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Improving of an Automated Storage and Retrieval System in a Construction Material Retailer

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Abstract: The growth in real estate sector and the raise of minimum wage in Thailand have transformed construction material business and posted labor challenge. To address the challenge, many retailers have adopted automated material handling equipment, called miniload Automated Storage and Retrieval System (AS/RS) a set of industrial automated cranes operating within high-density storage racks and narrow aisles for totes. Equipped with guided conveyors for transfer totes an AS/RS eliminates traveling of pickers by automatically transporting selected products inside totes to workstations. As a result, the efficiency of system depends on operating policy as well as the business nature of a retailer. In this study such policy of a construction material retailer that has recently implemented a miniload AS/RS was analyzed. The primary analysis showed that the inefficient utilization of totes causing by storage and retrieval policies. As a result, a simulation is selected to experiment with the effects of various configuration settings such as order batching, storage assignment and retrieval sequencing. By comparing average travel time and throughput the results of experiment suggest the most suitable settings of the system.

Key words: Simulation, miniload AS/RS, construction material retailer, transporting selected products, storage and retrieval policies, effects

INTRODUCTION

During the last decades, the influx population from countrysides to Bangkok and its vicinity has led to high population density, development of real estate along the transportation infrastructure and unprecedented growth in all related businesses. The growth has transformed construction material business from a small traditional store into a large multi-location modernized retailer. Despite such transformation, construction material business in Thailand is unable to fully reap benefits of urbanization as the nature of business and the varieties of products require significant handling costs. Furthermore, the business is challenged by the shortage of labors and the rise in minimum wage.

A typical worker in such a warehouse is required to distinguish between many different products with a similar physical appearance. Hence, a well-trained worker who has good understanding of products and many years of experiences commands higher wage.

To address this labor challenge and improve pro-ductivity in a warehouse, many retailers have adopted automated material handling equipment called miniload Automated Storage and Retrieval System (AS/RS) a set of industrial automated cranes operating within high-density storage racks and narrow aisles designed for totes storage as shown in Fig. 1.

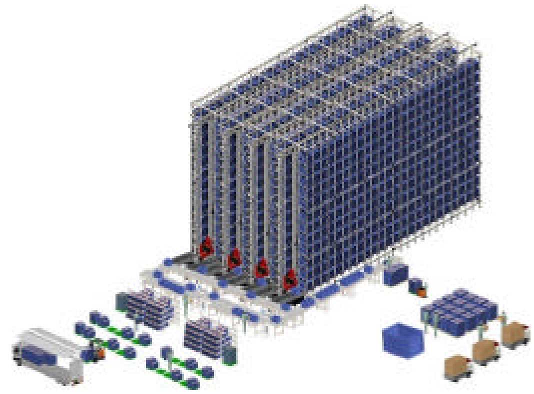

Fig. 1: A four-Aisle miniload AS/RS with workstations

Equipped with guided conveyors for transfer totes, an AS/RS eliminates traveling of pickers by automatically transporting selected products inside totes to work-stations. As a result the efficiency of system depends on configuration such as operating policies as well as the business nature of a retailer. In this study such policy of a case study construction material retailer that has re-cently implemented a miniload AS/RS was analyzed to give insights on the operation. Before the analysis it is important to provide relevant researches and background of a case study retailer.

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Literature review: Literatures related to this study can be grouped in two categories: warehouse operation and AS/RS.

Warehouse operation: As one of the most important parts of logistics system, a warehouse or a distribution center serves as a buffer point between manufacturers and consumers that provides better customer service, improves underlying profitability through transportation economics and performs value-added-processing such as labeling and product customization. In general, warehouse operation begins when incoming products from suppliers are received and ends when completed orders of products are shipped to customers. To operate smoothly at desired productivity requires well-designed operations and systematic controls. As a result, earlier researchers focused on designs and planning of warehousing systems (Schwarz *et al*., 1978; Hausman *et al*., 1976). As computational capability increases the next generation of researches concentrated on a specific objective in ware-housing operation using optimization or simulation models such as minimizing the expected response time by determining optimal storage configurations (Pandit and Palekar, 1993). The relation-ship between product allocation and functional areas, particularly receiving, shipping, crossdocking as well as forward and reserved storages for in a warehouse was considered by Heragu *et al*. (2005) who formulated an optimi-zation model that determines the size of each area and proposed a heuristic to minimize the total material hand-ling and storage costs. In addition to space allocation, many researchers have addressed operational policies and variations to further improve underlying performance (Gu *et al*., 2010).

Among standard warehousing activities (Gwynne, 2011) order picking is the most labor-intensive and costly activity as it accounts for >60% of all operating costs (Van den Berg and Zijm, 1999). Therefore, many companies have adopted automation including an AS/RS.

Automated Storage and Retrieval Systems (AS/RS): An AS/RS has been widely adopted in warehouse and distribution centers for storage and retrieval of products to reduce operating time and eliminate traveling time of pickers. The system consists of input/output stations, storage racks, guided conveyors and Storage/Retrieval machines (S/R machines). Designed for storing and retrieving small items stored in plastic totes an miniload AS/RS transfers requested totes to picking stations at the end of an aisle by guided conveyors. As the most important component in the system an S/R machine can be classified by number of payloads in each cycle. A cycle is called dual-command cycle when an S/R machine performs both storing and retrieving in a single trip. This interleaving system can potentially generate higher throughput (Graves *et al*., 1997). On the other hand, a single-command cycle is referred to a machine that operates either storing or retrieving. Therefore, the productivity of the system is reduced as the machine partially travels without a payload (Gue and Meller, 2009).

The sequencing of S/R machines has been studied in many operation circumstances. In the earlier works, researchers simplified operations to gain insights. By assuming single command cycles for instance (Hausman *et al*., 1976) studied three request sequencing, particularly random assignment, turnover assignment and class-based assign-ment. The result turnover-based can significant reduce the traveling time and distance of the machines.

Because of the complexity in analysis of the dual-command cycles, researchers proposed heuristics to select retrieving tote after storage is completed. Some heuristics group products stored in a miniload AS/RS into blocks to reduce traveling times or traveling distances within blocks. Others focus on available tasks and select a retrieving tote based on nearest-neighbor sequencing rule (Han *et al*., 1987). As a result of Hachemi *et al*. (2012) compared these heuristics with first-come first-served rule and showed that the nearest neighbor rule dominates others in terms of average cycle time. Nevertheless, a simulation model is a preferable analysis tool as the cycle of an S/R machine is more complex. For example, Randhawa and Shroff (1995) studied an application of an AS/RS in different storage assignments and retrieval sequencing policies using a simulation model. The result suggests that a combination of class-based turnover storage policy and nearest neighbor sequencing policy can improve throughput and reduce waiting time. In many applications, wave sequencing and dynamic sequencing of orders play an important role in warehouse operation (Berg and Gademann, 2000) as it involves selection a wave of storage, retrieval requests and sequencing the requests. The researchers showed that sequencing of storage and retrieval requests affects traveling time and response time of S/R machines.

MATERIALS AND METHODS

Construction material retailer: Before discussed the current operation of the miniload AS/RS it is important to understand its nature of business. The retailer consists of 5 stores scattering in different regions and 6 stores located in Bangkok greater Area as well as a single distribution center north of Bangkok as shown in Fig. 2.

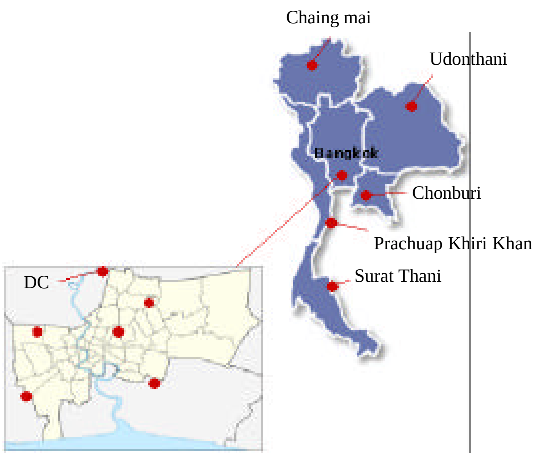

Fig. 2: Locations of store and DC of the retailer

Because of high product variety, the retailer receives all incoming shipments at the distribution center before consolidates and ships through all stores across Thailand. To facilitate sales and distribution of products the retailer has invested in a state-of-art information technology systems including warehouse management system. In terms of material handling equipment, the retailer has experienced with semi-automation material handling system to increase storage positions and productivity as ceramic tiles and sanitary ware are heavy and require careful handling. Having successful implemented of bulky products the retailer has recently shifted its focus to small products that require large sorting area and skilled workers by automated picking operation with a miniload AS/RS.

Application of miniload AS/RS: In general the most suitable candidates for a miniload AS/RS should be compact and high variety of slow-medium moving products that require relatively large footprint to storage or to sort. As a result the retailer selects assortment products, called fitting product that consists of small and local products such as chrome plated sanitary fittings, bathroom sink faucets and angle valve taps. Accounted for 20% of total sales the products vary in styles, sizes and suppliers. Consequently, fitting product significantly contributes to stock keeping units.

Before the implementation of a miniload AS/RS, the retailer partially synchronized incoming shipments of fitting products with requested orders and crossdocked majority of the products to stores while the remaining quantities were stored in bin-shelves for the future orders. The crossdocking actvities required large area and many skilled workers to sort products as each store ordered less than carton quantities. Despite the best effort the crossdocking operation suffered from loss of products and incorrect deliveries. To counter these problems the implementation of miniload AS/RS are aimed to increase storage density and to reduce the traveling time by automatically storing and retrieving totes. Before the explanation of current operation and the preliminary analysis, it is important to describe the nature of fitting products that stored in the miniload AS/RS.

Inventory policy of fitting products: Because of distinct demand patterns, fitting pro-ducts are categorized into two types based on inventory policies: standard product and regular product. The former type consists of popular fitting products therefore the retailer maintains their quantities using automatic replenishment that accounts for historical demand, lead time, profitability and targeted service level. On the contrary, the retailer maintains no inventory for regular product type as they are new and fashionable products. As a result the retailer orders them periodically with minimum quantity for customers. Despite the different inventory policy, a miniload AS/RS handles both product types identically.

Current operation of miniload AS/RS: After the verification of an incoming shipment, products are placed in an empty tote, registered into the system and transferred to a selected storage position in high density racks. The picking process is the reverse of put-away process in which an S/R machine moves to a specific position and retrieves a tote. The tote is then, transferred by guided conveyors to one of two available workstations where a standby worker picks a specific quantity of product before discard the empty tote or return the tote to high density racks. At any given time, the system could have multiple empty storage positions and/or identical products in multiple totes. Consequently, selected storage positions and retrieval totes are determined by storage and retrieval policies.

Policies and alternative: With exception of an urgent order the retailer currently uses the simplest policies because of recently implementation. Furthermore, the historical data investi-gation and discussion with managers led to three possible areas of improving: order batching, storage assignment policy and retrieval sequencing policy.

Order batching policy: Is referred to as combination of arrival purchase orders from different stores that presents to a miniload AS/RS. The policy can be futher divided into two alternatives.

Batch by store (B0): Is current order batching policy of the system in which all orders for a particular store is combined by products. The total quantity of each product is presented to a miniload AS/RS and a worker picks a particular product of a particular store at a workstation.

Batch by article (B1): Is a proposed improvement in which different orders of an identical product are combined into batch before present to a miniload AS/RS. A worker must pick a specific quantity of product multiple times for different stores at a workstation. This policy implies less work for crane and longer cycle time for a worker.

Storage assignment policy: Is referred to as a way in which an empty position in a miniload AS/RS is selected. The policy can be futher divided into three alternatives.

Random storage (S0): Is current storage assign-ment policy of the system where a storage position is assigned randomly.

Turnover based storage (S1): Is an alternative policy suggested by researchers. The policy relies on historical demand and frequency of products to group them into zones and suggests storage position of a particular product by its associated zone.

Class based storage (S2): Is a proposed improvement based on the nature of products. For this study the inventory policy of fitting products, mentioned in study is used to divide the rack into two zones. Hence, a suggested storage position is based on the class of a product.

Retrieval sequencing policy: Is referred to as a logic in which an S/R machine selects a next storage position for retrieval tote in dual cycle operation. The policy can be futher divided into two alternatives.

First come first served (R_0): Is current retrieval policy of the system in which an S/R machine moves to a next storage position based on its next picking task regardless the traveling distance.

Nearest-neighbor (R1): Is a myopic improvement based on the comparison of traveling distance all possible tasks and selects the one that has minimal distance from the current storage position.

Having discussed these policies and alternative, a group meeting applied the concept of design of experiment and decided to experiment with the following combination of policies using a simulation model as shown in Table 1.

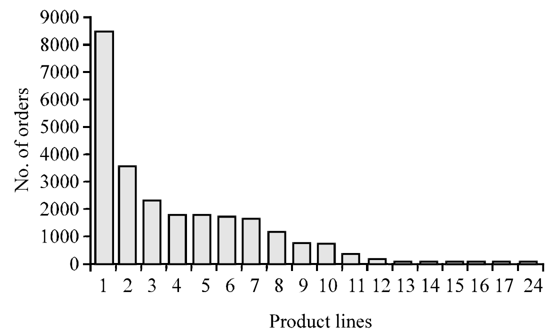

Fig. 3: Distribution of product lines per order

Table 1: Combination of policies to evaluate performance

Scenario	Order batching	Storage assignment	Retrieval sequencing
0	B0	S0	R0
1	B0	S1	R0
2	B0	S2	R0
3	B0	S0	R1
4	B1	S1	R0
5	B1	S1	R1

In Table 1, Scenario 0 serves as a base case whereas Scenarios 1-4 are used to probe different policy and to compare with the base case. Based on previous literature, Scenario 5 should dominate others significantly.

Simulation model: Before explaining a simulation model it is important to discuss the specification of the system and nature of demand.

Specification of miniload AS/RS: The miniload AS/RS consists of four aisles and eight selective high density racks. Each rack has 19 levels and 100 bays or 19,000 storage positions. Because differences and demand patterns of products, storage positions in the system can be classified into three different heights based on levels, particularly 325 mm in levels 1-8, 475 mm in levels 9-17 and 925 mm in levels 18-19. In terms of S/R machines the crane can travel at speeds 200 m/min in horizontal direction and 80 m/min in vertical direction.

Nature of demand: Based on the historical data, Fitting product exhibits unexpected demand pattern in each order as shown in Fig. 3.

The distribution of product lines in Fig. 3 reveals that majority of stores and customers order a single product at time. This nature of demand implies that batch picking could improve throughput of the system.

Simulation model: As the most suitable tools to model and analyze a complex system, a discreted-event time simulation is selected to provide insights and compare combination of policies without disrupt the ongoing operation. The simulation is organized similar to current operation that schedule into three four-hour slots: 8 a.m. to 12 p.m., 12-4 p.m. and 4-8 p.m. The first and second slots are designed for picking products and shipping to stores whereas the main intension for the remaining slot is used to refill the rack.

After further analysis of historical data it is clear that the demand pattern has no any distinct underlying pattern and known matching distribution. As a result, a three month empirical data are embedded into the model after removing noticeable outlier. As an S/R machine can travel both horizontal and vertical simultaneously the chebyshev distance or maximum norm is selected to calculate distance.

Other important parameters in the model are derived work study from ongoing operation and specification from user manual. These include 18 sec of retrieval time, 30 sec traveling time and 10 sec picking time.

RESULTS AND DISCUSSION

Having determined parameters the scenarios listed in Table 1 are embedded and experimented with the simulation that was programmed in R/R studio version 0.99.491. Based on 90 replications the results of the experiments include percentage of space utilization, throughput and average travel time per shift as shown in Table 2.

To provide insights the effects of order batching policy, storage assignment policy and retrieval sequencing policy are discussed along with statistical test.

In terms of order batching policy, the comparison between Scenario 1 and 4 reveals that order batching by article is more superior than order batching by store because S/R machines experienced work after combining order quantities. Nevertheless both policies are not statistically difference.

The effects of storage assignment policy can be found in Scenario 0-2. The result in Table 2 and ANOVA tests demonstrates that class-based storage or Scenario 2 statistically dominates both turnover-based storage and random storage. Despite, the domination of the nearest neighbor policy in Table 2 the experiments were unable to statistically confirm its performance of that of first-come first-serve policy.

Table 2: Percentage of space utilization, throughput and average travel times from simulation model

Scenario	Utilization (%)	Throughput (unit)	Average travel time (sec)
0	90.27	380	4242.63±470.74
1	90.23	380	2095.98±220.09
2	90.47	380	1737.41±153.53
3	90.27	380	3508.53±300.25
4	90.23	353	1965.16±178.42
5	90.23	353	1743.28±173.38

CONCLUSION

This study reported an ongoing effort to adopt automated material handling equipment in Thailand and studied operating issues of a miniload AS/RS used in a construction material retailer. After the analysis and discussion with managers, we embedded empirical data of Fitting products and their parameters into a simulation model and experimented with three operation policies of the system, particularly order batching, storage assign-ment and retrieval sequencing. The combinations of these policies were selected and grouped into 6 different scenarios in which percentage cubic utilization and throughput as well as average traveling time are com-puted. In additional to a preferred combination of operation policies the result revealed that class-based storage assignment policy is statically dominated another alternative as the policy matches the demand pattern.

The study also suggested possible further research directions, particularly picking policy and order optimi-zation. For picking policy, a researcher may be interested in a picking sequence that balances numbers of empty totes and workloads of S/R machine. Given a current computational power it is possible to optimizing order batching and order sequencing. Instead of a simple order batching such as batch by store or batch by study, a retailer can minimize total workload by optimizing order quantities and order sequencing presented to a miniload AR/RS.

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REFERENCES

Berg, J.P.V.D. and A.J.R.M. Gademann, 2000. Simulation study of an automated storage-retrieval system. Intl. J. Prod. Res., 38: 1339-1356.

Graves, S.C., W.H. Hausman and L.B. Schwarz, 1977. Storage-retrieval interleaving in automatic warehousing systems. Manage. Sci., 23: 935-945.

Gu, J., M. Goetschalckx and L.F. McGinnis, 2010. Research on warehouse design and performance evaluation: A comprehensive review. Eur. J. Oper. Res., 203: 539-549.

Gue, K.R. and R.D. Meller, 2009. Aisle configurations for unit-load warehouses. IIE. Trans., 41: 171-182.

Gwynne, R., 2011. Warehousing Management. Kogan Page Publisher, Philadelphia, Pennsylvania,.

Hachemi, K., Z. Sari and N. Ghouali, 2012. A step-by-step dual cycle sequencing method for unit-load automated storage and retrieval systems. Comput. Ind. Eng., 63: 980-984.

Han, M.H., L.F. McGinnis, J.S. Shieh and J.A. White, 1987. On sequencing retrievals in an automated storage-retrieval system. IIE. Trans., 19: 56-66.

Hausman, W.H., L.B. Schwarz and S.C. Graves, 1976. Optimal storage assignment in automatic warehousing systems. Manage. Sci., 22: 629-638.

Heragu, S.S., L. Du, R.J. Mantel and P.C. Schuur, 2005. Mathematical model for warehouse design and product allocation. Intl. J. Prod. Res., 43: 327-338.

Pandit, R. and U.S. Palekar, 1993. Response time considerations for optimal warehouse layout design. Trans. Am. Soc. Mech. Eng. J. Eng. Ind., 1415: 322-322.

Randhawa, S.U. and R. Shroff, 1995. Simulation-based design evaluation of unit load automated storage-retrieval systems. Comput. Ind. Eng., 28: 71-79.

Schwarz, L.B., S.C. Graves and W.H. Hausman, 1978. Scheduling policies for automatic warehousing systems: Simulation results. AIIE Trans., 10: 260-270.

Van den Berg, J.P. and W.H.M. Zijm, 1999. Models for warehouse management: Classification and examples. Int. J. Prod. Econ., 59: 519-528.