Warehouse Picking Model for Single Picker Routing Problem in Multi Dimensional Warehouse Layout Using Genetic Algorithm Approach to Minimize Delay

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Abstract. Order picking process is one of the most time-consuming activities at a 3PL's warehouse system. This paper aims to determine picking process and routing method in finding the optimal order picking by using Single Picker Routing Problem in a multidimensional warehouse. Single Picker Routing Problem (SPRP) is method development of general Traveling Salesman Problem (TSP). SPRP is used to determine the minimum route in picking process to several points including depot areas and choosing a concerned location. In this paper, we develop a model to minimize travel time considering "x-axis", "y-axis" and "z-axis" (height of racking system) using Genetic Algorithm (GA). Genetic Algorithm as the chosen method is carried out to calculate process quickly because the number of variables in the case study used in. The result of the model is the picking sequence not only considering 2D layout, but also the height of the racking system. By applying the model to the case study, the improvement of picking time is 60%.

Keywords: Picking and routing method · Traveling salesman problem (TSP)
Single picker routing problem (SPRP)

1 Introduction

Warehousing is one of the activities in the logistics is very important and critical in industrial systems and services. Warehouse has an important role to enhance the success of business in the level of costs and customer service. Thus, in the activities of the warehouse is required allocation of products with classification based on the

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characteristics and speed of each product as well as to the arrangement and preparation of the number of products on every slot on every shelf in the warehouse [1].

One way to improve warehouse activity is by product allocation. The process used to solve these problems by making the process of classifying products based on Class-Based Storage using analysis of FSN. After that, the process of storage allocation by ZABRLS (zone, aisle, bay, row, level, and slot). In this research, will be the development of allocating goods stored by the optimal route using the Single Picker Routing Problem (SPRP) and supported by the WMS application.

Picking Activity is one of the largest contributions in the warehouse activity [2]. In picking activity, Genetic Algorithm (GA) selected in the determination of the routing method in the case of Traveling Salesman Problem (TSP), which serves to determine the optimal order picking. Another research aims to determine picking and routing method which result in two dimensions picking orders by ignoring racking heights 4. The method can not be applied to the most 3PL company as a supply chain because it does not pay attention to high-racking and time the process used to obtain the order picking optimal results take a long time because the value of outbound throughput at the facility is very high.

Single picker routing problem considering multidimensional warehouse is needed to be developed because picking time not only consider 2D warehouse (x-axis and y-axis) but also consider 3D (vertical racking height).

2 GA for Single Picker Routing Problem

2.1 Existing Model for Single Picker Routing Problem

In conducting warehouse activities necessary to optimize the location of the warehouse which aims for determining exact location and suitable for products in a storage area and aims to minimize time and costs, both in product storage process (storing) and picking process.

SPRP (Single Picker Routing Problem) is a routing problem in warehouse at the time of picking activity. SPRP is used to determine the minimum route in picking process to several points including depot area and choosing a concerned location. Thus, a special case of the TSP is able to represent a general TSP formulation which means that the general TSP could be eligible for modeling the SPRP [3].

Model development of Single Picker Routing Problem in this research was based on previous studies with basic concepts of the Traveling Salesman Problem 5. Traveling Salesman Problem basic model used to solve Single Picker Routing Problem has an objective function to minimize the total distance from the whole point of picking by ensuring that each vertex can only be visited once.

In resolving Single Picker Routing Problem using the model cannot be applied optimally. That is because the model does not consider the number of goods carried by the material handling equipment. In the process of picking the warehouse, material handling equipment will depart from the starting point (depot), then to the point of picking to take the goods, and the goods are brought to a certain point, both to stagging and back to the depot.

Another research has developed a basic TSP model by adding variables to consider material handling equipment in the carriage of goods (commodities). The goods carried are palletized, so in one way material handling equipment can only be transported per pallet. The model ensures that the path is located at the end of the aisle are not included in the calculation, because the material handling equipment to maneuver between aisle [4].

Later research has developed a problem-solving in a warehouse for Single Picker Routing Problem using mathematical models. The objective function of the model has some functional purpose of determining the shortest route from basic TSP into several factors, i.e. [5]:

1. The distance between front cross aisle to cross aisle behind.
2. The distance between front cross aisle to cross aisle next (back cross aisle).
3. The distance between vertex distance between slots in racking).
4. The distance between nearest aisle.
5. The distance between depot with cross aisle.

The model has a lot of functionality for the purpose of storage has a very large spacious and pallet position of 145,000 pallet positions in a separate location block 124, so as to generate optimal repair requires a lot of research factors [5].

2.2 Improved Model for Single Picker Routing Problem Considering Rack Height

By considering the height of racks in the warehouse, an improved model for single picker routing problem is developed, referring to third in the journal by adding the variable of storage position vertically, which is symbolized by (v).

The proposed model has also the addition of a variable, i.e., a variable that shows time of the vertical p smaller than vertical position q, where tv is:

$$t_{vertical} = \frac{level\ height}{lifting\ speed} \tag{1}$$

Lifting speed is the speed of material handling when lift pallet will be allocated on a shelf. Calculation in speed lifting using data specification such as maximum lifting speed and lifting speed of at least the amount of material handling certain weight. Data specifications are then compared with the actual weight of the product is lifted in one pallet using interpolation formula. To obtain the lifting speed in the Eq. (1), using the following calculation:

$$lifting\ speed = v_{min} \frac{v_{max} - v_{min}}{weight_{max}} \cdot actual\ weight \tag{2}$$

The formulation of the model is constructed as follows:

$$\min \sum_{(p,q)\in E} c_{pq} \cdot x_{pq} \tag{3}$$

$$\sum_{p\in V} x_{pq} = 1 \quad \forall q \in V \tag{4}$$

$$\sum_{q\in V} x_{pq} = 1 \quad \forall p \in V \tag{5}$$

$$\sum_{q\in V} g_{pq} - \sum_{q\in V\{0\}} g_{pq} = 1 \quad \forall p \in V\{0\} \tag{6}$$

$$h_p - h_q + (n+1)x_{pq} \leq n \quad \forall_{pq} \in E; p, q \neq 0 \tag{7}$$

$$tv_p - tv_q + (n+1)x_{pq} \leq n \quad \forall_{pq} \in E; p, q \neq 0 \tag{8}$$

$$g_{pq} \leq nx_{pq} \quad \forall_{pq} \in E; p, q \neq 0 \tag{9}$$

$$x_{pq} \in \{0, 1\} \quad \forall_{pq} \in E \tag{10}$$

$$g_{pq} \geq 0 \quad \forall_{pq} \in E : q \neq 0 \tag{11}$$

Objective function (3) is to determine the shortest route (c) in the case of single picker routing problem from node (p) to node (q). Equations (4) and (5) ensure that each vertex p and q can only be visited once. Equation (6) which ensures there is only one commodity or goods (pallet) are brought in from vertex p to vertex q. Equation (7) ensuring that the position of the x-axis of a vertex p is smaller than q vertices. Equation (8) ensuring that the position of z-axis (racking height) of a vertex p is smaller than q vertices. Equation (9) ensures that the path is located at the end of the aisle are not included in the calculation, because the material handling equipment to maneuver between aisle.

For the model to be used, the process should be done in advance of the allocation based on the decision-making process of the fastest. The model is used to make process of slotting based on the time of the product is the fastest [6]. In the paper it is discussed slotting process with the objective function is to minimize the distance. With Material Handling Specification data, the distance is converted into a process.

The weakness of the Single Picker Routing Problem model developed with TSP concept is that the calculation takes a long time when picking a point (p, q) and many of the high throughput. The project will be carried out this great solution model using genetic algorithm approach. Genetic Algorithm is applied for Single Picker Routing Problem [7].

In modeling of the GA model for the case, picking points are interpreted as chromosomes. In Table 1 is shown the example of six picking points within a generation for five location points:

Table 1. Example of cumulatif probability calculation

Chro no.	Variat random uniform (*i*)				
	A	B	C	D	E
1	0.13	0.63	0.28	0.72	0.36
2	0.45	0.29	0.64	0.21	0.47
3	0.51	0.38	0.11	0.27	0.68
4	0.17	0.08	0.36	0.81	0.49
5	0.37	0.31	0.42	0.39	0.74
6	0.26	0.28	0.67	0.21	0.33

From the random number table above, the position i indicates the location (picking point) that must be visited. While the random value that is in position i determine the visit sequence of each point for the process of picking.

With the above random number parameter, it can be determined that on the second chromosome, the value of 0.21 is the smallest random number. So point D (point four) on the second chromosome is the first point to be visited (Table 2).

Table 2. Result of encoding

Chro no.	Result of encoding				
1	A	C	E	B	D
2	D	B	A	E	C
3	C	D	B	A	E
4	B	A	C	E	D
5	B	A	D	C	E
6	D	A	B	E	C

Fitness value of a chromosome in this case, is calculated from the total travel distance of the picking list. Chromosomes that have a high fitness value will have a greater chance of surviving in the next generation. After getting the fitness value, the next step is to calculate the fitness value evaluation to get cumulative value of chromosomal probability, then the selection process is done by using the roulette wheel method.

To have some good alternative solutions, cross over is done by using cut-point method, and the final chromosome is obtained by doing the mutation processes.

3 Discussion

As described in the background problems, Single Picker Routing Problem in the situation of the warehouse XYZ can not be solved using the model developed before [3–5]. All models had not considered the height of the racking system for storing goods. The next discussion will explain the analysis of model development and the application result of the model to the case study in XYZ, and the validation process by Monte Carlo simulation.

3.1 Total Picking Time

In this study will discuss about an improved model for single picker routing problem, which is consider racking height. Single picker routing problem is an activity performed for the picking (dropping) process on a pallet using the shortest route in executing a picking list to minimize the delay time.

In conducting picking activity at XYZ, there are four variables that influence the picking time: horizontal travel time, vertical travel time, picking time and double handling time. So to know the total picking time can be formulated as follows:

$$\text{Total Picking Time} = \text{HT} + \text{VT} + \text{PT} + \text{DDT}$$

Notation:

HT	Horizontal Travel Time
VT	Vertical Travel Time
PT	Picking Time
DDT	Double Handling Time

Horizontal Travel Time

Horizontal travel time is the time required to perform picking activity from zero or central point (location of MHE) to the nearest picking location. The distance from the zero point or the center point to the nearest picking location is called the horizontal distance based on rectilinear. Rectilinear is a measured distance following a perpendicular path from a central point of a location to another central location point. Horizontal travel time is obtained from the horizontal distance division that is reached by the average speed of material handling.

If known the point of the location of material handling to the closest rack that is equal to 3.375 m, travel speed of 2.5 m/s. It is known horizontal travel time of 1.35 s.

Vertical Travel Time

Vertical travel time is the time it takes to do the rack picking process at a level above the zero level (level one, level two and so on). Vertical travel time is obtained by dividing the vertical distance obtained from the height of the rack specification with the specification of lifting speed material handling used per unit of total product weight on a pallet.

If it is known that the height of the rack is 1.67 m, then at level 1 has a vertical distance of 0, at level 2 has a vertical distance of 1.67 m, and on the next level has a vertical distance of distance at level 2 plus the height of the rack, and so on, as the number of levels. So it can be seen, the vertical travel time at level 1 is 0 s, where the vertical distance of level 1 is 0 m divided by lifting speed of 0.27 m/s.

Picking Time

Picking time is the time spent in the process of moving goods from storage to meet a specific need at each level. Picking time is obtained from observations in XYZ warehouse. Observations were made 30 times. The average picking time at level 1 is 11 s, level 2 is 23.47 s, and level 3 is 43.83 s.

Double Handling Time

Double handling time is the time spent for repetitive activities in handling one product. Double handling time has different time for each level and position.

If known a SKU is at location C at level 1, then double handling time equal to 33 s that is picking time multiply three. This happens because, when it comes to issuing

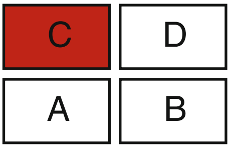


Fig. 1. Position of laying of goods on rack

SKUs from location C, the first thing to do is to issue another SKU at location A, then issue the destination SKU at location C and re-enter the previous SKU A location to location A again (Fig. 1).

3.2 Monte Carlo Simulation to Determine the Number of Picking Points

Simulation is a mathematical modeling technique that is used to mimic the real picking system. In this study, the real system to be emulated is the number of picking points on finished goods warehouse PT XYZ. The simulation model of stochastic simulation monte carlo, because the data demand affect picking point has a certain probability. Stochastic simulations are needed to compare the random variable is raised to determine the location of picking by sampling the probability of demand. Steps to perform Monte Carlo simulations are:

a. Calculate the probability of demand for each SKU's
   The first step taken to perform Monte Carlo simulations is to calculate the probability of demand (delivery order) for each SKU's within a certain period. The result of the calculation of the probability of demand can be seen in Table 2.
b. Generating random numbers to determine the number of picking points on each trial picking list

In this simulation process, will use ten experiments picking list by generating a random variat uniform distribution to determine the number of points each picking list a number of twenty to fifty. Variate generated random uniform distribution, in accordance with the distribution of the demand of each SKU's.
H0: data distribution is uniform
H1: data distribution is not uniform
Because the test results for five pieces of SKU's has a value of greater significance than the alpha (0.05), then accept H0, so that it can be concluded that the distribution of data demand is uniform.
The generation of random variat for each picking list can be is then generated (Table 3).

c. Generating random picking locations for each SKU's trial to determine which point would be picked and the amount uniform random numbers generated in accordance with the number of picking points each trial. Then random sampling will be done on demand probability distribution in accordance with the process of Monte Carlo (Table 4).

Table 3. Example of cumulatif probability calculation

SKU's	Probability	Cum. probability
G01D	3.62241E-07	3.62241E-07
V02FP	3.62241E-07	7.24482E-07
K09HL	7.24482E-07	1.44896E-06

Table 4. Random numbers number of picking points each trial

Picking list	Number of picking points
Picking 1	23
Picking 2	29
Picking 3	34
Picking 4	41
Picking 5	35
Picking 6	26
Picking 7	24
Picking 8	31
Picking 9	26
Picking 10	36

3.3 Genetic Algorithm Calculation for Single Picker Routing Problem

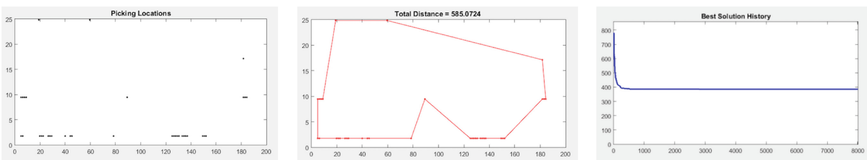
In this study, the use of Genetic Algorithm for Single Picker Routing Problem aims to obtain optimal results in determining the picking route. The reason for using Genetic Algorithm is because the model in this research can not be solved with simple mathematics solver. This happens because the SPRP model has a considerable limitation that can be seen in the above mathematical model. The steps in performing calculations using Genetic Algorithm as follows:

1. Encoding Chromosome
   Encoding is the process of determining the value to be used as input of a genetic algorithm. Encoding process on single picker routing problem will use random generator technique in permutation representation. Random generator is one of the encoding techniques which generates chromosomes as the initial population by involving random numbers.
2. Evaluation and Selection of Chromosomes
   The concept of genetic algorithm is that individuals who have a high fitness value will survive, whereas individuals who have low fitness values will die (eliminated). This process aims to get the best parent, because a good parent will produce good offspring as well. The value of fitness is a value that indicates the level of good or not an individual. Chromosomes that have a high fitness value will have a greater chance of surviving in the next generation.
3. Cross Over
   Cross over process requires two parent chromosomes. This process serves to swap some of the information held by the first parent with the second parent and vice versa. The selected parent chromosome is randomly selected and influenced by cross over rate (ρc). The higher cross-over rate will result in a more varied achievement of alternative solutions and reduce the likelihood of generating undesirable optimum value. However, if the value of cross over rate is too high, it will lead to a longer time wastage to calculate in a solution area that is not as promising as an optimal solution. Cross over process will use cut-point method.
4. Mutation
   The mutation process is needed to replace the genes of a population during selection. In addition, mutations also serve to form genes that are not present in the initial population. In this process, a gene pair is selected in a random chromosome for gene exchange.

In the problem of traveling salesman problem, mutation scheme will use swapping mutation method (exchange mutation), that is mutation process by choosing two genes randomly and exchange them. The chromosome that undergoes a mutation in a population will be determined by the mutation rate (ρm). The mutation rate should be applied with a small value, because if the mutation rate is too large it will produce too many mutations, resulting in a weak individual because the configuration of the superior genes is mutated.

3.4 Calculation Result

From the mathematical model of SPRP, the calculation using Gemetic Algorithm which is processed using matlab application produces the image below which shows



(a) (b) (c)

Fig. 2. Output MATLAB simulation

Table 5. Simulation result

Trial	1	2	3	4	5	6	7	8	9	10
Number picking location	23	29	34	41	35	26	24	31	26	36
Existing picking time (s)	466.9	588.7	690.2	832.3	710.5	527.8	487.2	629.3	527.8	730.8
Proposing picking time (s)	186.76	235.48	276.08	332.92	284.2	211.12	198.88	250.72	221.12	292.32

the points of picking location contained in the warehouse. These location points are used to perform the picking process.

In addition, the results of SPRS calculations using Genetic Algorithm resulted in a sequence of routes used for picking activity. In doing the picking activity is not determined from where to start to do picking, but in doing the picking activity must be in accordance with the order determined according to the results of the calculations performed.

To obtain the optimal distance results are iterated repeatedly so as to obtain steady state value, the optimal value where the graph does not increase or decrease shown in the existing graph (Fig. 2c).

Simulation result shown in Table 5. Number of picking location have been determined in Table 3 using Monte Carlo Simulation. The simulation result, our proposing algorithm can minimize the picking time about 60% from the existing.

4 Conclusion

SPRP (Single Picker Routing Problem) is a routing problem in the warehouse at the time of picking activity. SPRP relating to the determination of minimum service in doing picking to several points including depot picking and choosing the location in question. Thus, a special case of the TSP is able to represent a significant public TSP formulation TSP that can generally be feasible to do modeling SPRP. This paper has developed single picker routing problem consider racking height, because lot of logistics operation use racking system for the storage system.

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