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DEVELOPMENT OF MOBILE VOICE PICKING AND CARGO TRACING SYSTEMS WITH INTERNET OF THINGS IN THIRD-PARTY LOGISTICS WAREHOUSE OPERATIONS

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ABSTRACT

Market competition, customer expectation and increasing warehouse operations cost have motivated third-party logistics practitioners in the continuous improvement on warehouse operations. Cargo tracing in order picking process is time-consuming for warehouse operators when handling enormous flow of goods through the warehouse each day. Internet of Things (IoT) with mobile cargo tracing apps and database management systems are developed in this research to reduce cargo tracing time in the order picking process of a third-party logistics firm. An operations review was carried out with identified opportunities for improvement, including inaccurate inventory record in warehouse management system, excessive tracing time with stored products, and product misdelivery. The facility layout was improved by modifying the designated locations of various types of products. The relationships among pick and pack processing time, cargo tracing time, delivery accuracy, inventory turnover, and inventory count operation time in the warehouse are evaluated. The correlation of the factors affecting the overall cycle time is analysed. A mobile app is developed with the use of MIT App Inventor and Access management database to facilitate cargo tracking anytime, anywhere. The information flow framework from warehouse database system to cloud computing document sharing, and further to the mobile app device is developed. The improved performance of cargo tracing in the order processing cycle of warehouse operators is evaluated. The developed mobile voice picking and tracking systems have brought significant benefits to the third-party logistics firm, including eliminating unnecessary cargo tracing time in order picking process and reducing warehouse operators overtime cost. A mobile tracking device is planned to enhance the picking time and cycle count of warehouse operators with voice picking system in the developed mobile apps.

Keywords: Warehouse, Order picking process, Cargo tracing, Mobile app, Third-party logistics, Internet of things.

Contribution/ Originality

This paper contributes the cargo tracing and voice picking in third-party logistics warehouse through the development of Internet of Things (IoT) with warehouse management system, cloud-based database and mobile apps, after conducting the operations review, facility layout re-design and statistical analysis in the warehouse.

1. INTRODUCTION

Maintaining an efficient flow of goods in the warehouse is of high importance to third-party logistics firms, especially in the inbound shipment delivery to the distribution hub from which products are further transported to retail chain stores. The import operations and distribution are often operated in a pull-mode. This mode demands

the utilization of third-party logistics in providing a highly flexible and efficient short-term small-lot replenishment service. Unnecessary time and processes should be eliminated to cater for the dynamic demand and to be competitive in the market. Swift cargo tracking and tracking mechanism in order picking process, efficient warehouse management system, effective information flow to warehouse operators anytime anywhere, well-designed facility layout, utilization of suitable technologies and continuous improvement in operation process are needed in logistics firms. This paper analyses recent literature in warehouse order picking operations, warehouse management technologies and the latest development of interconnection of warehouse systems integrated through internet communication technology. An operations review was conducted in the warehouse operations to evaluate the current processes and recommend areas for improvement. Enhancement of current order picking process, warehouse layout, and warehouse management systems are carried out. Integration of the current system enhancement and the development of a voice picking and tracking mobile apps with warehouse management systems through internet communication technology are discussed. The degree of improvement in the order picking process with the reduction of cargo tracing time was measured and presented, followed by an analysis of implementation results and suggestions for future development of the project.

2. WAREHOUSE OPERATIONS AND TECHNOLOGY

Order picking in warehouse has long been an important area for operations improvement. Verschure (2014) valuated the order pick process in a warehouse and compared the effectiveness of picking process with respect to the information availability and batch size. Ene and Öztürk (2012) revealed the key factors, including time interval and storage location proximity, impacting the order picking operations in the warehouse. The study indicated that over half of the warehouse operating costs were incurred in order picking process. Chan and Chan (2011) conducted a simulation study on the storage assignment problems of manual-pick and multi-level rack warehouse operations. The study proposed the adoption of ABC class-based storage policy and found combined routing polices had improved the order picking performance. Hsieh and Tsai (2006) evaluated the impact of several factors on the performance of order picking system, including warehouse layout, cross aisle design, storage assignment policy, picking route and order combination. Malmborg *et al.* (1986) derived a heuristics model for warehouse operations for better inventory management and lower order picking cost. Other literature on order picking process includes Hagspihl (2012); Henn (2012); Roodbergen (2012) and De Vries *et al.* (2015).

The development of latest technologies on warehouse operations has come to the attention of both industrial practitioners and research investigators. The move from adopting a warehouse management system and bar code system to Radio Frequency Identification (RFID) and Voice Picking Systems, and further to Global Positioning System (GPS) and Internet of Things (IoT) can be observed throughout recent years. There is an increasing number of literature investigating the use of RFID in logistics, supply chain and warehouse operations (Angeles, 2005; Chow *et al.*, 2006; Gonzalez *et al.*, 2006; Yan *et al.*, 2008; Ballestín *et al.*, 2013; Chen *et al.*, 2013; Royoa *et al.*, 2013). Mayer (2015) analysed various scenarios of RFID applications in a third-party logistics warehouse, ranging from full pallet or item level RFID-tagging. The study indicated the use of RFID had shown positive financial savings for well-selected pallet handling operations along the supply chain. Zhu *et al.* (2015) applied RFID technology in warehouse operations and developed a Management Information System (MIS) that integrated with the data acquisition system based on the RFID and Office Automation (OA) system to reduce manual work intensity and improve work efficiency. The advancement in cloud computing and mobile apps development, as well as the demand of real-time information flow has put warehouse management into a more integrated framework with various building blocks of technologies linked together through the internet to facilitate practitioners performing warehouse management anytime anywhere. This framework is referred to as Internet of Things (IoT). It is the

interconnection of physical objects equipped with sensors, actuators and communication technology through the internet (Dijkman *et al.*, 2015). Shen *et al.* (2013) proposed a radar equipment warehouse management system based on IoT technology. The authors integrated the system with RFID and sensors to improve the efficiency of warehouse operations. Hao and Zhao (2015) analysed the application of RFID technology in logistics warehouse operations and proposed the development of a warehouse management system based IoT RFID technology. Reaidy *et al.* (2015) proposed an IoT infrastructure for collaborative warehouse order fulfillment based on RFID, ambient intelligence and multi-agent system. The development of IoT in warehouse management will continue to be one of the major focuses in logistics and supply chain business (Yang and Ye, 2014; Yang *et al.*, 2014).

Mobile device applications have been adopted in warehouse operations in recent years. Gaspar *et al.* (2011) proposed a client warehouse application to allow workers to use personal digital assistant (PDA) with internet connection to synchronize essential data for daily warehouse operations. Partridge (2011) indicated the importance of mobile devices in assisting assets and shipment tracking, transaction execution, and partner collaboration. An example quoted is a Chicago-based third-party logistics launching an EchoTrak Mobile supporting users in tracking and tracing shipments, getting rate quotes and receiving shipment notifications. Gelogo and Kim (2014) discussed a mobile Enterprise resource planning (ERP) system with the use of cloud computing to improve the performance and productivity of a firm through better tracking on the business resources and raw materials.

3. OPERATIONS REVIEW

An operations review was carried out in a third-party logistics firm. The firm offers logistics support for various retail chain stores and operates a subcontracted warehouse of a multinational corporation. The performance, operations and supporting systems of the subcontracted warehouse are analyzed. A process mapping was carried out, starting from receiving customer order; storing incoming goods; performing value-added services; arranging pick and pack operations and assigning trucks for product delivery; to delivering the product to customers.

Through process mapping and gap analysis in warehouse operations, several opportunities for improvement were identified. The storage locations of incoming products were not systematically assigned by warehouse operators. They were stored temporarily in an empty space of a warehouse in a random manner instead of following pre-defined basic location labels. Inbound and outbound products were mixed without designated storage location and product identification. Lack of zoning and location identification was observed which made tracking and tracing the stored goods difficult. Various types of stocks were stored in the same location. Unnecessary time of warehouse operators was wasted in locating the stored goods. The operators relied on a warehouse manager to advise them of the locations. When handling huge volume of cargoes, the warehouse operations became seriously impeded. The warehouse management system was only able to record the quantity of incoming goods, while the computer facility was installed in an office located at the corner of the warehouse.

To evaluate the performance of the operation process, a time study has been conducted. The time required for 119 invoice order picking tasks carried out by a total of six warehouse operators are measured. The average time for order picking process is 9.12 minutes while the average time used in order picking process is 180.85 minutes, i.e. 3.01 hours. There is a need to explore ways to facilitate the operators to locate the stored products in a more efficient way in order to reduce the order picking time and eliminate unnecessary time in searching for the stored goods.

Considering the current warehouse management system, operations processes, and available resources, an enhanced process flow is recommended. The identification of products to undergo value-added process is advanced to facilitate the assignment of product storage location. An improved warehouse layout with zoning and location identification coding system is suggested. The current warehouse management system is advised to add the

quantity and location of products with the use of Microsoft Access. The order picking process is also modified in the new process with the introduction of Microsoft Access, cloud-based database storage, and mobile apps to facilitate the searching of stock location and enhance the current order picking process.

4. IOT IMPLEMENTATION IN ORDER PICKING PROCESS

To reduce the extensive unnecessary time consumption for warehouse operators in searching for a product, several measures are implemented. First, the warehouse layout has been enhanced with zoning and multiple rack partition identification. Several zones, including Zone A, B, C, D, M, and X, are developed. Each rack partition is labelled and identified. All warehouse operators are trained to store incoming goods following the zoning and location identification systems. Second, identification and location labels are coded in the warehouse management system and the inventory search capability is built into the Access of warehouse management system. The missing location data of each stock keeping unit (SKU) on three floors of the warehouse are input and verified. Third, an integrated cloud-based voice-activated order picking system is developed in the warehouse. The integrated system includes the Access database system added into the current warehouse management system, cloud-based storage fusion table and database, and mobile applications development. A mobile app is developed with the use of MIT App Inventor 2. The flow of the IoT development is shown in Figure 1. The Access database, fusion table, TinyDB database, and mobile apps are integrated to allow users to input a SKU number for searching its location. The result will be generated by voice to facilitate warehouse operators in processing the order picking operations.
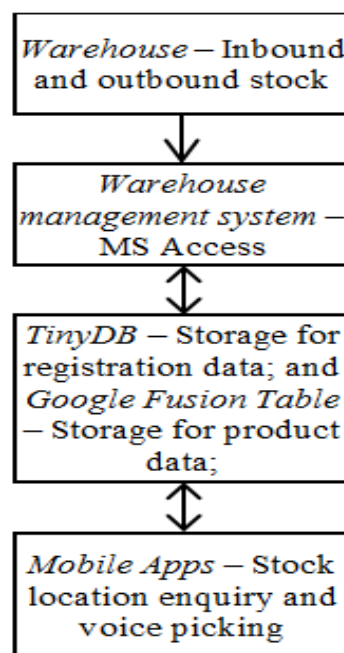
Figure-1. Implementation flow of integrated IoT system for warehouse tracking and order picking process

Trial tests are carried out after the development of the integrated system on stock location track and trace. Upon the login of Mobile Apps, a SKU, e.g. 100325HK, is input, and a data calling interface is displayed to notify users that the system is undergoing a searching process. After searching in the database, the location and quantity of the SKU are displayed, e.g. Location: 3B06W21 and quantity: 960 units, refer to Table 1. Similarly, inputting SKU 101076HK will show the location 5F07W20 and quantity, 1,260 units. A rollout implementation is conducted, including user training and manual compilation.

Table-1. Input and output of mobile apps enquiry on SKU location

Input	Displayed Location	Displayed Quantity
100325HK	3B06W21	960
101076HK	5F07W20	1,260
100186	Damage	1

5. PILOT ROLLOUT EVALUATION

After the improvement on warehouse layout, zoning and location identification in the first and second stages as described in Section 4 throughout the first three months of the project, the performance of order picking time is measured. The time of 124 invoice order picking tasks are recorded in the time study. The average time for the order picking process is 7.57 minutes while the average time used in the order picking process each day is 156.38 minutes per operator, i.e. 2.47 hours. The average order picking time and the average time used in order picking process each day is improved by 17%. An improvement in order picking process has been observed with time reduction in product search and a larger number of invoice order picking could be handled each day.

The order picking performance is further evaluated after the implementation of the mobile apps tracking device. The time of 123 invoice order picking tasks are recorded in the time study. The average time for order picking process is 7.52 minutes while the average time used in order picking each day is 154.36 minutes per operator, i.e. 2.43 hours. This shows a further improvement of an average order picking time of 0.6%. The overall performance on order picking process is improved by 17.5%. Unnecessary time in searching for the product has been eliminated. Positive responses from workers are received. With the support of the mobile tracking device, operators have found it easier to locate the stock.

Security access is often one of the considerations in the development of IoT in warehouse operations. The security settings were carefully evaluated during the mobile apps programming. Further to the evaluation of rollout with management, it was found that efficiencies, process simplifications and easy-to-use for warehouse operators are more important than an excessive security verification process. It could be considered in future development that the login security could be skipped as the data involved are mainly on the SKU codes and location identification. Further to the rollout implementation of the system, a manual has been compiled to facilitate the sustainability and continuity of warehouse operators in adopting the new technologies in their daily work. The installation of mobile apps and steps in using the track and trace functions are illustrated in the manual to ensure new comers are able to understand and make use of the developed system in order picking operations.

6. CONCLUSION

To cope with the high flexibility of customer demand, severe competition in market, and increasing warehouse operating cost, third-party logistics are seeking ways to perform their operations in a lean and efficient way. Continuous process improvement and adopting latest warehouse management technologies are crucial in their daily operations. This paper aims to improve the cargo tracking and tracing time in the order picking process. Critical factors and operations impacting the order picking process are reviewed. Improvements on facility layout, warehouse management systems and products identification system are conducted. A mobile apps integrating into the warehouse management system is developed to facilitate the warehouse operators in their order picking operations and reduce the long product location searching time. The improved performance after the implementation is measured and analysed. It is observed that the overall performance in the order picking process has been improved by 17.5%. This reduces unnecessary time wasted in searching for product location and lowers the costs incurred in the over-time work of warehouse operators. Additional features and functionalities in the

warehouse management system and the mobile apps are suggested in the future development of the third-party logistics firm.

REFERENCES

Angeles, R., 2005. RFID technologies: Supply-chain applications and implementation issues. Information Systems Management, 22(1): 51-65.

Ballestín, F., Á. Pérez, P. Lino, S. Quintanilla and V. Valls, 2013. Static and dynamic policies with RFID for the scheduling of retrieval and storage warehouse operations. Computers & Industrial Engineering, 66(4): 696-709.

Chan, F.T.S. and H.K. Chan, 2011. Improving the productivity of order picking of a manual-pick and multi-level rack distribution warehouse through the implementation of class-based storage. Expert Systems with Applications, 38(3): 2686-2700.

Chen, J.C., C.H. Cheng, P.B. Huang, K.J. Wang, C.J. Huang and T.C. Ting, 2013. Warehouse management with lean and RFID application: A case study. International Journal of Advanced Manufacturing Technology, 69(1-4): 531-542.

Chow, H.K., K.L. Choy, W.B. Lee and K.C. Lau, 2006. Design of a RFID case-based resource management system for warehouse operations. Expert Systems with Applications, 30(4): 561-576.

De Vries, J., R. De Koster and D. Stam, 2015. Aligning order picking methods, incentive systems, and regulatory focus to increase performance. No. ERS-2015-009-LIS.

Dijkman, R.M., B. Sprenkels, T. Peeters and A. Janssen, 2015. Business models for the internet of things. International Journal of Information Management, 35(6): 672-678.

Ene, S. and N. Öztürk, 2012. Storage location assignment and order picking optimization in the automotive industry. International Journal of Advanced Manufacturing Technology, 60(5-8): 787-797.

Gaspar, V., L. Madarasz, J. Paralic and K. Tenaiova, 2011. Design and implementation of a client warehouse application over an enterprise resource planning system for mobile devices. In 3rd IEEE International Symposium on Logistics and Industrial Informatics.

Gelogo, Y.E. and H.K. Kim, 2014. Mobile integrated enterprise resource planning system architecture. International Journal of Control & Automation, 7(3): 379-388.

Gonzalez, H., J. Han, X. Li and D. Klabjan, 2006. Warehousing and analyzing massive RFID data sets. In data engineering, 2006. ICDE'06. Proceedings of the 22nd International Conference on. IEEE. pp: 83-83.

Hagspihl, R., 2012. The number of pickers and SKU arrangement on a unidirectional picking line. Unpublished Bachelor's Dissertation, Stellenbosch University, Stellenbosch, South Africa.

Hao, H. and B. Zhao, 2015. Application of RFID technology in development of warehouse logistics management system by internet of things. In International Conference on Education, Management, Commerce and Society (EMCS-15). Atlantis Press.

Henn, S., 2012. Algorithms for on-line order batching in an order picking warehouse. Computers & Operations Research, 39(11): 2549-2563.

Hsieh, L.F. and L.H. Tsai, 2006. The optimum design of a warehouse system on order picking efficiency. International Journal of Advanced Manufacturing Technology, 28(5-6): 626-637.

Malmborg, C.J., S. Balachandran and D.M. Kyle, 1986. A model-based evaluation of a commonly used rule of thumb for warehouse layout. Applied Mathematical Modeling, 10(2): 133-138.

Mayer, A., 2015. Analysis of profitability by implementing RFID-technology in 3PL warehouse business. Journal of Applied Leadership and Management, 4(1): 48-62.

Partridge, A.R., 2011. Mobile communications: Managing supply chain on the go. Inbound Logistics. Available from http://www.inboundlogistics.com/cms/article/mobile-communications-managing-supply-chains-on-the-go/ [Accessed October 2011].

Reaidy, P.J., A. Gunasekaran and A. Spalanzani, 2015. Bottom-up approach based on internet of things for order fulfillment in a collaborative warehousing environment. International Journal of Production Economics, 159(1): 29-40.

Roodbergen, K.J., 2012. Storage assignment for order picking in multiple-block warehouses. In warehousing in the global supply chain. London: Springer. pp: 139-155.

Royoa, J., P. Lambána, J. Valenciaa, M. Oliverab and M. Monsrealb, 2013. Study to determinate the feasibility of RFID to facilitate traceability in a logistics operator. Procedia Engineering, 63: 829-834.

Shen, H.H., Q.H. Liu, Y.Y. Han, Y. Liu and Z. Tang, 2013. A radar equipment warehouse management system research based on the internet of things. In Applied Mechanics and Materials, 416(1): 975-979.

Verschure, A., 2014. Improving picking efficiency in a warehouse with multiple floors at docdata NV. Unpublished Master's Thesis, Eindhoven, Technische Universities Eindhoven, Netherlands.

Yan, B., Y. Chen and X. Meng, 2008. RFID technology applied in warehouse management system. In Computing, Communication, Control, and Management, 2008. CCCM'08. ISECS International Colloquium IEEE, 3: 363-367.

Yang, L. and M. Ye, 2014. The design and development of intelligent warehouse management system based on. NET and internet of things. In International Conference on Logistics Engineering, Management and Computer Science (LEMCS 2014). Atlantis Press.

Yang, S., R. Tao, W. Tan and W. Zhang, 2014. Gateway of internet of things for intelligent warehouse management system based on embedded web server. In Proceedings of International Conference on Computer Science and Information Technology. Springer India. pp: 213-220.

Zhu, S.Y., J.Y. Liu, L.H. Zhao and X.Y. Wang, 2015. Application of radio frequency Identification technology in information system for warehouse management. In multimedia, communication and computing application: Proceedings of the 2014 International Conference on Multimedia, Communication and Computing Application (MCCA 2014), Xiamen, China, October 16-17, 2014. CRC Press.