately determine the quantities of each material and component that need to be either purchased or produced, with the end goal to efficiently meet the demand. The key MRP input data are collected from three main sources: (1) MPS – independent demand data; (2) BOMs – the hierarchical structure of how the final products are made; and (3) inventory data. Companies use MRP to generate in a short time an MRP plan that ensures that the right items are ready for use, in the exact quantity and time that they are needed. Efficient MRP reports provide companies with exact timelines for when they should order or produce items, for them to be available. While also not creating any unnecessary dead stock or overstock and ensuring there aren't any delays in production caused by not having stock.

The method of using MRP isn't perfect, its value for the companies depends on their production strategy model and volume of production. Authors Jacobs and Chase [15] indicated that companies that experience the most benefits of implementing MRP have a production strategy of either assembly-to-order or engineering-to-order, while companies producing complex, expensive and low quantity make-to-order products, can experience low benefits of using MRP. They suggest for those companies to use methods focused on network scheduling.

MRP processes data by using a seven-step system (e.g. [6, 15]):

1. Determine gross requirements (GR_t) – or the total demand for each item in each planning period. Gross Requirements is determined by combining the independent demand of the item (this data is in the MPS) and dependent demand (is derived from the BOM).
2. Calculate net requirements (PNR_t) – this is done by using formula 1, where POH_t represent projected on-hand inventory. This expression also taking into considerations other relevant variables such as: initial on-hand inventory (OH), overdue schedule receipts (OSR), overdue gross requirements (OGR), safety stock (SS), scrap rate percentage (S), and scheduled receipts in period t (SR_t).

$$PNR_t = GR_t - POH_t \tag{1}$$

3. Determine planned order receipts (POR_t) – for determining POR for each item a crucial role plays the selected lot-sizing rule (e.g. Lot-for-Lot (LFL), Fixed Order Quantity (FOQ), Economic Order Quantity (EOQ)). In the case of LFL the POR has the same value as calculated net requirements. Planners can manually adjust these values if needed.
4. Calculate projected on-hand inventory (POH_t) – the quantity of stock on hand changes for

each period, either by receiving new stock or for using the stock on hand for satisfy demand (formula 2). Most modern MRP reports can show a negative value to indicate a shortage that occurred, and is a signal that an order adjustment is needed.

$$POH_t = POH_{t-1} + SR_t - GR_t \tag{2}$$

5. Determine planned order releases – this step represents the needed adjustment for the items to arrive on time. Each item has a specified lead time, so the planned order releases are just the calculated planned order receipts that are shifted accordingly to the items lead time. This step is crucial for ensuring no delays happen, and that the MRP plan is realistic and executable.
6. Calculate total inventory costs (C) – calculating the total cost of inventory gives a financial dimension to the MRP plan. This ensures that the companies can compare different order strategies, adjust parameters such as lot-sizing rules, safety stock and/or lead times. The elements used for the total inventory costs calculation (formula 3) are: unit cost (cu), planned order releases ($PORlt$), number of planned orders (p), setup cost per order (cs), duration of a planning period (u), annual holding cost rate (chg), number of periods in a year (T), annual shortage cost (cpg), positive/negative inventory balances (POH_t^+ / POH_t^-).

$$\begin{aligned} C = cu \times \sum PORl_t + p \times cs + (u/T) \times chg \\ \times \sum POH_t^+ + (u/T) \times cpg \\ \times \sum POH_t^- \end{aligned} \tag{3}$$

7. Repeat steps for all items – For each item listed in the BOMs, each of these steps are repeated.

2.2 MRP: Educational Tools

In the domain of engineering education a variety of initiatives were undertaken to actively support development of MRP-related competencies of students. The game “Cooperstown Cars, Inc.” which enables making the MRP schedule was developed by Dolinsky and presented in [16]. The Excel-based “In-Class Manufacturing Game” was suggested by [17] to support linking between inventory management, production planning and MRP. The spreadsheet based simulator called MRP-SIM was presented by Basnet and Scott [18] to enhance the understanding of interconnected topics such as forecasting, BOM, MPS, MRP, CRP, routing, and order review and release. The hand-on activity “Material Requirements Planning (MRP) Tinkertoy LawnMower” is provided by Fish [19] to facilitate comprehension of MRP concept i.e. their inputs, process and outputs. The simulation game “ERPsim” is created by several researchers at HEC Montreal [20] with the aim to prepare students for working in real enterprise system. The first versions of this simulation have helped practicing in demand forecasting, MRP, “production planning, material management, production scheduling, inventory management, sales management, and accounting and treasury management” [6, 20]. Today’s version is like as SAP ERP and SAP S/4HANA, and enables students to use a real-life ERP system to manage with virtual company which produces muesli cereals and sales them on competitive market. The ERPsim is broadly used at many faculties [20]. The building blocks-based game PPC is developed by several researchers from Federal Center for Technological Education of Rio de Janeiro [21] to enable practicing the concept of MRP. The simulation game “HECOp-Sim” is presented by [22] to simulate the logic of MRP. The simulation-based business game for teaching methods in production and logistics such as MRP, kanban and CONWIP is developed by Hubl and Fischer [23]. The open-source ERP system Odoo can also be used for educational purposes. This integrated system enables students to learn how to manage business processes with the help of ERP system. Odoo includes manufacturing module which can be used by students to better understand the inputs and outputs in an MRP system [24, 25]. The business simulation-based platform MonsoonSIM is developed in recent years to introduce students with the concept of ERP system [26, 27]. This experiential learning platform supports simulation of a broad spectrum of business processes, and among them the MRP process.

Also, a few educational software for teaching and learning MRP-related topics have been developed. The software package QSB (Quantitative Systems for Business) was developed by Professor Chang from the Georgia Institute of Technology in 1986 and it was improved in the following years. The first Windows version of this program, widely known as a WinQSB, was released in 1997, and the second version in 2001. The WinQSB is a very powerful set of tools for supporting decision-making in management science and operations management [28]. Among them is a module for MRP. The software package HOM: Operations Management Software for Windows was developed by Moses, Seshadri and Yakir at the Leonard N. Stern School of Business, New York University, and it was used several years at the same faculty from 1994 [29, 30]. This package also included the module for MRP. The software package POM was introduced by

Professor Weiss from the Temple University in 1987. The first version of this program for Windows, known as POM for Windows, was presented in 1996. Already next year, Weiss offered comprehensive package POM-QM for Windows which incorporates POM for Windows and QM for Windows. The POM-QM for Windows is a good set of educational tools for solving different problems in the field of production and operations management [31]. One of these tools is a MRP module. The software package OPR-MAN is developed by Professor Danilovic from FOS, University of Belgrade, since 2017. Today's web-based version of this software available from 2020 [32] is intended for solving various problems in operations and logistics management by using sophisticated algorithms and artificial intelligence. It includes modules for scheduling, partitioning, routing, assignment, packing and MRP.

3. Methodology

The multi-stage approach of this study is designed to address the following three key research questions:

- Which MRP educational tools are used?
- What are the advantages of new MRP tool from OPR-MAN package?
- What are the perceived usability and satisfaction levels among different generations of students?

The first phase involved a broad literature and internet survey to give overview of MRP basics and identify available MRP educational tools. In the second phase focus was on selection of the most suitable MRP educational software for use in the CIM course. A new online MRP tool from OPR-MAN software was selected and further used for teaching four generations of students at the FOS. The evaluation of their effectiveness is conducted both quantitatively, using students' test scores, and qualitatively, through online questionnaires. Finally, discussion and conclusion are drawn.

4. Selection of MRP Educational Software

At the CIM course for teaching topic of MRP traditional lectures wants to be supplemented by an appropriate educational software. The primary aim was to help students acquire advanced MRP competencies and prepare them for future business positions such as operations manager, material manager, industrial engineer, manufacturing manager, logistics manager, production planner, and inventory manager. Therefore, from the outset, educational tools that provide only basic MRP support were excluded from consideration.

A customized selection procedure for the identification of the most suitable MRP educational software was created according to [6], comprising the following stages:

1. Identification of affordable software systems offering MRP module that are compatible with contemporary Windows environments.
2. Comparison of these software.
3. Demonstration of each software.
4. Final selection of the most suitable software.

In the first stage, the three software systems – WinQSB, POM-QM for Windows, and OPR-MAN – which have MRP modules were extracted. These systems could not be differentiated in terms of cost, as WinQSB and POM-QM for Windows come with a textbook (e.g. [28, 33]), and OPR-MAN is freely available. However, WinQSB was excluded due to its incompatibility with contemporary Windows environments.

The POM-QM for Window is one of the first solutions that didn't require any coding done by the user, because of its very valuable feature of having an intuitive graphical user interface (GUI) which allowed users to enter data in table formatted template. In 2025 this solution has an average rating by users 3.9 out of 5 stars on public forums [34]. Users around the globe still use this software to further their education and expand their knowledge in different fields of management science.

The OPR-MAN is free and easy to access web software solution which can be used for students' enhancement of MRP skills. This software system is quite versatile and covers most of the fundamental operations management industry problems, as well as being "student oriented" with the UI/UX design and notes added. The OPR-MAN's module MRP is constructed based on idea of MRP module from WINQSB software.

In the second stage, the comparative analysis of these systems is performed on the basis of overall characteristics such as the need for license, Internet access, current versions, supporting languages, number of available modules, accessibility of use, areas of application, how user oriented the design is, and the software storage use (Table 1). These characteristics can be useful for potential "new" instructors. According to them, it can be concluded that both presented systems demonstrate a high level of user-friendliness.

In the third stage, both MRP modules from POM-QM for Windows and OPR-MAN are demonstrated through a following test MRP problem inspired by [35]. The company "Boo Burgers" sells three types of burgers – Classic, Cheese and BBQ which BOM compositions are shown in Fig. 1. Each subfigure illustrates the hierarchical relation-

Table 1. Overall characteristics of POM-QM and OPR-MAN software packages

Criteria	**POM-QM**	**OPR-MAN**
License	Yes, only for students, faculty personnel and institutions.	No, the software is free, the profile is created with a g-mail account.
Internet access needed	No, once installed on the device no need for internet access	Yes, web only software
Manual available	Yes, provided by the institution, and an older version is available online.	No, there are notes provided for each column for hints.
Version	5.3.	1.0.
Languages	English	English, Serbian
Modules	16	6
Accessibility of use	Limited accessibility	Highly accessible
Areas of application	Operations management, quantitative methods, management science, and operations research.	Operations management, quantitative methods, management science, and operations research.
User oriented design	Medium-high user orientation in design	High user orientation in design
Software storage use	Local application software, compatible with newer Windows and Mac IOS systems, low to medium storage space use.	No storage space needed from the user, online software.

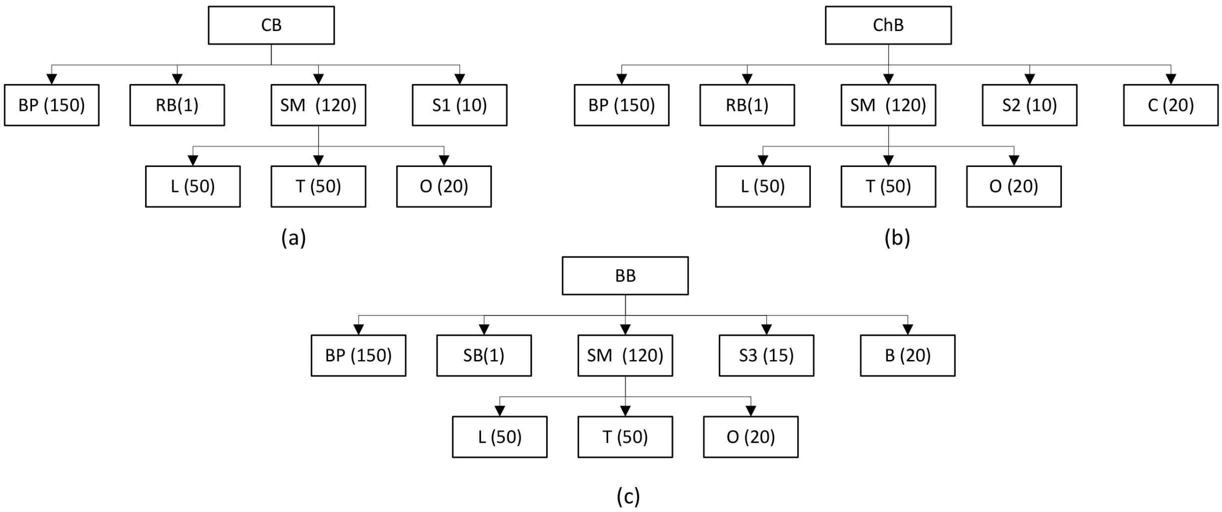

Fig. 1. Bill of Materials for "Boo Burgers" products. (a) Classic Burger (CB); (b) Cheese Burger (CHB); (c) BBQ Burger (BB). Abbreviations: B – Bacon; BP – Beef Patty; C – Cheese; CB – Classic Burger; CHB – Cheese Burger; L – Lettuce; O – Onion; RB – Regular Bun; S1/S2/S3 – Different sauces; SB – Sesame Bun; SM – Salad Mix; T – Tomato.

ship between the final product and its components used in this case study. For a period of 15 days the demand for each period for all three burgers, as well as for beef and lettuce is known and is a fixed quantity (Appendix 3). Other relevant data for final products and components are also known such as on hand inventory, safety stock, lead time, lot-sizing model, holding costs, setup costs and unite costs (Appendix 4).

The problem was first solved using POM-QM for Windows. A couple of setbacks were encountered, because the tool is limited to processes BOMs as flat structures, meaning we had to enter each BOM one after another and be extra careful with inputting components names, so that the solution can latter aggregate the results for the MRP. Other limitations are not having the option to have the value of lead time be zero, as well as the lack of safety stock and data needed for cost analysis. The start-up window was the place where the number of components, length of the planning period is added to enable further data entry for MRP calculation. Next, data regarding BOM, MPS and inventory were entered in the MRP calculation template and finally MRP plan is generated. The problems noticed with using this software were: (a) does not accept lead time of zero; (b) does not support using safety stock for items; (c) does not support using scheduled receipts; (d) does not support using inventory costs for items and consequently cannot perform cost analysis; (e) does not support using scrap; (f) only supports two lot size models for items (LFL and FOQ); (g) cannot create graphical BOM reports and (h) cannot create action order list.

Then, the problem was solved with OPR-MAN. The opening window enabled entering data specification for creation the Item Master, MPS, BOM, Inventory and Capacity entry window templates. The first window Item Master enabled entering the following data: Item ID, ABC Class, Source Code (is the element bought or made), Material Type (final product, semi-product, assembly element or a component), Unit Measure, Lead Time, Lot Size (EOQ, LFL, LTC, LUC, PPB, FOQ), Scrap percentage, Demand, Unit Cost, Setup Cost, Holding Cost, Shortage Cost, Item Description and Other Notes.

Further, BOM, MPS, Inventory and Capacity window templates were entered. The BOM template has a Show feature which allows the user to see the BOM diagram for each element. The MPS template has an extra column for adding any overdue requirements into considerations for each element. The Inventory template contains data columns for safety stock, on hand inventory, overdue plan receipts as well as any scheduled order receipts can be noted and put into consideration in the planning process. The Capacity template isn't needed for this particular problem, but its inclusion adds another dimension of restrictions and business data, that helps create a more efficient plan.

Finally, different detailed reports were generated with OPR-MAN – the main MRP reports, action plan reports (Appendix 5), cost analysis (Appendix 6) and indented BOM. The most expensive burger type was the most popular Cheeseburger with the total number of 1340 soled, and its inventory costs came out to be 6180EUR, while the least popular was the Classic Burger with and overall inventory cost of 2470EUR, for 580 soled burgers.

The fourth and final step in order to declare the better software solution was too compare the process of solving this problem, by comparing (Table 2): time needed for solving the problem, product structure, user interface, does it support multiple finished goods, component specificity, the ease of use, generated reports, lot size rules, entering data for safety stock and scheduled receipts, cost analy-

Table 2. User comparison of MRP tools from POM-QM and OPR-MAN software packages

Criteria	POM-QM	OPR-MAN
Time needed for solving example problem	Data entering + solving time + separately generation of cost analysis ≈ 45 min	Data entering: 15 min Software solving time: less than 1s
Product structure support	Modest, can handle multiple finished goods when all BOMs are entered simultaneously.	Very good, multi-level BOM
User interface	Old-fashion Windows-style interface	Modern web-based GUI, inspired by WinQSB
Input: multiple finished goods	Possible only by entering all product structures in one dataset. The order of entry is critical, overlapping components need to have the same name.	Supported
Component specificity	Doesn't have the option to select unique component per product, it requires the user to enter all components for all products, then it aggregates requirements by identical item names.	Allows unique components per product (e.g., cheese only for one burger).
Ease of use	Simple but outdated, limited flexibility.	Intuitive, clear layout with contextual help.
Generated reports	Basic, for cost analysis report reporting should be done by hand.	Advanced, modern and truer to industry level reports.
Lot sizing rules	Extremely limited (LFL and FOQ)	Multiple methods (LFL, FOQ, EOQ, LTC, LUC and PPB)
Safety stock & scheduled receipts	Not available for entering	Available for entering data
Cost analysis	No cost analysis	Has cost analysis reports for holding setup and unit cost
Penalty cost analysis	Not available	Not available
Units of measurements	No units of measurements can be added, making it harder to know what type of quantity is listed.	Adding different unites of measurements for each component
Export and accessibility	Standalone local application, no cloud integration	Web-based, accessible from Chrome browser. Reports can be printed or exported as PDF files.
Editing data after the first run	Possible	Possible
Subjective score of usefulness	2/5, functional but outdated, while it can be used for educational purpose and provides users with MRP reports, it requires entering repeated data due to the lack of advanced hierarchical linking between levels.	5/5, the program is more modern, gives a better understanding and preparation of using similar modules in ERP systems.

sis, penalty cost analysis, defining units of measurements, report export and accessibility, possibility of editing data after the first run, and the subjective score of usefulness. From the demonstration it can be concluded that in solving the MRP problems OPR-MAN outperformed POM-QM for Windows.

5. Educational Experience

The effectiveness of OPR-MAN's MRP module as a learning tool was evaluated both quantitatively (by assessing students' test scores) and qualitatively (by administering online questionnaires to gauge students' overall satisfaction with this tool).

The evaluations were conducted during the winter semester of four academic years (2020/2021 to 2024/2025). All students attending the CIM course at the FOS were required to take a test related to MRP at the end of the first learning phase. They were instructed to use the OPR-MAN software to solve one complex MRP problem and respond to several related open- and closed-ended questions. Table 3 provides scores achieved by each student cohort. According to the one-way ANOVA results, the four generations of students achieved statistically significantly different scores, $F(3) = 5.463$, $p = 0.001$. Moreover, Tukey post hoc test revealed that the scores reported for the 2020/2021 academic year were statistically significantly lower (5.05 ± 1.99 min, $p < 0.05$) than those noted for 2023/2024 (6.23 ± 1.80 min) and 2024/2025 (6.13 ± 1.79 min). These outcomes indicate that OPR-MAN is effective as a teaching and learning tool and its utility increases with continued use by the educators.

During the 4-year period, 145 students (26 from the first, 26 from the second, 46 from the third, and 47 from the fourth generation) completed the questionnaires. This period followed four distinct generations of undergraduate students enrolled in the Operations Management study program, all of whom attended the CIM course in their final year of bachelor's study. There were no overlap between generations and students belong to only one of the four generations 2020/2021 to 2023/2024. When it comes to the specific characteristics of students, all surveyed students were enrolled in the exact same academic program and had the exact same course structure and materials, without variations or changes in the way the course is presented or exams conducted over the four years.

While this figure reflects a relatively low Operations Management study program enrolment, it is also partly due to some students' reluctance to participate in the survey despite its voluntary nature and assurance that the responses provided would be treated as confidential.

As a part of the survey, students rated their experience with the use of OPR-MAN by indicating their level of agreement with 12 statements on a 5-point Likert-scale anchored at 1 = "Strongly disagree" and 5 = "Strongly agree." As can be seen from Table 4, the entire 2024/2025 student cohort would recommend OPR-MAN as a teaching and learning tool, highlighting its value for the generation of useful reports. As expected, students did not consider OPR-MAN particularly beneficial for gaining confidence in their ability to solve MRP problems in practice, as reflected in the lowest scores related to this item. This rating may be attributed to students' typical lack of real-world business experience and their inability to form realistic expectations of workplace demands.

Each cohort's ratings for the twelve statements were summed up to establish an "OPR-MAN satisfaction" composite score (67.44 for the first, 83.60 for the second, 76.95 for the third, and 65.04 for the fourth generation). The degree of internal consistency among these statements was assessed by considering the Cronbach's alpha for each generation, with values exceeding 0.7 considered acceptable [36]. Results reported in Table 5 further confirm the internal reliability of the composite score for each generation. However, as the obtained values were not normally distributed (as determined by the Shapiro–Wilk test), the Kruskal-Wallis test was conducted to test the hypothesis that students had the same level of overall satisfaction with the OPR-MAN tool irrespective of their year of enrollment.

The obtained findings supported this hypothesis, $\chi 2(3) = 4.197$, $p = 0.241$, confirming that students from all observed generations were highly satisfied with the use of OPR-MAN for learning MRP.

Table 3. Summary of MRP test scores for four generation of students in the CIM course

Students	N†	N1‡	Mean test score	Variance	Standard deviation	Shapiro-Wilk W test
Generation 2021/2022 (G1)	64	62	5.05	3.97	1.99	0.928*
Generation 2022/2023 (G2)	70	64	5.77	2.81	1.68	0.906*
Generation 2023/2024 (G3)	65	61	6.23	3.25	1.80	0.868*
Generation 2024/2025 (G4)	73	71	6.13	3.20	1.79	0.866*

* $p < 0.01$; † N – total number of students; ‡ N1 – number of students who participated in the test.

Table 4. Summary of statements about new MRP tool provided by students attending the CIM course

Statement	Generation†	Mean‡	Variance	Standard deviation	Shapiro-Wilk W test
Using the OPR-MAN is easy	G1 G2 G3 G4	3.96 4.19 4.28 4.21	0.358 0.402 0.296 0.215	0.599 0.634 0.544 0.463	0.661* 0.661* 0.711* 0.614*
Using the OPR-MAN is useful	G1 G2 G3 G4	4.35 4.46 4.35 4.30	0.395 0.258 0.276 0.388	0.629 0.508 0.526 0.623	0.762* 0.639* 0.686* 0.763*
Solving the MRP problem with the help of OPR-MAN is interesting	G1 G2 G3 G4	4.04 4.27 4.24 4.26	0.758 0.205 0.497 0.368	0.871 0.452 0.705 0.607	0.848* 0.565* 0.784* 0.759*
Using the OPR-MAN helped me to better understand the MRP logic	G1 G2 G3 G4	3.96 4.19 4.17 4.04	0.678 0.562 0.414 0.346	0.824 0.749 0.643 0.588	0.807* 0.789* 0.749* 0.708*
I understand better the role of BOMs in the MRP	G1 G2 G3 G4	4.00 4.19 4.30 4.09	1.120 0.562 0.305 0.514	1.058 0.749 0.553 0.717	0.795* 0.789* 0.718* 0.815*
I understand better the importance of MPS in the MRP	G1 G2 G3 G4	4.00 4.08 4.13 3.96	0.800 0.554 0.649 0.476	0.894 0.744 0.806 0.690	0.784* 0.812* 0.816* 0.813*
I understand better the application of lot-size models in the MRP	G1 G2 G3 G4	3.85 4.19 4.15 4.02	1.175 0.562 0.399 0.543	1.084 0.749 0.631 0.737	0.861* 0.789* 0.778* 0.830*
I understand better the importance and use of safety inventories in the MRP	G1 G2 G3 G4	3.88 4.35 4.22 3.74	0.506 0.315 0.396 0.629	0.711 0.562 0.629 0.793	0.812* 0.729* 0.773* 0.824*
I understand better the determination of inventory costs after using the OPR-MAN	G1 G2 G3 G4	3.85 4.23 4.15 3.74	0.855 0.505 0.576 0.629	0.925 0.710 0.759 0.793	0.841* 0.750* 0.719* 0.824*
The OPR-MAN enables generation of useful reports	G1 G2 G3 G4	4.42 4.42 4.33 4.30	0.414 0.334 0.358 0.301	0.643 0.578 0.598 0.548	0.749* 0.728* 0.749* 0.714*
I gained more confidence for solving MRP problems in practice	G1 G2 G3 G4	3.65 3.68 3.65 3.94	1.035 0.977 0.899 0.800	1.018 0.988 0.948 0.895	0.758* 0.880* 0.878* 0.857*
I recommend using the OPR-MAN in teaching process	G1 G2 G3 G4	4.46 4.60 4.50 4.34	0.338 0.250 0.389 0.360	0.582 0.500 0.624 0.600	0.724* 0.625* 0.715* 0.748*

* $p < 0.01$; † G1, G2, G3 and G4 – the first, the second, the third and the fourth generation of students; ‡ mean in range from 1 to 5.

Table 5. Summary of constructs measuring satisfaction with the MRP module from OPR-MAN

Composite variable	Generation†	Mean‡	Variance	Standard deviation	Cronbach's alpha	Shapiro-Wilk W test
OPR-MAN satisfaction	G1	48.42	50.014	7.072	0.907	0.950 ($p = 0.231$)
	G2	50.96	24.957	4.996	0.845	0.934 ($p = 0.108$)
	G3	50.48	24.433	4.943	0.847	0.952 ($p = 0.054$)
	G4	48.94	23.670	4.865	0.834	0.982 ($p = 0.662$)

* $p < 0.05$; † G1, G2, G3 and G4 – the first, the second, the third and the fourth generation of students; ‡ mean in range from 12 to 60.

6. Discussion

Different educational methods and tools can be employed to enhance the teaching and learning processes associated with the CIM course. Integrating suitable, affordable, and modern educational tools with traditional lectures is an effective method for delivering this course, as it allows educators without access to costly specialized CIM laboratory equipment to leverage the resources provided in well-equipped computer laboratories.

This paper contributed to this endeavor by demonstrating the utility of computer-aided MRP instruction, which is essential for mastering operations management and industrial engineering curricula. The customized selection procedure allowed identification of an MRP educational tool suitable for adoption in the CIM course at the FOS. Initially, the three software systems offering MRP modules – WinQSB, POM-QM for Windows, and OPR-MAN – were considered. As WinQSB is incompatible with contemporary Windows environments, it was excluded, while MRP modules from POM-QM and OPR-MAN were subjected to further evaluation, based on which the latter tool was retained for adoption in the CIM course. OPR-MAN's MRP outperforms POM-QM's MRP because this software is web-based and can be used on any device connected to the internet; the tool supports different lot size models, lead times, safety stock, and overdue planned receipts; it enables generation of different useful reports (such as MRP report, cost analysis report, action order list, and indented BOM); it has better visuals; and is more modern and intuitive.

The results obtained by implementing the OPR-MAN's MRP module in the teaching of four generations of undergraduate students attending the CIM course at the FOS showed that this tool is highly effective and efficient. Students' test results confirmed that all cohorts learned MRP data processing, utilizing various lot size rules, and calculating inventory costs in the MRP environment. Students that took part in the qualitative survey also stated that they were very satisfied with the use of OPR-MAN's MRP. Their overall satisfaction scores were high with no statistically significant differences among the four generations. When interpreting these findings, some limitations of this study should be noted, especially the small sample size and the reliance on data related to a single undergraduate course offered at one academic institution.

7. Conclusion

As MRP remains a highly relevant topic in industrial engineering and operations management study programs, to actively support the teaching and learning processes associated with this topic, traditional lectures should be supplemented by appropriate MRP educational software. Therefore, the main aim of this paper was to objectively assess the educational value and effectiveness of using a new MRP tool from OPR-MAN package. To ensure objectivity and to prevent subjectivity due to personal preferences, this tool is compared with a long-time used and favored MRP tool from POM-QM software. The research in that direction was guided by three key objectives: to identify educational tools for teaching MRP, to analyze and compare characteristics of MRP tools from POM-QM and OPR-MAN packages, and to evaluate the effectiveness of MRP tool from OPR-MAN through both quantitative and qualitative measures, using Operations Management students as test subjects.

For the CIM course at one engineering school, a customized procedure was developed and implemented to identify the most suitable MRP educational software. Three educational software which offer MRP functionalities are identified – WinQSB, POM-QM for Windows, and OPR-MAN. The software solution WinQSB has been exclude mainly due to incompatibility of the solution with current operating systems that are mainly used, following this exclusion solutions POM-QM and OPR-MAN were further analysed, using comparative analysis method. The comparison was done using the overall characteristics and through demonstration of both solutions. The results show that OPR-MAN outperforms the POM-QM in multiple aspects, such as provide users with: various lot-sizing models, cost analysis, inclusion of safety stock and overdue receipt parameters, useful reports, and with a easy to follow and modern design with web-based accessibility. By just looking at these key functionalities the OPR-MAN solution offers more for educators and students, making it more accessible to students and educators. As such, after the selecting the web-based OPR-MAN tool, was adopted in the course delivery across four academic years, confirming its capacity to promote both teaching and learning.

Further, a quantitative and qualitative evaluation approach with data collected by either using test score data or data collected via surveying four student generations (2020/2021–2024/2025) have proven that there is a continuous improvement in students' test performance and in their level of satisfaction. The students emphasized the user-friendliness of the solutions due to an intuitive interface, as well as the ability to generate meaningful and easy to analyse MRP reports. While the students give mostly positive response, they did provide slightly lower scores in relation to their perception of their knowledge and self-confidence in using their knowledge in real-life scenarios, mainly due to the lack of industrial experience, not due to the deficiencies of the software. The findings yielded by this study are beneficial primarily for those engaged in the teaching and learning of resource planning strategies as a part of engineering and related disciplines.

The paper also provides a demonstration test problem, that was modeled on small scale manufacturing of multiple similar products, the mostly used the same resources with slight variation between the main components. Using this scenario problem ("Boo Burgers") this paper has provided a practical, easy to replicate framework for assessing the difference between the two selected solutions. Just looking at the steps needed to use the POM-QM solution, its limited functionality becomes evident. This solution requires complete manual data entry for all components, even when several products share identical parts, which makes the process time-consuming and prone to repetition. The framework has shown that even after completing all steps, the generated results must be analyzed and partially interpreted using a spreadsheet application to consolidate the final MRP and cost analysis reports. In contrast, the OPR-MAN solution generates the MRP report as well as a cost analysis report and an action order list, with just one iteration, which yields ready-to-use results with minimal additional work required. The example scenario has proven that the new OPR-MAN solution provides students with realistic MRP reports and can help them better understand how to engage with a realistic MRP process. In conclusion, all the different research approaches and outcomes have validated the initial research objectives: The OPR-MAN solution effectively supports the teaching of MRP principles, surpassing traditionally used software solutions in terms of functionality and usability, with statistically confirmed improvements that support the enhancement of students' MRP-related competencies and satisfaction.

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Appendices

Appendix 1. Acronyms

APICS – American Production and Inventory Control Society
ASCM – Association for Supply Chain Management
ANOVA – Analysis of Variance
BOM – Bill of Materials
CAGR – Compound Annual Growth Rate
CIM – Computer Integrated Manufacturing
CPIM – Certified in Production and Inventory Management
CRP – Capacity Requirements Planning
DRP – Distribution Requirements Planning
EOQ –Economic Order Quantity
ERP – Enterprise Resource Planning
ERPsim – Enterprise Resource Planning Simulation Game
FOS – Faculty of Organizational Sciences
FOQ – Fixed Order Quantity
GUI – Graphical User Interface
LFL – Lot-for-Lot
LTC – Least Total Cost
LUC – Least Unit Cost
MPS – Master Production Schedule
MES – Manufacturing Execution System
MRP – Material Requirements Planning
MRP II – Manufacturing Resource Planning
MRP-SIM – Manufacturing Resource Planning Simulation Game
PPB – Part-Period Balancing
QSB –Quantitative Systems for Business
UI/UX – User Interface/User Experience

Appendix 2. Abbreviations

C – Total inventory cost
chg – Annual holding cost rate
cpg – Annual shortage cost
cs – Setup cost per order
cu – Unit cost
GR_t – Gross requirements in period t
OH – Initial on-hand inventory
OGR – Overdue gross requirements
OSR – Overdue schedule receipts
PNR_t – Planned net requirements in period t
POH_t – Projected on-hand inventory in period t
POH_t^+ – Positive inventory balance
POH_t^- – Negative inventory balance
POR_t^- – Planned order receipts
$PORlt$ – Planned order releases
p – Number of planned orders
S – Scrap rate percentage
SR_t – Scheduled receipts in period t
SS – Safety stock
T – Number of periods in a year
u – Duration of a planning period

Appendix 3. Independent demand for "Boo Burgers" items for the 15 days planning horizon

Planning Period [day]															
ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CB	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
CHB	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
BB	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
BP							500						500		
L			1000				2000							1000	

Appendix 4. Inventory data for "Boo Burgers" items

ID	**Name**	**Measure**	**Lot Size**	**Lot Quantity**	**Lead Time [day]**	**On Hand Inventory [UoM]**	**Safety Stock [UoM]**	**Unit Cost [EUR/ UoM]**	**Holding Cost [EUR/ yr.UoM]**	**Setup Cost [EUR/ order]**
CB	Classic Burger	piece	LFL			20		4	0.4	10
CHB	Cheeseburger	piece	LFL			10		4.5	0.45	10
BB	BBQ Burger	piece	LFL			20		5	0.5	10
BP	Beef Patty	grams	FOQ	2000	1	1000	1000	0.01	0.002	5
RB	Regular Bun	piece	FOQ	100	2	100	50	0.3	0.03	2
SB	Sesame Bun	piece	FOQ	200	2	100	50	0.35	0.035	2
SM	Salad Mix	grams	LFL			1500	1000	0.005	0.001	3
L	Lettuce	grams	FOQ	1000	1	500		0.004	0.001	3
T	Tomato	grams	FOQ	1000	1	500		0.003	0.0006	3
O	Onion	grams	FOQ	5000	1	100		0.002	0.0004	3
S1	Sauce 1	grams	LFL			200		0.006	0.0012	2.5
S2	Sauce 2	grams	LFL			200		0.005	0.001	2.5
S3	BBQ Sauce	grams	FOQ	1500	2	500	150	0.007	0.0014	2.5
C	Cheese	grams	FOQ	3000	1	500		0.009	0.0018	4
B	Bacon	grams	FOQ	1500	1	200		0.012	0.0024	4

Appendix 5. Action order list for "Boo Burgers" items from OPR-MAN's MRP

ID	**Overdue**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**	**Day 11**	**Day 12**	**Day 13**	**Day 14**	**Day 15**
CB	0	20	40	40	40	40	40	40	40	40	40	40	40	40	40	40
CHB	0	80	90	90	90	90	90	90	90	90	90	90	90	90	90	90
BB	0	50	70	70	70	70	70	70	70	70	70	70	70	70	70	70
BP	0	54000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	30000	0
RB	0	400	100	100	100	200	100	100	200	100	100	200	100	100	0	0
SB	0	200	200	0	0	200	0	0	200	0	0	200	0	0	0	0
SM	0	11500	15600	15600	15600	15600	15600	15600	15600	15600	15600	15600	15600	15600	15600	15600
L	0	1355000	781000	780000	780000	780000	782000	780000	780000	780000	780000	780000	780000	781000	780000	0
T	0	1355000	780000	780000	780000	780000	780000	780000	780000	780000	780000	780000	780000	780000	780000	0
O	0	545000	310000	315000	310000	310000	315000	310000	315000	310000	310000	315000	310000	315000	310000	0
S1	0	0	400	400	400	400	400	400	400	400	400	400	400	400	400	400
S2	0	600	900	900	900	900	900	900	900	900	900	900	900	900	900	900
S3	0	3000	1500	1500	0	1500	1500	0	1500	1500	0	1500	1500	1500	0	0
C	0	3000	3000	3000	0	3000	0	3000	3000	0	3000	0	3000	3000	0	0
B	0	3000	1500	1500	1500	1500	1500	1500	0	1500	1500	1500	1500	1500	1500	0

Appendix 6. Cost analysis for "Boo Burgers" items from OPR-MAN's MRP

ID	Name	Setup Cost	Holding Cost	Shortage Cost	Unit Cost	Overall Cost
CB	Classic Burger	150	0.02	0.00	2,320.00	2,470.02
CHB	Cheese Burger	150	0.01	0.00	6,030.00	6,180.01
BB	BBQ Burger	150	0.03	0.00	5,150.00	5,300.03
BP	Burger Patty	70	0.00	0.00	4,440.00	4,510.00
RB	Regular Bun	26	0.11	0.00	570.00	596.11
SB	Sesame Bun	10	0.23	0.00	350.00	360.23
SM	Salad Mix	45	0.00	0.00	2,299.00	2,344.00
L	Lettuce	42	0.00	0.00	0.00	42.00
T	Tomato	42	0.00	0.00	0.00	42.00
O	Onion	42	0.00	0.00	0.00	42.00
S1	Sauce 1	35	0.00	0.00	56.00	91.00
S2	Sauce 2	37.5	0.00	0.00	132.00	169.50
S3	Sauce 3 / BBQ sauce	25	0.00	0.00	165.00	190.00
C	Cheese	36	0.00	0.00	270.00	306.00
B	Bacon	52	0.00	0.00	210.00	262.00

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