CommIT Journal 16(2), 183–193, 2022

Integrated Information System of Material Resource Planning and Supply Chain Procurement: A Case Study of XYZ Company

Santo Wijaya[1]*, Marta Hayu Raras Sita Rukmika Sari[2], and Yeyeh Supriatna[3]
[1]Department of Software Engineering, Polytechnic META Industry Cikarang
Bekasi 17550, Indonesia
[2]Department of Industrial Engineering, Polytechnic META Industry Cikarang
Bekasi 17550, Indonesia
[3]Department of Purchasing, PT Trimitra Chitrahasta
Bekasi 17530, Indonesia
Email: [1]santo.wijaya@politeknikmeta.ac.id, [2]marta@politeknikmeta.ac.id, [3]yeyeh@pttrimitra.com

***Abstract*—Human errors are inevitable due to the mass customization and complex supply chain, which must be considered in the Material Resource Planning (MRP) explosion calculation and the Supply Chain Procurement (SCP) distribution of sales orders. Such errors lead to SCP problems with the subject company. The research presents the design and implementation of an integrated information system of MRP and SCP. The objective is to solve the issues in the subject company by designing and implementing an Integrated Information System (IIS) framework with an open-source software platform, which utilizes a generic Bill-of-Materials (BoM) explosion algorithm to calculate the MRP of customers' sales orders. Then, an algorithm is also proposed to calculate SCP distribution to enable the framework in the implementation stage. The research subject is the process business in Indonesia's local Original Equipment Manufacturer (OEM) for automotive components. The name of the company is concealed to be XYZ Company. The calculation is introduced in the testing phase to illustrate the algorithm's mechanism. This approach ensures a valid calculation of efficient supply chain processes. The combined approaches in the subjected business process yield satisfactory results. It reduces significant issues to 12.5% for the stated problems. Hence, the design objective is achieved.**

***Index Terms*—Integrated Information System, Material Resource Planning (MRP), Supply Chain Procurement (SCP)**

Received: Dec. 04, 2021; received in revised form: Feb. 10, 2022; accepted: April 19, 2022; available online: Sep. 19, 2022.
*Corresponding Author

I. Introduction

THE manufacturing industry makes discrete products, especially automotive manufacturers. Discrete products may be the final product or parts and sub-assemblies made into final products [1]. This supply chain process in the twenty-first century, influenced mainly by globalization, has created significant opportunities. At the same time, it places pressure on manufacturers to enhance quality, improve styling, and increase organizational efficiencies [2]. As a result, Supply Chain Management (SCM) practices have started moving towards leaner process approaches to increase supply chain efficiency [3] through the implementation of Just-In-Time (JIT), outsourcing, customized, and global networks [4].

Nowadays, the automotive industry has switched from mass production to Mass Customization (MC) to meet customer expectations better [5]. However, it increases the complexity and diversity of end-products that drive many commonalities and significant differences [6]. This situation generates Bill-of-Materials (BoM) for each product with its components [7]. Furthermore, because a car is the result of an assembly of hundreds of components, it has exploded a variety of components that far outstrips actual production volume [8, 9]. Therefore, handling Material Resource Planning (MRP) related to materials and components becomes a complex issue with increasing variability. Then, a practical approach is presented to handling product information in information technology and systems-related database environment for multi-

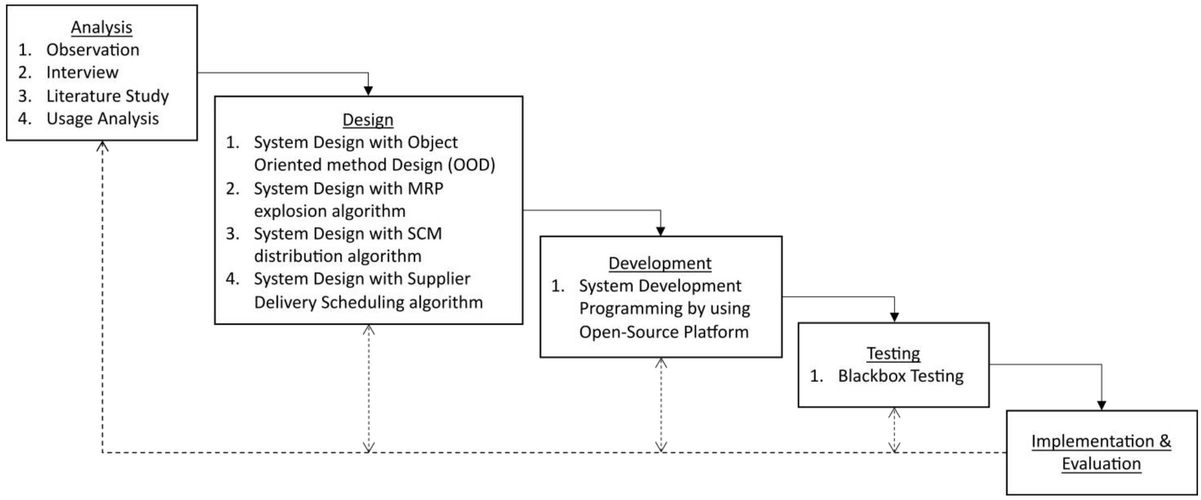

Fig. 1. Implementation and evaluation of the Waterfall method.

product and process production systems [5].

The research considers the MRP and SCM business processes in Indonesia’s local automotive component manufacturer (XYZ Company). As a first-tier Original Equipment Manufacturer (OEM) to Japanese automotive companies in Indonesia, it is also under transition to MC in a complex supply chain environment of the automotive industry. On the other hand, the MRP and SCM business processes workflow is still manually done and depends entirely on humans. Due to the MC and complex supply chain, which must be considered in the MRP calculation and the procurement of supply chain distribution for sales orders, human errors are inevitable. Such errors lead to Supply Chain Procurement (SCP) problems with the subject company.

Many successful design applications with an open-source platform have been proposed in previous studies (e.g., [10–13]). The research proposes a customized Integrated Information System (IIS) design with an open-source platform due to a limited budget and minimizing the risk of failed implementation with the subject company. The research also incorporates the algorithm proposed by previous research [5] with modifications according to the subject company’s process and routing to calculate MRP explosion by utilizing BoM. Then, an algorithm is proposed to calculate SCP distribution to enable the IIS framework in the implementation stage. Detailed data cannot be shown in the research due to its confidentiality. However, the research uses an example to illustrate the algorithm’s mechanism in the testing phase. Moreover, the design criteria meet the proposed method based on previous studies.

II. Research Method

The research follows the Waterfall method. It includes analysis of the existing system, design of a new system, software development, and testing of the system until it meets the requirements. In addition, the research includes the implementation phase in the method and evaluates the effectiveness of the information system to meet the research objective. Figure 1 shows the Waterfall method used [14].

The analysis phase consists of four stages. The first stage identifies the subject company’s background, production process, and as-is process model of the current MRP explosion and SCM distribution workflow. Based on the as-is process model and root cause analysis method, Pareto of the problems that occur with the current process model is summarized. The second stage describes the as-is process model of the current MRP explosion of BoM with its variation. The third stage mentions the as-is process model of SCM distribution that employs horizontal or vertical SCP depending on the production process requirements. The fourth stage is the usage analysis of the subject company that will use the IIS framework. Next, the design phase consists of three stages. In the first stage, the research describes the process design and to-be model of the IIS of MRP explosion and SCM distribution workflow. The second stage describes an algorithm to do MRP explosion based on the BoM process to calculate the child-parts quantity of the finished parts for customers’ orders. The third stage shows the algorithm of supply chain distribution to calculate the distribution of child-parts quantity that needs to be purchased from the supplier.

Moreover, the development phase describes the software platform and database to create IIS and a se-

Fig. 2. Production process.

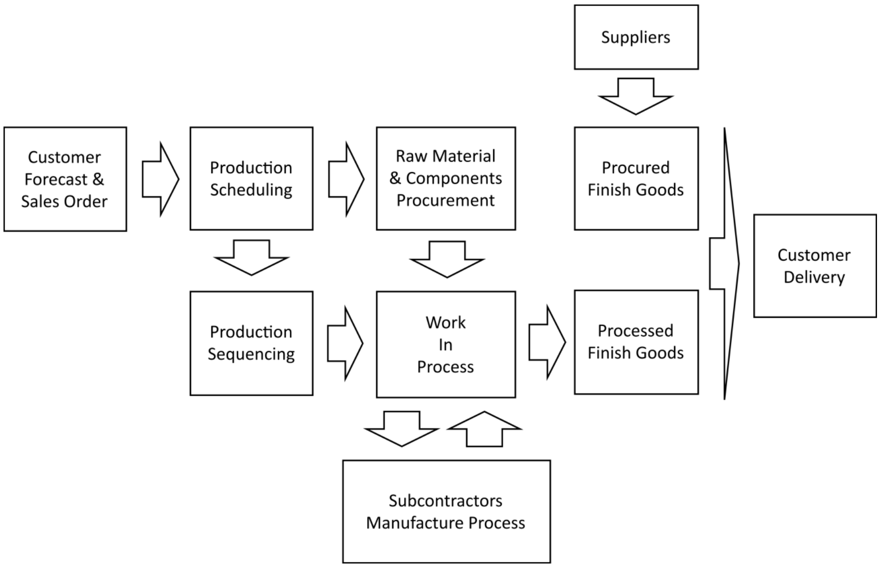

Fig. 3. Overall business process.

quence diagram of IIS to be used in the implementation phase. Next, the testing phase describes the output of black box testing of IIS compared to the manual calculation of the user. There are three main parameters to be evaluated: input result of customer forecast and sales order, the calculation result of supply chain distribution of forecast and purchase order, and calculation result about suppliers’ delivery schedule. In this phase, an example illustrates the IIS framework and algorithms mechanism. Last, the implementation phase shows the result of IIS implementation that can minimize Pareto of the problems stated in the analysis phase.

III. Results and Discussion

A. Analysis Phase

The first analysis is company’s background and as-is process model. The subject company was established in August 1994 and specialized in metal Stamping, dies, jigs, and Fixtures for automotive and motorcycle components. Generally, the production process consists of four main processes, as shown in Fig. 2. The subject company currently handles 4,273 finished parts consisting of regular production parts for local and export and spare parts. There are 1,776 parts for the stamping process, 1,202 parts for the welding process, 818 for the plating process, and 215 for the assembling process. Then, the SCM manages 17 subcontractors for the stamping process with 456 parts to be manufactured and 22 subcontractors for the plating process with 490 parts to be manufactured. Moreover, it manages 42 suppliers with 235 purchased parts/finished goods. The overall business process is shown in Fig. 3.

The research uses the as-is model to describe the current process model of MRP explosion and SCM distribution workflow calculation (see Fig. 4). As-is model identifies weaknesses and potential improvements for future changes [15]. Based on observation of the as-is model, interview data, and root cause analysis (Fishbone method and 5-Why method) as described [16], problems that occur mainly because of human errors in the workflow are found. There are:

1) Manual input of sales forecast and order into MRP explosion calculation sheet,
2) Manual input of forecast and order component of the SCM distribution calculation into the existing IS order system,
3) Manual BoM update into MRP explosion calculation sheet,

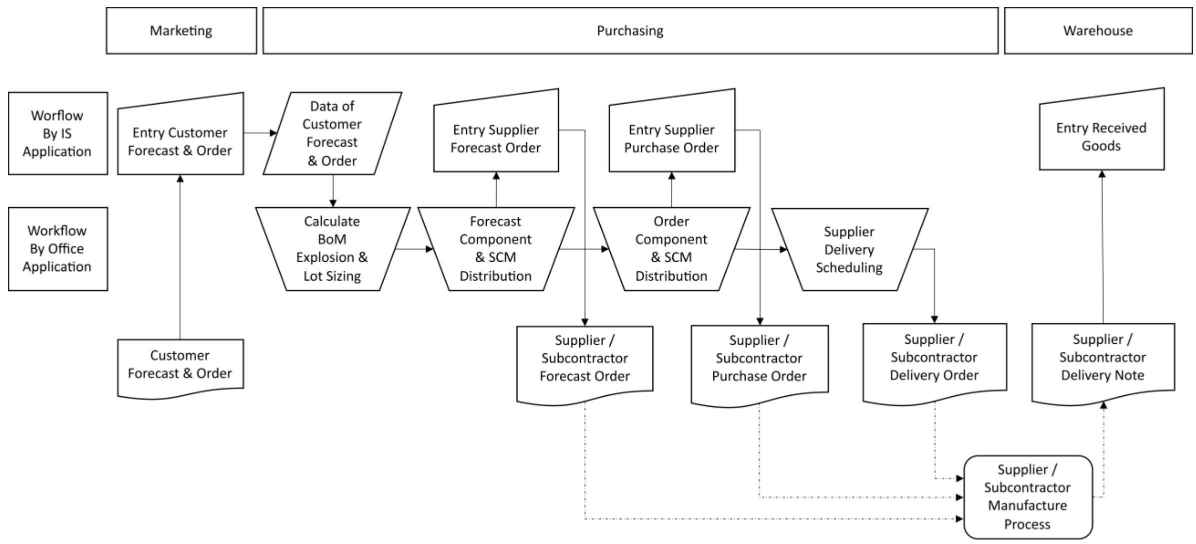

Fig. 4. As-is model of Material Resource Planning (MRP) explosion and Supply Chain Management (SCM) distribution workflow.

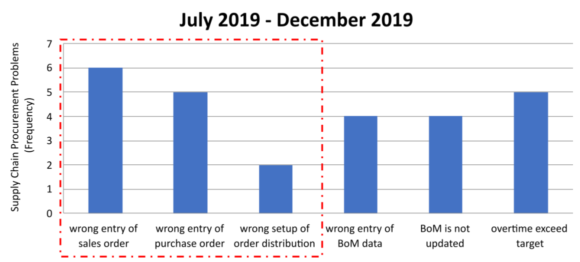

Fig. 5. Pareto of Supply Chain Procurement (SCP) problems before the Integrated Information System (IIS) implementation.

4) Manual and independent control of the SCM distribution per purchasing staff,
5) Late action of the supervisor due to delayed information from purchasing staff.

Based on the Pareto of the problems, six issues occur, such as wrong entry of sales order, wrong entry of purchase order, wrong setup of order distribution, wrong entry of BoM data, not updated BoM, and overtime exceeding target as shown in Fig. 5. There are three major issues, wrong entry of sales orders, wrong entry of purchase orders, and wrong calculation of order distribution, that are the focus of the research to solve. These significant issues have contributed to 50.0% of the problems on average from July to December 2019. Hence, the objective of IIS implementation is to reduce the issues to zero or minimize them to the acceptable range.

The second analysis is about BoM and MRP. The automotive industry has switched from mass production to MC to meet customer expectations better [5]. However, it increases the complexity and diversity of end-products that drive many commonalities and significant differences [9]. This case can also be applied to the subject company. It has 4,273 finished parts, but the number of components is more than 50% lesser than the finished parts for each process. Therefore, it becomes a complex issue, especially when performing the MRP explosion using BoM to calculate supply chain component orders based on customers' sales orders.

BoM is a complete, formal, structured list of components that lists the hierarchical membership and quantity relationships from raw materials to parts and components up to the end product [17]. Generally, it represents all the production processes in the subject company to manufacture product A, but the routing process may differ for other products. For example, Fig. 6a shows a process-based tree graph representing product A (BoM with standard routing). This process-based multi-level BoM representation can be more useful in MC systems since it deals with product variability at a very high level due to explosive customer choices [8, 18]. Furthermore, this representation is suitable for translating into a relational database environment [5]. Due to MC and complex supply chain, product A may have multiple routing and different functions, as shown in Fig. 6b.

BoMs are used to perform MRP explosion to calculate components and raw materials based on the customers' sales order. An approach with two algorithms is proposed to minimize the data entry efforts

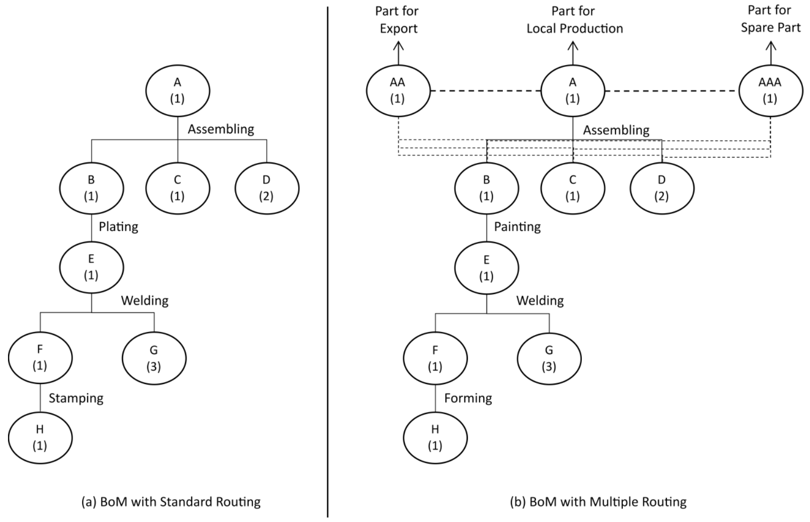

Fig. 6. Process-based multi-level BoM representation of product A.

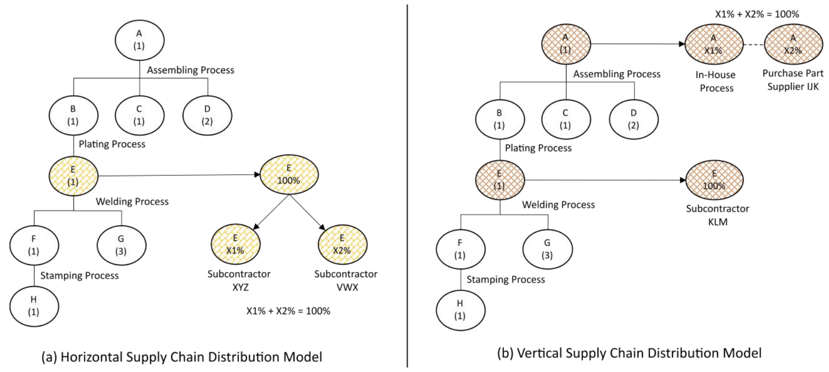

Fig. 7. Supply chain distribution model.

while representing BoM and calculating MRP utilizing the relational database environment [5]. The research incorporates these algorithms with modifications according to the subject company's process and routing.

The third analysis is SCP. Outsourcing in the automotive industry will continue due to differences in labor costs and disadvantages in scale and scope. SCM providers must offer flexible, modular solutions to benefit from continued outsourcing because not every manufacturer will concentrate on the same core capabilities and functions [19]. Hence, the SCM manages multiple subcontractors for each process.

The research describes the SCP network structure in the subject company using BoM representation, as shown in Fig. 7. Several SCM models have historically been defined by scholars in this field, such as [19, 20]. The horizontal supply chain model shows distributed outsourcing at the same BoM level. For example, plating process component E is distributed to subcontractors XYZ and VWX with a pre-defined distribution percentage. The vertical supply chain model shows distributed outsourcing in the different BoM levels. For example, product A is divided into purchase parts to supplier IJK and manufacture parts with the pre-defined distribution percentage. In the manufacturing process, a plating process is also outsourced to subcontractor KLM. In other cases, some products combine horizontal and vertical supply chain distribution models.

The fourth analysis is for the usage. The research identifies that three departments operate the IIS. First, the marketing department is tasked with entering customers' sales forecasts and orders in the IIS. It also ensures that MRP explosion calculation is finished

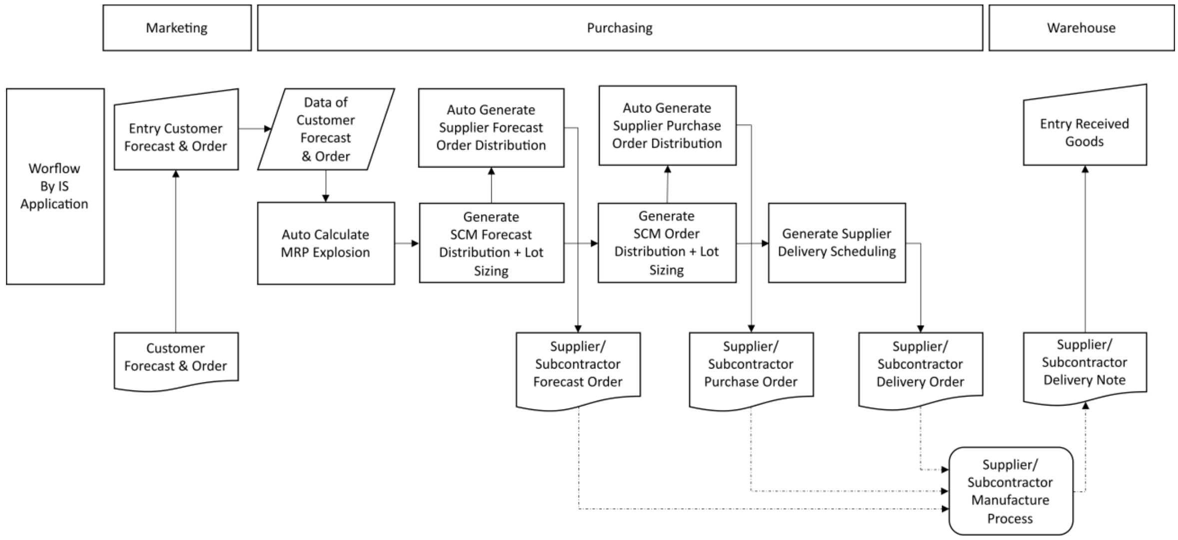

Fig. 8. To-be process model of MRP explosion and SCM distribution workflow.

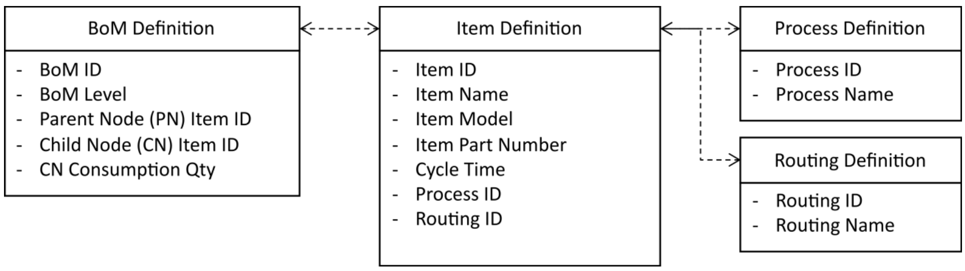

Fig. 9. Information partitions of Bill-of-Materials (BoM) representation.

correctly. Second, the cost control department enters master data of components, raw materials, and BoM. Third, the purchasing department inputs the master data of supplier, lot-sizing, horizontal SCM, and vertical distribution data and generates SCM forecast and order component and a delivery schedule.

B. Design Phase

The first design is for system and to-be process model. In the analysis phase, as observed in Fig. 4, purchasing department's workflow still engages in the manual operation of the MRP explosion for customers' forecast and sales order calculation, SCM distribution, and delivery schedule. It handles multiple subcontractors and suppliers with hundreds of components. On the other hand, customers' MC creates complex routing of even one end-products delivery, as shown in Fig. 6. Meanwhile, the SCM distribution model is also increasingly complex with horizontal and vertical distribution models or mixed distribution models like in Fig. 7.

Next, the research proposes a customized IIS system design with several factors in the to-be process model (see Fig. 8). It moves the purchasing department's workflow to the proposed IIS. It automates the work process to calculate the SCP in customers' orders. Six manual processes in the as-is process model are migrated into the IIS system, such as calculating MRP explosion process, generating SCM forecast distribution + lot sizing process, generating SCM order distribution + lot sizing process, generating supplier delivery scheduling process, generating suppliers' forecast order distribution process, and generating supplier purchase order distribution. It is also integrated with the marketing department's IIS system that is previously implemented. Hence, there is a smooth transition process for customers' forecasts and order data to be processed further.

The second design is MRP explosion utilizing BoM algorithm. A process-based multi-level BoM is proposed by previous research [5]. This method makes BoM elements can be partitioned according to each

Step 1. Insert the selected product as Parent Node (PN) whose BoM will be generated into Node List (NL_0), i.e., NL_0 = PN, and set the consumption of PN of the current BoM level to 1, i.e., parent-child-annotation $(pca)_0 = 1$.
Step 2. Set the current BoM level to zero, i.e. cl = 0, set the generated BoM array list to init default, i.e. BoM = [cl, NL_0, pca_0].
Step 3. Increase the BoM level by 1, i.e. current level (cl) = cl + 1.
Step 4. Assign $NL_{cl,i}$ to the current Child Node (CN) whose BoM will be generated based on the previous node NL_0 from the BoM definition table, i.e., $NL_{cl,i} = CN_i$. Also, set the consumption qty, i.e. $pca_{cl,i} = CN_i$ consumption qty.
Step 5. Populate BoM array list based on the data of $NL_{cl,i}$ and $pca_{cl,i}$, i.e. BoM = [cl, NL_0, pca_0; cl, $NL_{cl,i}$, $pca_{cl,i}$].
Step 6. Increase the BoM level by 1, i.e. cl = cl + 1.
Step 7. If $NL_{cl,i}$ is not null set, then go to Step 4.
Step 8. Else end.

Fig. 10. An algorithm for generating a BoM of a product.

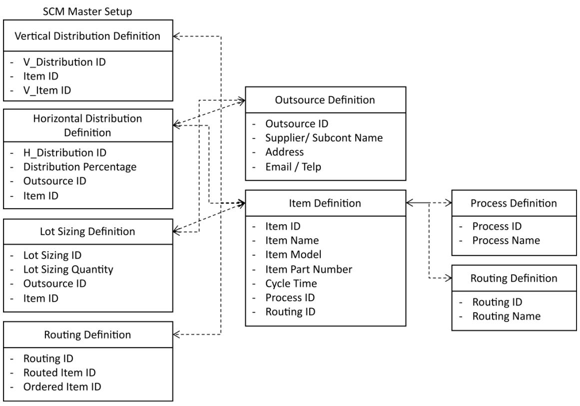

Fig. 11. Information partitions of an SCM representation.

process. The research utilizes this approach with modification according to the subject company's process and routing. Routing can be an in-house process or an outsourced process. The information partition of each level BoM representation is shown in Fig. 9.

An algorithm for generating a BoM of one product is shown in Fig. 10. The next step is calculating the MRP explosion by utilizing BoM for the products listed in the sales order. An algorithm for calculating MRP explosion is given according to previous research [5]. The BoM algorithm is executed individually for each product, and its material requirements are calculated according to the ordered quantity and consumption quantity of the component.

The third design is supply chain distribution algorithm. From the previous section, the algorithms calculate MRP for each component in the BoM. Then, with the proposed supply chain algorithm in this section, the research calculates the forecast and purchase order quantity of each outsource subcontractor or supplier. Figure 11 shows the information partition of an SCM representation in the relational database. An algorithm for generating forecast and purchase order of one outsource subcontractor/supplier is shown in Fig. 12.

Step 1. Set array of Component List (CL_i) that consists of array number (i), Item ID ($I_{k,1}$), Distribution Percentage ($I_{k,2}$), calculated MRP Qty ($I_{k,3}$), SubCont ($I_{k,4}$) to null, i.e., $CL_i = [i, I_{k,1}, I_{k,2}, I_{k,3}, I_{k,4}] = Ø$.
Step 2. Set the array number to zero, i.e., i = 0. Start increase the array list by 1, i.e., i = i + 1.
Step 3. Select the outsource, i.e., OS_1, whose components distribution will be generated.
Step 4. Get the item data, i.e., x_1, and distribution percentage data, i.e., x_2, in the Horizontal Distribution Definition table based on OS_1. Calculate total data and assign it to r, i.e., $r = \Sigma x_1$.
Step 5. If r is not null, set the array number to zero, i.e., k = 0. Start increase the array list by 1, i.e., k = k + 1.
Step 6. Populate $I_{k,1} = x_{1,i}$ and $I_{k,2} = x_{2,i}$.
Step 7. Get the calculated MRP Qty, i.e., x_3, from the current item, i.e., $x_{1,i}$, as the ordered item ID. Then populate array $I_{k,3}$, i.e., $I_{k,3} = x_3$.
Step 8. Get the routed item ID, i.e., I_5, from the current item, i.e., $x_{1,i}$, as the ordered item ID from the Routing Definition table. If I_5 is not a null set, get the calculated MRP Qty, i.e., x_4, based on I_5, as the routed item ID. Then populate array $I_{k,3}$, i.e., $I_{k,3} = I_{k,3} + x_4$.
Step 9. Get the vertical item ID, i.e., I_5, from the current item, i.e., $x_{1,i}$, as the item ID from the Vertical Distribution Definition table. If I_5 is not a null set, get the distribution percentage, i.e., D_5, based on I_5 and OS_1, as a horizontally distributed item. Then recalculate array $I_{k,2}$, i.e., $I_{k,2} = I_{k,2} \times (100\% - D_5)$.
Step 10. Append the array values to the Component array list, i.e., $CL_{i,k} = [CL_{i,(k-1)} ; CL_{i,k}]$.
Step 11. If the array number k is not equal to r, then go to Step 5.
Step 12. If the array number i is not equal to array_length of BoM, then go to Step 2.
Step 13. Else end.

Fig. 12. An algorithm for generating forecast and purchase order of one outsource subcontractor or supplier.

C. Development Phase

The system architecture employs the same approach as in previous studies [1, 21] due to the same subject company. The proposed IIS will connect to a fault-tolerant, scalable, and open-source MariaDB SQL for relational database on the server side. The desktop application interface uses the VB.Net software platform.

Figure 13 shows a sequence diagram of the proposed IIS. It also explains the relationship between the user, IIS interface, and database connection to meet the design criteria. The research also adapts the workflow with the current Standard Operating Procedure (SOP) between departments to make the implementation phase run smoothly.

D. Testing Phase

The test results using the black box approach [22] are shown in Table I. The research compares the output of testing results of the IIS with the excel-based calculation. It has been done manually by the purchasing department staff. The IIS implementation addresses the practical problems successfully.

The research uses an example to demonstrate the proposed IIS sequence and algorithms in this phase due to the data confidentiality of the subject company. In this example, the sequence starts the process input of customer forecast and sales order until the output of supplier forecast and the purchase order is obtained. For example, there is a sales order of 1 piece for

Cite this article as: S. Wijaya, M. H. R. S. R. Sari, and Y. Supriatna, "Integrated Information System of Material Resource Planning and Supply Chain Procurement: A Case Study of XYZ Company", CommIT Journal 16(2), 183–193, 2022.

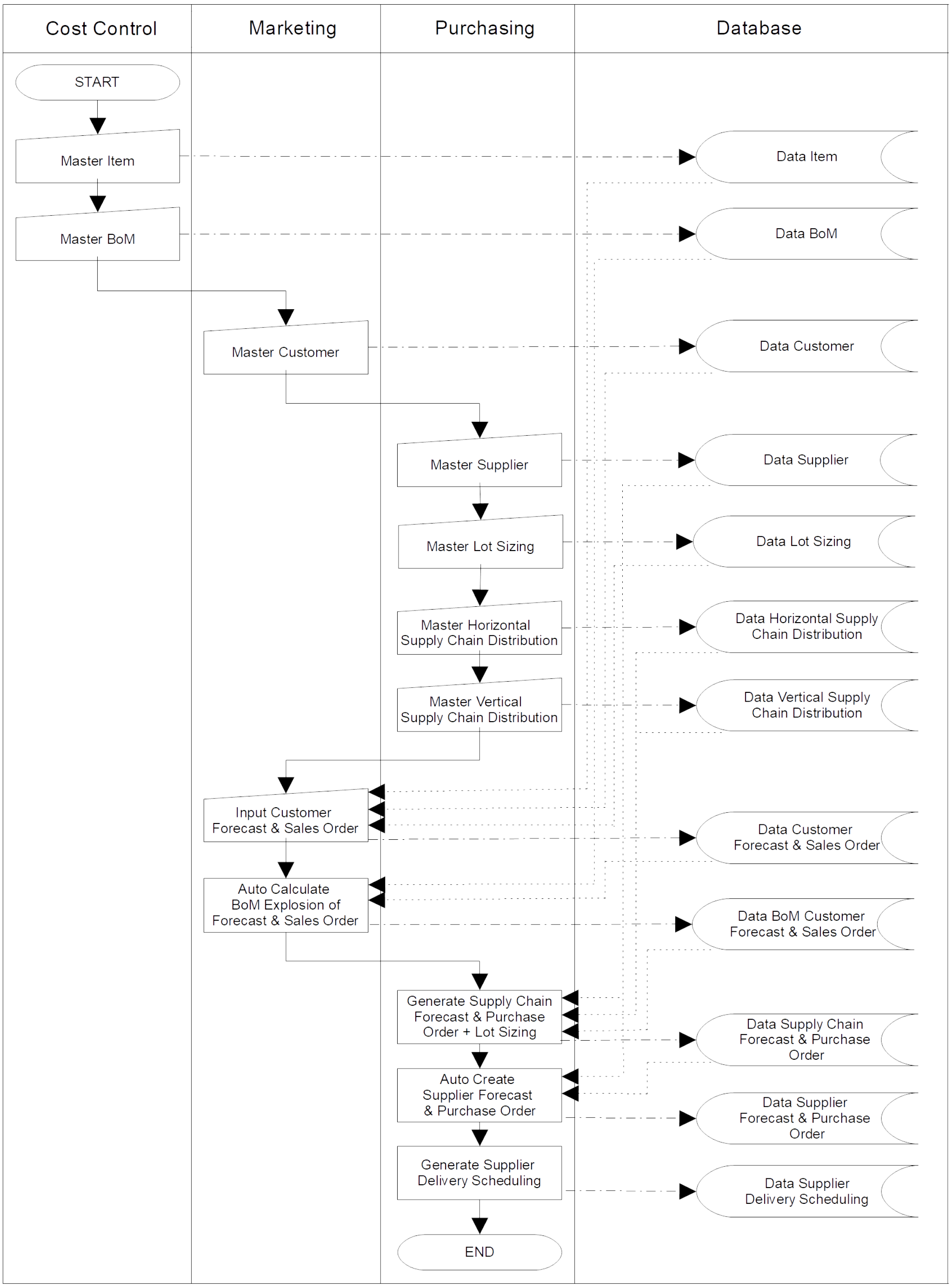

Fig. 13. Sequence diagram of the proposed Integrated Information System (IIS).

Cite this article as: S. Wijaya, M. H. R. S. R. Sari, and Y. Supriatna, "Integrated Information System of Material Resource Planning and Supply Chain Procurement: A Case Study of XYZ Company", CommIT Journal 16(2), 183–193, 2022.

TABLE I
BLACK BOX TESTING RESULTS.

No	Action	Testing Scenarios	Expected Results	Testing Results	Information
1	Input customer's forecast and sales order	The entry regarding customer's forecast and sales order monthly	Display of monthly customer forecast and sales order	Display customer's forecast and sales order with log activities	Valid
		Calculation of MRP explosion based on the entry data	Matching comparison result of forecast and sales quantity for each component with manual calculation	Same result of forecast and sales quantity for each component	Valid
2	Generate supply chain distribution of forecast and purchase order	Generate supply chain distribution of forecast order	Matching comparison result of supply chain distribution of forecast order with manual calculation	Same result of supply chain distribution of forecast order	Valid
		Generate supply chain distribution of purchase order	Matching comparison result of supply chain distribution of purchase order with manual calculation	Same result of supply chain distribution of purchase order	Valid
3	Generate supplier delivery schedule	Generate supplier delivery schedule based on the purchase order	Matching comparison result of supplier delivery schedule with manual calculation	Same result of supplier delivery schedule	Valid

(N) month (named X) and a forecast of 1 piece for ($N+1$) month (named Y) of product A from customer ADN. The marketing department inputs the customer's forecast and sales order into the IIS interface and saves the entry data. After being saved, the IIS starts calculating MRP explosion based on the BoM of product A. The BoM of product A is shown in Fig. 14. Child Node (CN) quantity for each Parent Node (PN) is also mentioned. The components array of product A is [A, B, C, D, E, F, G, H]. Then, the resulted array of BoM is [0, A, 1; 1, B, 1; 1, C, 1; 1, D, 2; 2, E, 1; 3, F, 1; 3, G, 3; 4, H, 1]. The MRP explosion based on the BoM array of the sales order is [0, A, 1 × X; 1, B, 1 × X; 1, C, 1 × X; 1, D, 2 × X; 2, E, 1 × X; 3, F, 1 × X; 3, G, 3 ×X; 4, H, 1 × X]. The MRP explosion is based on the BoM array of forecast order of [0, A, 1 × Y; 1, B, 1 × Y; 1, C, 1 × Y; 1, D, 2 × Y; 2, E, 1 × Y; 3, F, 1 × Y; 3, G, 3 × Y; 4, H, 1 × Y]. The arrays are saved to table [data BoM customer forecast and sales order] in the database and the algorithm sequence and completed after four iterations.

Then, purchasing department gets the calculation of MRP data. Based on the master data, a horizontal supply chain in sub-component E is distributed to subcontractor XYZ for 50% and subcontractor VWX for 50%. This example is without routed item ID and vertical supply chain distribution. It makes OS1= [XYZ, 50%; VWX, 50%]. The supply chain distribution algorithm starts to calculate after the distributions are confirmed. The generated array of sales order is CL4 = [4, E, 50%, 1 × X, XYZ; 4, E, 50%, 1 × X, VWX]. Then, the generated array of forecast order is CL4 = [4, E, 50%, 1 × Y, XYZ; 4, E, 50%, 1 × Y, VWX].

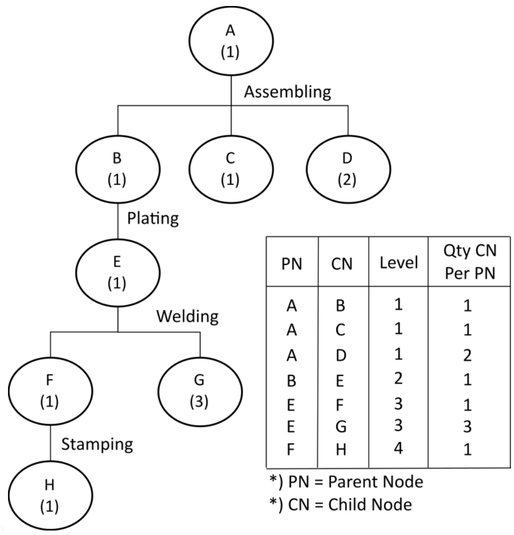

Fig. 14. Process-based multi-level BoM representation of product A.

E. Implementation and Evaluation Phase

Implementation results show that the IIS application effectively solves the supply chain procurement problems. Based on the collected data after implementation, the three major problems are significantly reduced to

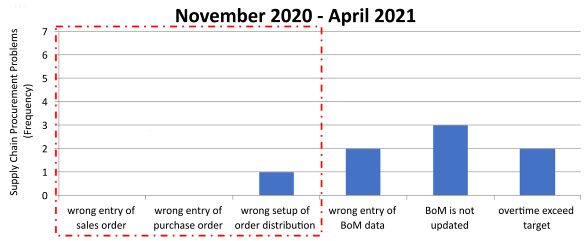

Fig. 15. Pareto of Supply Chain Procurement (SCP) Problems after the Integrated Information System (IIS) implementation.

12.5%. It has combined the average of overall problems from November 2020 to April 2021, as shown in Fig. 15.

The XYZ Company's sales reduce by around 30% in Fig. 15 (November 2020 – April 2021) compared to Fig. 5 (July 2019 – December 2019) due to the pandemic. Hence, the workload to manually calculate the MRP and SCP can also be reduced by approximately 30%. Without the proposed IIS and its algorithms, the same three major problems (marked with a red dot box) occur but are reduced by 30% in frequency for each problem. With the proposed IIS, the research can minimize the three major problems (marked with a red dot box) to almost zero. There are other non-human factors. However, human error is still significant due to workload and repetitive work. Thus, the research uses these evaluation results to show the effectiveness of the proposed method.

Furthermore, there is also a time-saving in workforce work hours. The proposed IIS can automate MRP explosion calculation (1), generate supply chain distribution forecast and purchase order (2), and generate supplier delivery schedule (3) with only verification work that needs to be done instead of manual workflow previously. Based on time cycle comparison, workflows (1), (2), and (3) are 91%, 94%, and 71% faster on average.

IV. Conclusion

As a first-tier OEM to Japanese automotive companies in Indonesia, the subject company is also under transition to MC in a complex supply chain environment of the automotive industry. Due to the MC, complex supply chain, and manually done workflow, human errors are inevitable. The approach presented in the research is developed to prevent human errors in the SCP workflow. The research utilizes the generalized BoM algorithm with modification according to the subject company's process and proposes an SCM distribution algorithm to minimize manual entry in the workflow. Moreover, the research uses an open-source platform to develop the proposed IIS to meet the budget constraint of the subject company. The test results show that the proposed IIS satisfies all requirements. In addition, the implementation result shows reduced SCP problems. Previously, the average percentage contribution of the three most significant issues from July to December 2019 is 50.0%. After improvement, the average percentage of the stated issues from November 2020 to April 2021 is 12.5%.

Nevertheless, the proposed IIS does not consider the level of stock in the subject company and the subcontractors or suppliers inside the SCP algorithm. Hence, inventory buildup is possible when the sales order changes. Future research can consider including existing inventory stock in the algorithm calculation and synchronize it with Manufacturing Planning System (MPS) to create lean supply chain procurement.

Acknowledgement

The research was supported by an internal grant from Polytechnic Meta Industry Cikarang in 2021-2022. The authors are indebted to XYZ Company as a test and implementation subject of the proposed system.

References

[1] S. Wijaya, S. Hariyadi, F. Debora, and G. Supriadi, "Design and implementation of poka-yoke system in stationary spot-welding production line utilizing Internet-of-things platform," *Journal of ICT Research & Applications*, vol. 14, no. 1, pp. 34–50, 2020.

[2] I. M. Ambe and J. A. Badenhorst-Weiss, "An automotive supply chain model for a demand-driven environment," *Journal of Transport and Supply Chain Management*, vol. 5, no. 1, pp. 1–22, 2011.

[3] J. A. Al-Doori, "The impact of supply chain collaboration on performance in automotive industry: Empirical evidence," *Journal of Industrial Engineering and Management*, vol. 12, no. 2, pp. 241–253, 2019.

[4] S. Brown, J. Bessant, and F. Jia, *Strategic operations management*. Routledge, 2018.

[5] A. O. Aydin and A. Güngör, "Effective relational database approach to represent bills-of-materials," *International Journal of Production Research*, vol. 43, no. 6, pp. 1143–1170, 2005.

[6] Y. Qi, Z. Mao, M. Zhang, and H. Guo, "Manufacturing practices and servitization: The role of mass customization and product innovation capabilities," *International Journal of Production Economics*, vol. 228, pp. 1–37, 2020.

[7] C. Zhou and Q. Cao, “Design and implementation of intelligent manufacturing project management system based on bill of material,” *Cluster Computing*, vol. 22, no. 4, pp. 8647–8655, 2019.

[8] C. Chatras, V. Giard, and M. Sali, “High variety impacts on bill of materials structure: Carmakers case study,” *IFAC-PapersOnLine*, vol. 48, no. 3, pp. 1067–1072, 2015.

[9] A. Alfieri, C. Castiglione, and E. Pastore, “A multi-objective tabu search algorithm for product portfolio selection: A case study in the automotive industry,” *Computers & Industrial Engineering*, vol. 142, pp. 1–15, 2020.

[10] B. N. Sari, O. Komarudin, T. N. Padilah, and M. Nurhusaeni, “Bill of Material (BOM) pada sistem inventori kawasan Berikat untuk pelacakan material movement,” *ILKOM Jurnal Ilmiah*, vol. 10, no. 3, pp. 323–330, 2018.

[11] D. Cahyono, “Sistem informasi standard bill of material quantity genset di PT Conductorjasa Suryapersada,” *An International Journal on Information and Communication Technology*, vol. 2, no. 1, pp. 1–5, 2017.

[12] S. Wijaya, G. Supriadi, F. Debora, and P. Y. D. Arliyanto, “Inhouse quality check system improvement with Kanban system and analysis quality control circle,” *Oper. Excell*, vol. 13, no. 1, pp. 22–35, 2021.

[13] I. T. Adiwinoto and A. Santoso, “Desain sistem informasi untuk tracking dan tracing pada warehouse dengan menggunakan teknologi QR code,” *J@ti Undip: Jurnal Teknik Industri*, vol. 16, no. 2, pp. 102–108, 2021.

[14] M. D. Chairudin, N. B. Ginting, and H. Fajri, “Information system for selection of production line for plastic item injection machine number A36 using priority scheduling method,” *INTENSIF: Jurnal Ilmiah Penelitian dan Penerapan Teknologi Sistem Informasi*, vol. 4, no. 2, pp. 232–246, 2020.

[15] E. Agapaki and I. Brilakis, “State-of-practice on as-is modelling of industrial facilities,” in *Workshop of the European Group for Intelligent Computing in Engineering*. Springer, 2018, pp. 103–124.

[16] A. Nagyová, H. Pačaiová, A. Gobanová, and R. Turisová, “An empirical study of root-cause analysis in automotive supplier organisation,” *Quality Innovation Prosperity*, vol. 23, no. 2, pp. 34–45, 2019.

[17] H. Zhang, “Development of cost management and aided decision system for casting enterprises based on ERP,” in *ITM Web of Conferences*, vol. 17. Wuhan, China: EDP Sciences, Dec. 15–17, 2018, p. 03010.

[18] C. Zhou, X. Liu, F. Xue, H. Bo, and K. Li, “Research on static service BOM transformation for complex products,” *Advanced Engineering Informatics*, vol. 36, pp. 146–162, 2018.

[19] D. Mathivathanan, D. Kannan, and A. N. Haq, “Sustainable supply chain management practices in Indian automotive industry: A multi-stakeholder view,” *Resources, Conservation and Recycling*, vol. 128, pp. 284–305, 2018.

[20] C. L. Garay-Rondero, J. L. Martinez-Flores, N. R. Smith, S. O. C. Morales, and A. Aldrette-Malacara, “Digital supply chain model in Industry 4.0,” *Journal of Manufacturing Technology Management*, vol. 31, no. 5, pp. 887–933, 2020.

[21] S. Wijaya, F. Debora, G. Supriadi, and I. Ramadhan, “A framework of e-Kanban system for Indonesia automotive mixed-model production line,” *International Journal of Science and Research (IJSR)*, vol. 8, no. 6, pp. 2109–2117, 2019.

[22] A. Špakova and M. Uhanova, “An overview and evaluation of black-box testing methods for system testing,” in *International Conferences Big Data Analytics, Data Mining and Computational Intelligence 2019; and Theory and Practice in Modern Computing 2019*, 2019, pp. 225–229.