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Applications of Fishbone Diagram and DEMATEL Technique for Improving Warehouse Operation—A Case Study on YMT Overseas Imported Components

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A case study on YMT (Yamaha Motor Taiwan Co., Ltd.) overseas imported components was initiated by Yan-zhang Lin who is responsible for efficiently managing warehouse operation to YMT three factories, whose objective was to improve the process efficiency of warehouse operation for supplying overseas imported components. This paper is aimed at describing the improved course of events which include identifying encountered problems in practical works, classifying relative problems of cause-and-effect relationship by Fishbone Diagram, understanding the influential relationships through decision making trial and evaluation laboratory (DEMATEL) technique, and improving the warehouse operation of overseas imported components. The results showed that the crucial factor "process" should be first improved on the supply of YMT overseas imported components. In a sense, the company can gain a better performance in the entire warehouse operation because "process" is the most important crucial factor. In addition, the crucial factors of "environment" and "people" can be taken into consideration for enhancing the "process" performances because they can remarkably influence on crucial factor of "process", and further impact on overall process performance of warehouse operation. The main contribution is a submission of the six critical factors for improving the process performance by using Fishbone Diagram, as well as including an importance and influential relationships among six critical factors through DEMATEL method. Also, a proposed process will be able to be utilized for improving on YMT overseas imported components of warehouse operation in practice. The research limitation is that due to time limitation, this paper has not taken all problems into consideration. Hence, it is necessary to focus on the other critical factors for improving warehouse operation performance in future studies.

Keywords: warehouse operation, Fishbone Diagram, DEMATEL technique, influential relationship

Introduction

Establishing a proper strategy of the warehouse operation to gain a competitive advantage is essential for any business enterprise. It has acted as the hub, the nodes to be connected to the respective spokes, which is used to enhance responsiveness to customers and profitability for a company (Shashidharan, 2021). In addition,

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"warehousing" and "inventory" are important crucial factors of logistics strategy (Gunasekaran & Nga, 2003) which are regarded as connecting bridge between producers and end-consumers (Russo & Comi, 2010). The continuous improvement to develop the distinctive capabilities and competencies is the key to gain a competitive advantage based upon the customer unique requirement (Shashidharan, 2021). And then, the distinctive capabilities and competencies will be able to reduce overall costs of logistics operation and enhance service levels under the bigger demand fluctuations (Russo & Comi, 2010).

The need for continuous improvement has been raised for developing the distinctive capabilities and competencies. Hiroshi Mikitani (Mrasetyawan, 2010) is a founder and CEO of Rakuten, Inc. in Japan, who has said that if you could make better by 1% every day, you would be able to get a 365% improvements in a year. People are encouraged to identify encountered problems in practical works, find ways for improving encountered problems, and put them into actions to enhance effectiveness. It is a kind of joy added by your life and work. The improvement principle is widely used for continuously eliminating wastes under the various situations. It is used not only in the manufacturing area, but also in different field of various industries. Recently, the improvement in the warehouse area has been getting concerns in logistics because it is not only stated a certain step of improvement warehouse operation but also facilitated the whole company performance (Prasetyawan & Ibrahim, 2020).

A warehouse operation improvement of case study on YMT (Yamaha Motor Taiwan Co., Ltd.) overseas imported components is initiated by Yan-zhang Lin who is responsible for efficiently managing warehouse operation to YMT three factories. Fishbone Diagram has been an important analysis method for identifying and classifying encountered problems to create guidelines for analyzing problems, which uses flow process charts by observing practical work, asking relative question for solving problems (Phunlarp & Phudetch, 2019). In addition, Fishbone Diagram has often been used to understand cause-and-effect relationship and improve relative issues of warehouse operation or performance (Sooksai, 2019; Frusman & Wibisono, 2014). Furthermore, decision making trial and evaluation laboratory (DEMATEL) technique is widely used to present the important and influential relationships (Düzgün, 2021; Mishra, 2020).

For the aforementioned reasons, on a case study on YMT overseas imported components for improving warehouse operation, this paper is aimed at describing the improved results which include the processes of the important evaluation of critical factors, applying DEMATEL technique for analyzing the influential relationships of critical factors. The objectives are:

- To identify encountered problems in practical works of warehouse operation;
- To classify relative problems of cause-and-effect relationship by Fishbone Diagram;
- To understand the importance and influential relationships through DEMATEL; and
- To improve the warehouse operation of the overseas imported components.

This paper comprises five sections. Apart from the introduction in Section one, the second section reviews the theoretical background, followed by the research methodology in Section three. The results of the most important and influential critical factors are stated in detail in Section Four, and the last section provides further discussions and conclusions to the paper.

Theoretical Background

Having previously been considered as a burden because of high capital and operating expenses, warehouse operations are now increasingly regarded as an important crucial factor of logistics strategy, and the topic of warehousing is attracting increased attention (Kembro, Norrman, & Eriksson, 2018). The availability of good management of warehouse operation is one of important strategies which should be concerned in a company. The demand for warehouse operation comes from several factors, such as providing storage to reduce shipping costs, producing larger quantities to reduce purchasing costs, or shortening response time to improve customer service level, etc. (Dharmapriya & Kulatunga, 2011). The managed important activities include receiving goods from production section, transferring them from one location to another within same warehouse or another, delivering to customers which includes picking and loading activities, and physical verification activities which compare to the recorded data in the system (Van den Berg & Zijm, 1999). One company usually faces several warehouse problems, such as missed products shipping to customers, or not timely updated position of goods leading to great confusion. This evidence consequently decreases company image and gives effect on customers' trust for the company (Frusman & Wibisono, 2014).

A warehousing system can be the combination of equipment and operating policies used in an item picking or storage/retrieval environment. With respect to the level of automation, we also may distinguish three types of warehousing systems (Van den Berg & Zijm, 1999):

- Manual warehousing systems (picker-to-product systems): The order picker rides a vehicle along pick locations, and a wide variety of vehicles is available.
- Automated warehousing systems (product-to-picker systems): The order picker serves two to four carousels in parallel. While the order picker is extracting items from one carousel, the other carousels are rotating. Therefore, this reduces the waiting time of the order-picker.
- Automatic warehousing systems: An automatic order-picking system is an order picker of a carousel system or rotary rack by a robot. It usually performs high-speed picking of small- or medium-sized non-fragile items of uniform size and shape, e.g., compact disks or pharmaceuticals.

Research Methodology

Fishbone Diagram

Fishbone Diagram is a cause-and-effect diagram and considered one of the important tools of quality control, which was created by Kaoru Ishikawa in 1960. In the quality management processes, it is an important tool to identify the potential causes of a specific event and then to classify these sources of variation (Liliana, 2016). Fishbone Diagram can help enterprises to reversely analyze and infer the problems of factors from the results. The causes emerge is often through brainstorming sessions for conducting various analysis, and then to be grouped into categories on the main branches off the fishbone (Yazdani & Tavakkoli-Moghaddam, 2012).

Therefore, most potential cause can be traced back to find the root cause, which often uses the six Ms technique, including materials, machine/equipment, manpower/people, management, method/process, and mother nature/environment (Luca, 2015). The way to classify is to place the problem (fish head) on the right side of the diagram. And the potential crucial factors are divided into several categories as well as subdivided into small categories by the major categories on the left side of the diagram. In order to show the stratum branches clearly, the present situations are usually to be described the major issues by placing fish-head position, middle issues by placing fish-body position, and small issues by placing fish-bone position (Abdel Aziz Allam et al., 2022).

DEMATEL Technique

Most studies in economics and social sciences often lack prior information or objective data as references, and sometimes, the data collected are inadequate and discrete. Under this situation, an analysis of multiple criteria decision making (MCDM) for the weight analysis is considered a better method for researching the exploratory explanation (Hwang, Hsu, Kung, & Su, 2020). Also an influential network relationship map (INRM) is obtained by using DEMATEL technique to assist in identifying the critical factors (Lo et al., 2020).

The DEMATEL technique was submitted by the Battelle Memorial Association of the Geneva Research Center, which was used to analyze the correlations among several criteria of complex assessment systems (Lo, Shiue, Liou, & Tzeng, 2020). DEMATEL technique is widely used for solving MCDM problems because it is based on graphic theory, which facilitates analysis and solves problem by providing a method for visualization. The structural schematic diagram is presented as a directed line graph representing the interdependent relationships between the influential effects among the criteria. The obtained cause-effect diagram can help decision makers better understand which factors are critical for helping them solve complicated problems (Lo, Liou, et al., 2020).

Therefore, the six root Ms (materials, machine/equipment, manpower/people, management, method/process, and mother nature/environment) are important classified factors for solving problems, which do not act independently but interact and interdepend to determine the overall logistic performance (Chopra & Meindl, 2016). Therefore, the paper applies the DEMATEL technique to the analysis of the relationships among various critical factors (Lu, Hsu, Liou, & Lo, 2018). The methodological steps of DEMATEL (Lo, Shiue, et al., 2020) are described in Appendix 1, and the calculation steps of the DEMATEL are described in detailed as shown in Appendix 2.

Results

A case study on YMT (Yamaha Motor Taiwan Co., Ltd.) overseas imported components was initiated by Yan-zhang Lin who is responsible for efficiently managing warehouse operation to YMT three factories. There were five professionals involved in this improvement plans, who included Yan-zhang Lin, Pinxian Li, Zheng-xun Cai, Hsin-Yao Hsu, and Po-Heng Tsou. The objective was to improve the process efficiency of warehouse operation for supplying overseas imported components. Their work experiences of the involved professionals are all over 10 years. Right now, there are four involved professionals work in relative logistics or warehouse except Pinxian Li. YMT is a joint venture between Taiwan and Japan and is the Top 3 locomotive manufacturers in Taiwan. YMT has three factories, including Zhongli Factory (engine processing), Hsinchu Factory (assembly production on engine and car-body), and Guoling Factory (component production center).

Warehouse Operation of the Overseas Imported Components

The purchased inventory of the overseas imported components is usually to match the container size, shipping time, which is filled in the same big box as much as possible for cutting down the cost of the procurement and shipping. Therefore, the imported components need to be disassembled, picked, and classified because the large box (pallet type) usually has a single item in a large box, and a large box mixed with a small box (carton type and box type) with multiple items.

The warehouse operations are that imported components are first picked up and sent to the Guoling Factory for unpacking, removal, and classifying after the goods arrive at the Taiwan port. And then, they are sent to Zhongli Factory for storage according to different sizes of components. After that, according to production plan demands of component quantity, the personnel of Hsinchu Factory contact the Zhongli Factory staff to find out the required components and send them to the Hsinchu Factory warehouse which receives materials and places them on racks for preparing production/assembly of the locomotive.

Lead time with overseas imported items during production, it is necessary to confirm the storage location of the large box where are the located large-and-small items in advance. And the items are unpacked, sorted, loaded into the small containers, and sent to the production line. After that, some unused components are usually sent back to the warehouse of Zhongli Factory for storage again.

An Analysis of Fishbone Diagram

A brainstorming session first started at the beginning of the March. A total of eight times sessions were held from the beginning of March to the end of April every Monday about one hour each time. An analysis of Fishbone Diagram was used to classify results of potential problems in overseas imported components, whose summary description is shown in Figure 1. The materials of overseas imported components more than 2,000 items have been used for producing motorcycles/locomotives in Taiwan. In order to reduce the cost of shipping by sea, it is necessary to fill the entire containers. Therefore, the large and small imported components are often mixed in the package process in Japan. A type of the whole container is directly shipped by sea to Taiwan's factory.

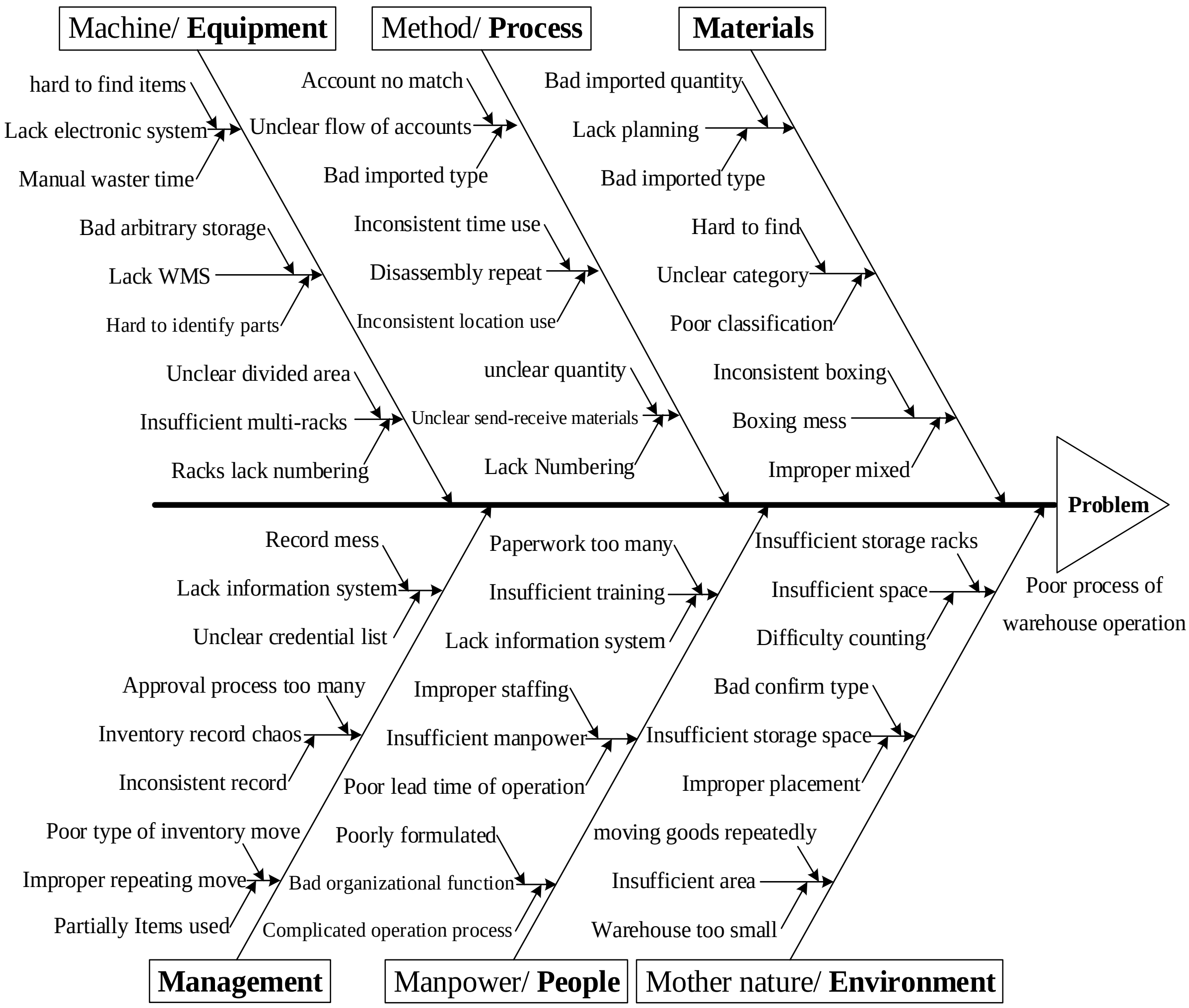

Figure 1. Results of the potential problems in overseas imported components.

Also, it seems difficult to make a good method of label and classification after packaging because there are too many mixed items. As a result, it is impossible to directly make the overseas imported components enter the warehouse operation for store in Taiwan. It is partially conducted a rough disassembly, classification, assembly, and package before being transported to rack for storage.

First, due to the limitation of insufficient space, the warehouse of the Hsinchu Factory cannot store all the components. More than 70% of overseas imported components are used in the assembly process of the Hsinchu Factory, but most of them are still transported to warehouse of the Zhongli Factory for storage. In addition, due to the rough and improper classification, package, and storage in the Zhongli Factory, the big box (pallet type) of the overseas imported components usually needs to be moved to the Hsinchu Factory for disassembling, and then transported to the production line.

However, some unused components are usually moved back to the Zhongli Factory for storage. The insufficient storage place and improper warehouse operation therefore cause many problems, such as increasing transportation costs between the Zhongli to Hsinchu Factory, actual inventory quantity not matching with the accounts, wasting time to look for the unclear inventory, etc. Furthermore, based on the lack electronic numbering and information system, it causes poor utilization of resources and operational efficiency. It seems necessary to re-merge and reorganize to improve warehouse operation process, especially to simplify relative repetitive process.

An Analysis of MEMATEL Technique

The objective of the data analysis from the DEMATEL is to reveal the interrelationships among six critical factors of warehouse operation and to find the importance level among ones. Four interviewees were asked to provide their answers to the questions by the following scores which used 0, 1, 2, 3, and 4. The calculation steps of DEMATEL are presented in Section 3 and Appendix 1. First, the combined (average) Matrix $A = [Aij]n \times n$ was calculated. And then, we could obtain the Matrix T for all relationships by calculating the normalized primary direct matrix which is as shown in Table 1. After calculating this matrix, we obtained *Ri*, *Ci*, *(Ri + Ci)*, and *(Ri - Ci)* from each Matrix T as shown in Table 2.

Table 1

Total-Influence Matrix T of Six Critical Factors of Warehouse Operation

	S1	S2	S3	S4	S5	S6	*Ri*
Environment	0.377	0.390	0.344	0.596	0.460	0.667	2.834
Equipment	0.447	0.240	0.318	0.535	0.423	0.580	2.542
Materials	0.496	0.369	0.272	0.634	0.468	0.665	2.904
Management	0.504	0.373	0.397	0.451	0.465	0.597	2.787
People	0.493	0.346	0.359	0.640	0.343	0.607	2.788
Process	0.533	0.334	0.331	0.640	0.493	0.459	2.791
Ci	2.851	2.052	2.021	3.496	2.652	3.574	

Table2

Results of DEMATEL Analysis for Six Critical Factors of Warehouse Operation

	Ri	*Ci*	*Ri + Ci*	*Ri - Ci*	*Wi*	Rank
Environment	2.834	2.851	5.685	-0.017	0.171	3
Equipment	2.542	2.052	4.593	0.490	0.138	6
Materials	2.904	2.021	4.925	0.883	0.148	5
Management	2.787	3.496	6.283	-0.709	0.189	2
People	2.788	2.652	5.441	0.136	0.163	4
Process	2.791	3.574	6.365	-0.784	0.191	1
			33.291			

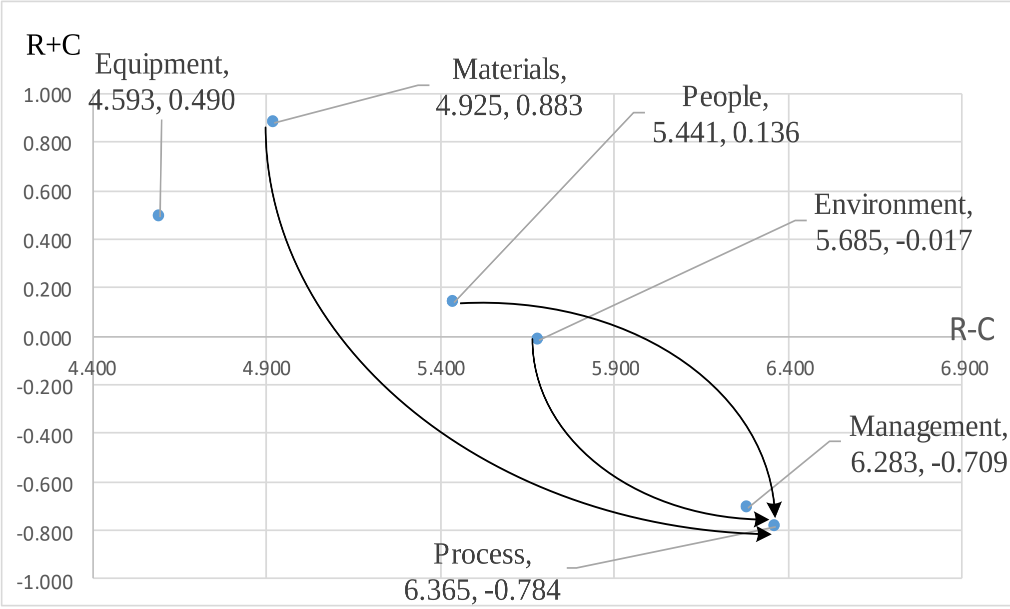

Figure 2. INRM of six critical factors of warehouse operation.

The DEMATEL is applied to achieve the total-relation matrix, and then to obtain the inner dependence matrix and impact relationship map, which can help decision makers for acquiring more strong decisions. In this step obtaining the inner dependence matrix, the sum of each column in total-relation $n \times n$ matrix is equal to one by the normalization method and then the inner dependence matrix can be acquired. "*Ri*" demonstrates the total effects including both direct and indirect. Similarity, "*Ci*" represents total effects, direct and indirect. As a result, the sum (*Ri* + *Ci*) that is called "Prominence" proves the degree of importance role. Also, the sum (*Ri* - *Ci*) that is called "Relation" shows the net effect. When (*Ri* - *Ci*) is positive, criterion will be to the cause group and when (*Ri* - *Ci*) is negative, criterion is a net receiver as shown in Table 2 and Figure 2.

The correlations of differences can be visualized using INRM (influential network relationship map) of six critical factors of warehouse operation. The results of Table 2 can be depicted in a model which reveals the relationships among the main factors according to the *T* values as shown in Figure 2. It (*Ri* + *Ci*) can be seen that the important rates of six critical factors on "environment", "equipment", "materials", "management", "people", and "process" are respectively, *T* = 5.685, *T* = 4.593, *T* = 4.925, *T* = 6.283, *T* = 5.441, and *T* = 6.365. Therefore, the importance is shown that "process > management > environment > people > materials > equipment".

That means if we select the crucial factor of "process" and improve the process of warehouse operation, we will be able to gain a better performance in the entire warehouse operation because it is the most important crucial factor. In addition, the result of (*Ri* - *Ci*) in this figure shows that the influence rates of six critical factors on "environment", "equipment", "materials", "management", "people", and "process" are respectively, *T* = -0.017, *T* = 0.490, *T* = -0.883, *T* = -0.709, *T* = 0.136, and *T* = -0.784. Therefore, the crucial factors of "equipment", "materials", and "people" will be bigger impact on "process", "management", and "environment".

Besides, the influential relationship is based on a threshold figure larger than 0.6 which is calculated from the average of the values in *T* matrix as shown in Table 1. When the figure is larger than 0.6, the critical factors of "environment", "materials", and "people" affect "process" remarkably. That means three critical factors should be taken into consideration when the business enterprise wants to improve “process” performance for enhancing the entire warehouse operation.

To sum up, based on the analysis of Fishbone Diagram, the results of the potential problems in overseas imported components show that many issues need to be improved. However, because a company has some strengths and weaknesses, limited resource and time, it is impossible to improve all the problems at the same time. In addition, based on the analysis of MEMATEL technique, the crucial factors of “environment”, “materials”, and “people” affect “process” remarkably. Therefore, the “process” of crucial factor is first selected for improving warehouse operation. Besides, that the crucial factor “materials” of overseas imported components more than 2,000 items are used in Taiwan might be able to have a better plan for improving imported type in the next phase. As for the crucial factors of “environment” and “people”, some shortcomings of them can be partly taken into consideration for enhancing the “process” performances of warehouse operations.

Results of the Improved Process of Warehouse Operation

The results of the improved process of warehouse operation are shown in Figure 3. The main process problem is that more than 2,000 oversea imported components were mixed packaging and shipping by sea in Japan. When all of them through customs export arrive at Guoling Factory, that the components will be used for the different location of Zhongli Factory and Hsinchu Factory is usually rough unpacked, re-sorted, and re-packing. It results, frequent disassembly of items/components from the big boxes (pallet type) because all of them are packed in the same box and are used in different places or in different time.

The process problems can be seen that disassembly of items/components from the big boxes (pallet type) are multiple times; flows of goods are manufacturing process required or replacement of consumables; and accounts are only manual records which are usually errors from the wrong record or forgot to record, etc. As a results, no match the number of records keeps happening because of using only manual records, no computerization is in the inconsistent location use and inconsistent time use.

In addition, the process problems also can be seen that frequently unpacking items/components should have been improved first. It should use information system to record the storage location and quality, to ship only required parts to the workplace, and to reduce time waste and cost losses of the repeated transportation and warehouse operation between Hsinchu Factory and Zhongli Factory. Therefore, the situations of the inconsistency of the inventory quantity, unclear send-receive materials, lack numbering, unclear flow of accounts, bad imported type, and account no match, will be getting better and better.

Furthermore, the shortcoming results of the crucial factors of “environment” and “people” can be partly taken into consideration for enhancing the “process” performances of warehouse operations. Due to the limitation of area and function, the Hsinchu Factory cannot accommodate all overseas imported items/components. Therefore, it is only able to be opened and placed in Guoling Factory and Zhongli Factory.

When this assessment project is made at the crucial factor of “environment”, the shortcoming results of insufficient area and storage space, warehouse too small, improper placement, insufficient storage racks, etc., cause the storage parts placed arbitrarily and the items/components are mixed and difficult to count. YMT has decided that the Zhongli Factory will be relocated to the Hsinchu Factory by the end of 2022 for reducing transportation/distribution cost between two factories. Due to the land lease of the Zhongli Factory, it will continue to be used until the end of 2023.

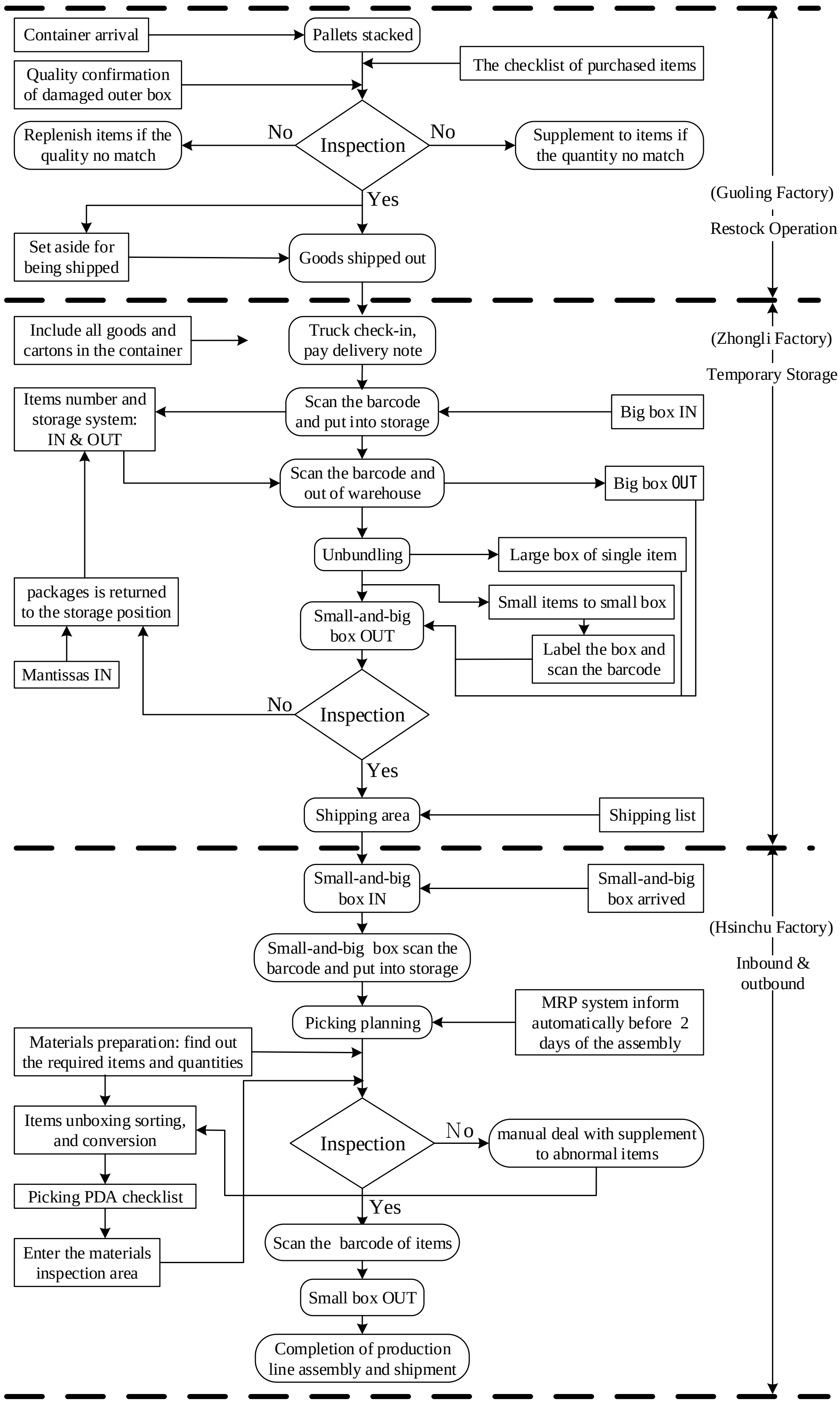

Figure 3. Results of the improved process of warehouse operation.

Right now, when the relative warehouse operation returns to the Zhongli Factory, to design large and small box storage locations must be made first for correcting classification and storage, including MRP (Material Requirement Planning) for improving process performance of warehouse operation of storage location and inventory-tracking.

As for the crucial factor of "people", the shortcoming results include bad organizational function and operation process, poor lead time of operation, paperwork too many, and improper staffing only one person, etc. MRP will be introduced in the future, the warehouse operation process will be simplified, and the people will be properly trained to implement MRP system. It is believed that the mentioned problems will be gradually improved for enhancing the entire warehouse operation process performance in the future.

Discussion & Conclusion

A case study on YMT (Yamaha Motor Taiwan Co., Ltd.) overseas imported components is initiated by Yan-zhang Lin who is responsible for efficiently managing warehouse operation to YMT three factories. This paper is aimed at describing the improved course of events which include identifying encountered problems in practical works, classifying relative problems of cause-and-effect relationship by Fishbone Diagram, understanding the importance and influential relationships through DEMATEL method, and improving the warehouse operation of overseas imported components. The results of DEMATEL is summary description as shown in Table 1, Table 2, and Figure 2.

The results showed that if we select the crucial factor of "process" and improve the process of warehouse operation, we will be able to gain a better performance in the entire warehouse operation because it is the most important crucial factor. Also, the crucial factors of "environment" and "people", some shortcomings of them can be partly taken into consideration for enhancing the "process" performances of warehouse operations because they will be able to remarkably influence on "process" factor, and further impact on overall process performance of warehouse operation.

The main contribution is a submission of the six critical factors for improving the process performance of warehouse operation by using Fishbone Diagram analysis, as well as including an importance and influential relationships among six critical factors through DEMATEL method. And then, an improved process of warehouse operation will be able to be utilized for improving on YMT overseas imported components of warehouse operation process in practice as shown in Figure 3. The research limitation is that due to time limitation, this paper has not taken all problems into consideration. Hence, it is necessary to focus on the other critical factors in future studies.

References

Abdel Aziz Allam, S. A., Sabry, A. M., Habashy, M. H., Alameldeen, M. I., Nour, S. N., Elsamahy, N. E., ... Nageeb, A. M. (2022). Utilization of quality tools to prevent unnecessary prescriptions of Antibiotics in hospitals. *Medicine Updates, 9*(9), 26-37.

Chopra, S., & Meindl, P. (2016). *Supply chain management: Strategy, planning and operation* (4th ed.). Essex: Person Education.

Dharmapriya, U. S. S., & Kulatunga, A. K. (2011, January). New strategy for warehouse optimization-lean warehousing. In *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management* (pp. 513-519). Kuala Lumpur, Malaysia.

Düzgün, M. (2021). Identification of the effective criteria for the selection of a warehouse site in the healthcare logistics industry and their placement in order of importance by the Dematel method. *Beykoz Akademi Dergisi, 8*(2), 363-375.

Frusman, P., & Wibisono, D. (2014). Design and implementation of warehouse management improvement strategy using barcode system approach at PT Latinusa Tbk. *4th International Conference on Technology and Operations Management (ICTOM04)*. 18-19 August 2014, Kuala Lumpur, Malaysia.

Gunasekaran, A., & Ngai, E. W. (2003). The successful management of a small logistics company. *International Journal of Physical Distribution & Logistics Management, 33*(9), 825-842.

Hwang, M. H., Hsu, H. Y., Kung, C. Y., & Su, T. S. (2020). Information strategic framework for leagile supply chain-grey relational analysis approach. *International Journal of Uncertainty and Innovation Research, 2*(3), 295-318.

Kembro, J. H., Norrman, A., & Eriksson, E. (2018). Adapting warehouse operations and design to omni-channel logistics: A literature review and research agenda. *International Journal of Physical Distribution & Logistics Management, 48*(9), 890-912.

Liliana, L. (2016, November). A new model of Ishikawa diagram for quality assessment. In *IOP Conference Series: Materials Science and Engineering* (Vol. 161, No. 1, p. 012099). Bristol: IOP Publishing.

Lo, H. W., & Liou, J. J. (2018). A novel multiple-criteria decision-making-based FMEA model for risk assessment. *Applied Soft Computing, 73,* 684-696.

Lo, H. W., Liou, J. J., Huang, C. N., Chuang, Y. C., & Tzeng, G. H. (2020). A new soft computing approach for analyzing the influential relationships of critical infrastructures. *International Journal of Critical Infrastructure Protection, 28,* 100336.

Lo, H. W., Shiue, W., Liou, J. J., & Tzeng, G. H. (2020). A hybrid MCDM-based FMEA model for identification of critical failure modes in manufacturing. *Soft Computing, 24*(20), 15733-15745.

Lu, M. T., Hsu, C. C., Liou, J. J., & Lo, H. W. (2018). A hybrid MCDM and sustainability-balanced scorecard model to establish sustainable performance evaluation for international airports. *Journal of Air Transport Management, 71*, 9-19.

Luca, L. (2015). The study of applying a quality management tool for solving non-conformities in an automotive. In *Applied mechanics and materials* (Vol. 809, pp. 1257-1262). Bach: Trans Tech Publications Ltd.

Managertoday. (2010) Retrieved from https://www.managertoday.com.tw/articles/view/2280?

Mishra, R. (2020). An analysis of factors influencing omnichannel retailing adoption using ISM-DEMATEL approach: An Indian perspective. *International Journal of Retail & Distribution Management, 49*(4), 550-576.

Phunlarp, U., & Phudetch, P. (2019, November). Solutions to solve problems and increasing efficiency warehouse a case study of XYZ company limited. In *International Academic Multidisciplinary Research Conference in Japan 2019* (pp. 257-263). Tokyo-Hokkaido, Japan.

Prasetyawan, Y., & Ibrahim, N. G. (2020, April). Warehouse improvement evaluation using lean warehousing approach and linear programming. In *IOP Conference Series: Materials Science and Engineering* (Vol. 847, No. 1, p. 012033). Bristol: IOP Publishing.

Russo, F., & Comi, A. (2010). A classification of city logistics measures and connected impacts. *Procedia-Social and Behavioral Sciences, 2*(3), 6355-6365.

Shashidharan, M. (2021). Importance of an efficient warehouse management system. *Turkish Journal of Computer and Mathematics Education (TURCOMAT), 12*(5), 1185-1188.

SOLE. (2020). Logistics management. *The International Society of Logistics Taiwan (Taipei) Chapter, 6*(3), 226-228. Retrieved from https://sole.org.tw/

Sooksai, T. (2019, November). The study of work processes within the warehouse: A case study XYZ company limited. In *International Academic Multidisciplinary Research Conference in Japan 2019* (pp. 397-404). Tokyo-Hokkaido, Japan.

Van den Berg, J. P., & Zijm, W. H. (1999). Models for warehouse management: Classification and examples. *International Journal of Production Economics, 59*(1-3), 519-528.

Yazdani, A. A., & Tavakkoli-Moghaddam, R. (2012). Integration of the fish bone diagram, brainstorming, and AHP method for problem solving and decision making—A case study. *The International Journal of Advanced Manufacturing Technology, 63*(5), 651-657.

Appendix 1

The methodological steps of DEMATEL are described as follows (Lo, Shiue, et al., 2020):

Step 1. Calculate the direct relationship Matrix A

$$A = [a_{ij}] = \begin{bmatrix} 0 & a_{12} & \cdots\cdots & a_{1n} \\ a_{21} & 0 & \cdots\cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots\cdots & 0 \end{bmatrix}, i, j = 1,2, \ldots, n \tag{1}$$

Step 2. Calculate the normalized direct-relation Matrix X

$$X = k \times A \tag{2}$$

$$\text{Where } k = \min\left[\frac{1}{max_i \sum_{j=1}^{n} a_{ij}}, \frac{1}{max_i \sum_{i=1}^{n} a_{ij}}\right], i, j = 1,2, \ldots, n \tag{3}$$

Step 3. Derive the total-relation Matrix T

$$\mathrm{T} = [t_{ij}]_{n \times n}, \ i, j = 1,2, \ldots, \mathrm{n}$$

$$T^h = X + X^2 + X^3 + \cdots + X^h = X(I - X)^{-1}, when \ \lim_{p \to \infty} x^p = [0]_{n \times n} \tag{4}$$

where $(I - X)(I - X)^{-1} = I$; I represents the identity matrix.

Step 4. Determine the row and column sums of Matrix T

$$R = (r_1, r_2, \ldots r_n)^T = (r_i)_{n \times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n \times 1}, j = 1, 2, \ldots, \mathrm{n} \tag{5}$$

$$\mathrm{C} = (c_1, c_2, \ldots c_n) = (c_i)_{1 \times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1 \times n}, i = 1, 2, \ldots, \mathrm{n} \tag{6}$$

Step 5. Obtain the weights of the risk factors

$$w_i = (r_i + c_i) \Big/ \sum_{i=1}^{n} (r_i + c_i) \tag{7}$$

Appendix 2 The DEMATEL calculation steps by Excel

Step1	S1	S2	S3	S4	S5	S6	=SUM
S1	0	2	1.25	2.25	1.75	3.5	10.75
S2	1.75	0	1.25	2	1.75	2.75	9.5
S3	1.75	1.5	0	2.75	1.75	3.25	11
S4	2.25	1.75	2.25	0	2	2.25	10.5
S5	2	1.25	1.5	3.25	0	2.5	10.5
S6	2.75	1	1	3.25	2.5	0	10.5
=SUM	10.5	7.5	7.25	13.5	9.75	14.25	14.25

Step 2	S1	S2	S3	S4	S5	S6
S1	0.000	0.140	0.088	0.158	0.123	0.246
S2	0.123	0.000	0.088	0.140	0.123	0.193
S3	0.123	0.105	0.000	0.193	0.123	0.228
S4	0.158	0.123	0.158	0.000	0.140	0.158
S5	0.140	0.088	0.105	0.228	0.000	0.175
S6	0.193	0.070	0.070	0.228	0.175	0.000

Step 3-1	S1	S2	S3	S4	S5	S6
S1	1	0	0	0	0	0
S2	0	1	0	0	0	0
S3	0	0	1	0	0	0
S4	0	0	0	1	0	0
S5	0	0	0	0	1	0
S6	0	0	0	0	0	1

Step 3-2	S1	S2	S3	S4	S5	S6
S1	1.000	-0.140	-0.088	-0.158	-0.123	-0.246
S2	-0.123	1.000	-0.088	-0.140	-0.123	-0.193
S3	-0.123	-0.105	1.000	-0.193	-0.123	-0.228
S4	-0.158	-0.123	-0.158	1.000	-0.140	-0.158
S5	-0.140	-0.088	-0.105	-0.228	1.000	-0.175
S6	-0.193	-0.070	-0.070	-0.228	-0.175	1.000

Step3-3	S1	S2	S3	S4	S5	S6
S1	1.377	0.390	0.344	0.596	0.460	0.667
S2	0.447	1.240	0.318	0.535	0.423	0.580
S3	0.496	0.369	1.272	0.634	0.468	0.665
S4	0.504	0.373	0.397	1.451	0.465	0.597
S5	0.493	0.346	0.359	0.640	1.343	0.607
S6	0.533	0.334	0.331	0.640	0.493	1.459

STEP4	S1	S2	S3	S4	S5	S6	
S1	0.377	0.390	0.344	0.596	0.460	0.667	2.834
S2	0.447	0.240	0.318	0.535	0.423	0.580	2.542
S3	0.496	0.369	0.272	0.634	0.468	0.665	2.904
S4	0.504	0.373	0.397	0.451	0.465	0.597	2.787
S5	0.493	0.346	0.359	0.640	0.343	0.607	2.788
S6	0.533	0.334	0.331	0.640	0.493	0.459	2.791
	2.851	2.052	2.021	3.496	2.652	3.574	

Step 5	*R*	*C*	*R+C*	*R-C*	*Wi*	RANK
S1	2.834	2.851	5.685	-0.017	0.171	3
S2	2.542	2.052	4.593	0.490	0.138	6
S3	2.904	2.021	4.925	0.883	0.148	5
S4	2.787	3.496	6.283	-0.709	0.189	2
S5	2.788	2.652	5.441	0.136	0.163	4
S6	2.791	3.574	6.365	-0.784	0.191	1
			33.291			