IMPLEMENTATION ANALYSIS OF KIVA ROBOT AS A MATERIAL HANDLING EQUIPMENT AT E-COMMERCE DISTRIBUTION CENTER

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KEYWORDS

Kiva Robot, Order Picking, Economic Analysis

A B S T R A C T

The growth of the e-commerce market in Indonesia is always increasing, which simultaneously triggers the order picking activities at Blibli warehouse to be increasingly busy. These busy activities give impact to high operational costs and the limited ability of workers to handle huge volume of demand, hence new strategies are needed in the order picking process, one of which is the use of kiva robots. The purpose of this research is to determine the effect of the implementation of kiva robot as a material handling equipment on the productivity of order picking activities and also to evaluate the economical aspects of the implementation of kiva robot. Numerical simulation method is chosen to select the best scenario as a solution suggested to the company. Three scenarios are implemented as in the following: Scenario 1 uses 3 kiva robots and 1 picking station, Scenario 2 uses 4 kiva robots and 1 picking station, and Scenario 3 uses 3 kiva robots and 2 picking stations. The best scenario is selected from the value of order fulfillment time and the average waiting time of the kiva robot at the station. The research concludes that Scenario 3 is selected as the best scenario, with order fulfillment time of 3 hours 27 minutes 27 second, which is 31,89% and 31,28% faster than Scenario 1 and 2. From the results of economic analysis, scenario 3 is feasible to be implemented because it meets the minimum eligibility requirements. The value of net present value (NPV) is Rp 671,801,045, the rate of return (ROR) value is 19.27%, benefit-cost ratio (BCR) value is 1,21, and payback period (PP) value for 3 years and 6 months.

INTRODUCTION

The growth of the e-commerce in Indonesia has always increased in five years. That way, Indonesia has great prospects for the e-commerce market. According to McKinsey & Company, the value of the e-commerce market in Indonesia will reach 910 trillion rupiahs in 2022, an increase of 14% compared to the value in 2017. The development of operational management in warehousing activities is needed to take advantage of this momentum. The warehouse is an important entity in the supply chain system. Business actors consider that the activities in the warehouse are controlling the overall logistics costs [1]. The increasing share of the e-commerce market will make warehouse activities in companies even busier. Warehouse management development is required so that the material handling process can run quickly, accurately, safely, and economically. To achieve these goals, an appropriate strategy is needed so that order picking activities can run optimally [2].

In warehousing activities, there are several activities in it, including receiving, put-away, order picking, packing, cross-docking, and shipping [3]. Of the six existing processes, order picking activity has the greatest influence on the quality of warehouse operations. This is because 55% of warehouse operating costs must be allocated for these activities [4]. Figure 1.2 shows the percentage of cost allocation for each warehousing activity. In addition to the relatively large operational costs, several problems that often arise in order picking activities are long search duration, errors in picking up goods, not being able to track the whereabouts of the pickers, and requiring a lot of workers [4].

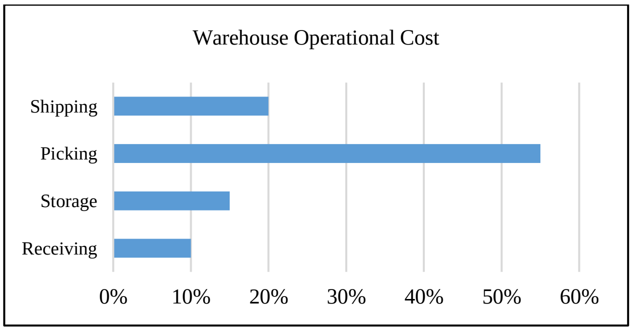

Figure 1. Warehouse Operational Cost [5]

One alternative to increase the productivity of order picking activity is the use of the parts-to-picker method through the Robotic Mobile Fulfillment System (RMFS). RMFS is a new paradigm that integrates picking, packing, and shipping activities. The part to picker method has advantages over conventional methods, including increasing the utilization of the storage area, the position of the picker can be tracked through the Warehouse

Management System (WMS) application, and it can operate for 24 hours [6]. This method has been implemented by several e-commerce companies in the world, such as Amazon and Alibaba. The use of kiva robot can increase order picking productivity three times better than other material handling tools [7]. Amazon claims that using the part to picker method can save operating costs by 20%.

PT XYZ is one of the largest e-commerce companies in Indonesia, with a total warehouse area of around 16,000 m2 and is currently preparing six new warehouses with a total area of around 200,000 m2. As the center of PT XYZ's business activities, the warehouse owned by the company has increased throughput, with recorded Gross Merchandise Value (GMV) increasing by 11 times during Harbolnas (Hari Belanja Online Nasional), PT XYZ monthly demand chart is shown in Figure 2. In carrying out order picking activities, PT XYZ still uses conventional methods, namely by assigning employees as pickers. The picker on duty will pick up items in the storage area according to the picklist provided by the admin. Then the goods that have been taken will be brought to the packaging department. By using this method, an order can be completed in less than two hours, starting from the order picking process, packaging, until the product is ready for distribution.

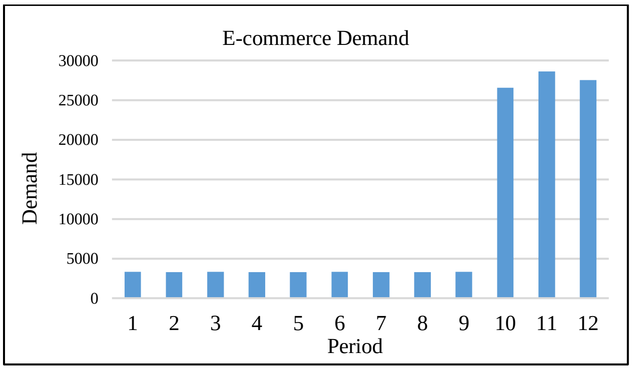

Figure 2. PT XYZ Demand

With a high throughput value and a large warehouse area, the use of conventional methods is considered to be inefficient, due to limitations on employee working hours and the large possibility of human error, and the high operational costs that the company must incur [7]. Therefore, the researcher wanted to determine the effect of implementing the kiva robot as a material handling tool on the operational productivity of PT XYZ's warehouse. The approach used is a numerical simulation using Microsoft Excel software and the Python programming language in finding the kiva robot route. To achieve this goal, the researcher developed several scenarios by considering the parameters that can be changed such as the number of robot kiva and the number of order picking stations.

The rest of this paper is organized as follows. Section 2 describes literature review about Kiva Robot System, Breath First Search Algorithm, and Economic Analysis, while the proposed Numeric Simulation for solving the problem is explained in Section 3. Sections 4 present a thorough discussion on result and discussion of the problems. Finally, concluding remarks are made in Section 5.

LITERATURE REVIEW

This section briefly discusses basic theories about kiva robot system, Breath First Search (BFS) algorithm and economic analysis that applied in this research.

Kiva Robot System

Kiva Robot is one of the automated material handling tools owned by e-commerce company Amazon. Kiva Robot have 76 cm long, 64 cm wide, and 41 cm high. Despite its relatively small size, Kiva Robot can carry goods weighing one tone. Amazon claims that the Kiva Robot's work accuracy reaches 99.99%, so it can minimize human error [8].

In carrying out its duties, there are four steps that Kiva Robot [8] must take:

1. Step 1
   Kiva Robot takes orders and will walk to the bottom of the pre-determined pods.
2. Step 2
   Kiva Robot transports pods from the storage location to the order-picking station and prepares them for processing.
3. Step 3
   Items in the pods are picked up, packaged, and grouped according to the order number by the picker.
4. Step 4
   The completed pod will be returned to the storage location by Kiva Robot.

The figure 3 below is an illustration of the Kiva Robot stages in fulfilling orders.

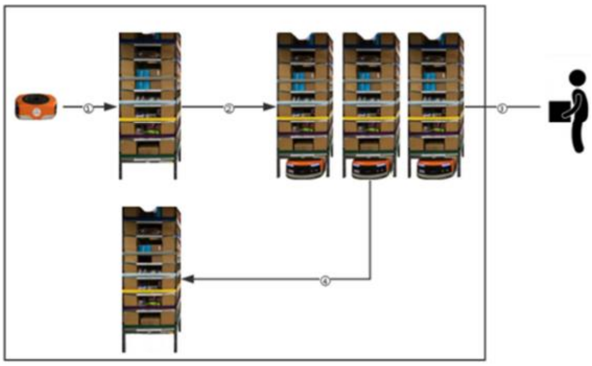
Figure 3. Kiva Robot Order Picking Process

Breath First Search Algorithm

The Breadth-First Search (BFS) algorithm is a route search algorithm that starts by approaching the initial node to the destination node at each level to get several possible paths that can be traversed [9]. The special characteristic of BFS is that when searching for a path, the algorithm will start from the initial state and then continue searching for the path at each level in the tree diagram. Then the related nodes will be checked to a deeper level until they reach the goal state.

The first step in finding a route is to visit all nodes at level n. Then proceed to visit the n+1 level nodes. The route search starts from left to right at node level 1 and will be repeated from the left again when entering node level 2. Figure 3 below illustrates the route search process on the BFS algorithm.

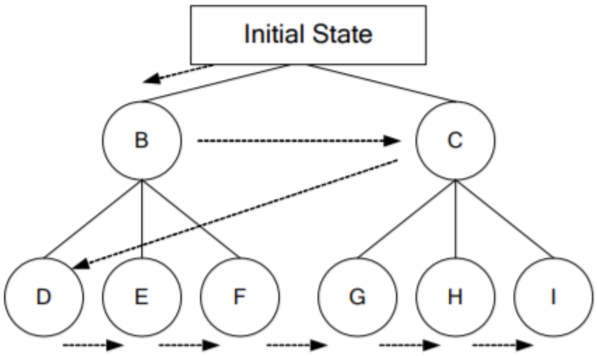

Figure 4. Breath First Search Algorithm Tree Diagram

The advantage of the BFS algorithm is that there is always a solution for every route-finding problem encountered. Besides, this method also provides an alternative route if there is more than one solution [10]. However, in performing route searches, the BFS algorithm takes a relatively long time, because it has to test all nodes at each level [11].

Economic Analysis

Investment decisions can use by carrying out economic analysis. The results of the economic analysis are used to determine whether an existing investment is feasible or not. The following are several methods that can support analyzing the feasibility of an investment:

1. Payback Period
   Payback Period is the time required for the amount of profit to be equal to the investment value. There are two ways to calculate the Payback Period value, namely:
   a. If the cash flow per year is different
   $$\text{Payback Period} = n + \frac{(\text{a}-\text{b})}{(\text{c}-\text{b})} \text{x 1 year} \quad (1)$$
   Information:
   n = the last year for which the total cash flow has not covered the initial investment.
   a = amount of initial investment.
   b = the cumulative amount of cash flows in n year
   c = the cumulative amount of cash flows in n+1 year
   b. If the cash flow per year is equivalent
   $$\text{Payback Period} = \frac{(\text{initial investment})}{(\text{cash flow})} \text{ x 1 year} \quad (2)$$
2. Rate of Return (ROR)
   Rate of Return (ROR) is a method of calculating the interest rate which makes the current value of all cash inflows equal to the value of cash outflows. The IRR value that is greater than the cost of capital indicates that the investment taken will produce a greater return. The following is a formula that can be used in calculating the IRR value:
   $$\text{Rate of Return} = \text{n} + \frac{PW \text{ cumulative (n)}}{PW \text{ (n+1)}} \quad (3)$$
   Information**:**
   n = the last period the cash flow is negative
   PW = present worth cash flow
3. Net Present Value (NPV)
   NPV used to find out about the difference between the present value of cash inflows and cash outflows in a certain period. A positive NPV value is projected to benefit from a project, and if the NPV has a negative value it will get a loss.
   $$\text{Net Present Value} = \sum_{t=1}^{N} \frac{R_t}{(1+t)^t} \quad (4)$$
   Information**:**
   N = number of period
   t = investment period
   Rt = cash flow at t-time
4. Benefit cost ratio (BCR)
   Benefit-cost ratio (BCR) is a method of calculating project feasibility by comparing the present value of cash flows with the value of project investment. The following is a formula for getting the value from PI:
   $$\text{Benefit cost ratio} = \frac{present\ worth\ in\ flow}{present\ worth\ out\ flow} \quad (5)$$

METHODOLOGY

This research was conducted using a numerical simulation approach. Numerical simulations were carried out using Microsoft Excel and Python to find the kiva robot route. Python is used to run the BFS algorithm. The results of the BFS algorithm will be used as input for the numerical simulation. The results obtained from the numerical simulation process are the total order fulfillment time and the average waiting time at the station which are used as parameters in determining the best scenario from the simulation. An explanation of numerical simulation will be explained in this section.

Problem Limitation

Warehouse operation is a very complex activity because many entities must be considered. On this basis, this study determined several problem boundaries, including:

1. The object of research is the warehouse of PT XYZ.
2. The research only focuses on order picking activities at PT XYZ warehouse.
3. Using a Batch Picking order fulfillment strategy.
4. The study has not considered the possibility of a collision between the robots during order picking activity.
5. The storage pods will be returned to their original location after the picking process is complete.
6. The determination of the kiva robot path is carried out using the Breadth-First Search (BFS) algorithm using the Python programming language.
7. Numerical simulation is performed using Microsoft Excel software.
8. Economic analysis of the implementation of Kiva Robot only focuses on order picking activities.

Data Processing and Analysis Techniques

Data processing is carried out using information obtained from the previous stage. There are two steps needed in processing data, namely:

1. Determination of the product storage layout
   In determining the product storage layout, order history data is required for several periods. Then from this information will be processed using apriori algorithm to determine the frequency of consumer orders, patterns of incoming orders, and the association relationship of each product. Products will be grouped by looking at the value of support and confidence

in each association. Product order patterns that have a high support value will be grouped into one pod or placed in an adjacent pod. Pods that store high-frequency items will be located in an area close to the order-picking station. Likewise, pods that store products with low-frequency levels tend to be located far away from the order-picking station. From this information, it can be determined about the product storage layout in PT XYZ's warehouse. By applying the a priori algorithm, it is expected to improve the efficiency of storage layout in the warehouse.

2. Order picking simulation
   Order fulfillment simulation is carried out after the new layout is known and will be executed by fulfilling orders for a certain number of orders. Three scenarios are considered in this study, including Scenario 1 using 3 robot kiva and 1 order-picking station, Scenario 2 using 4 robot kiva and 1 order-picking station, and Scenario 3 using 3 robot kiva and 2 order picking stations. The purpose of having several scenarios in the simulation is to determine the effect of each factor being considered on the duration of the fulfillment of all orders.

After the simulation is carried out, there is some information that will be obtained to answer the problems in this study, including:

1. The duration of each scenario in fulfilling the order
   The duration of each scenario in fulfilling an order can be obtained by looking at the time the first order is handled until the last order is completed. From this data, information can be obtained to compare order fulfillment times between the scenarios under consideration.
2. Waiting time average of kiva robot for order picking stations
   This information is needed to determine the effectiveness of the scenario under consideration. The longer the waiting time for the Kiva robot, the less effective the scenario being simulated.
3. Total trip, total travel distance, and total travel time
   Information about total trips, total travel distance, and total travel time is needed to determine the workload and utility of the Kiva robot. In addition, this information can also be used to calculate the charging requirements that the robot kiva needs to do periodically.
4. Economic analysis of the implementation of Kiva robots
   Before carrying out an economic analysis of the application of the kiva robot, the first calculations are made regarding the costs that must be incurred for the initial investment, overhead costs, and variable costs as well as budget projections that can be allocated annually by the company. In conducting economic analysis, there are several methods that can be used, namely: Rate of Return (ROR), Payback Period (PP), Net Present Value (NPV), and Benefit-Cost Ratio (BCR).

After data processing is complete, it is continued by analyzing the information that has been obtained. The analysis will be carried out by identifying the storage pod placement allocation process, the order fulfillment time for each considered scenario, what factors affect the level of operational productivity of the e-commerce warehouse, economic analysis for the best scenario in the order fulfillment process, and sensitivity analysis to determine the effect of parameter changes to the final result.

RESULTS AND DISCUSSION

This section describes the preparation of a store layout, the results of the order fulfillment simulation, economic analysis, and sensitivity analysis.

Layouting

The arrangement of the storage layout is done using the apriori algorithm. The apriori algorithm is used to identify product associations for classes A, B, and C. Identification of goods associations is carried out for each class A, B, and C with the number of transactions that each class has is 1,015 transactions, 1,418 transactions, and 1,645 transactions.

Table 1. Apriori Algorithm Result

No. Pods	Asociation	Sub Pods						Supp.	Conf.
		1	2	3	4	5	6		
1	A, K, H	A	A	K	K	H	H	0.048	0.211
2	A, K, H	A	A	K	K	H	H	0.048	0.211
3	A, N, G	A	A	N	N	G	G	0.033	0.591
4	A, N, G	A	A	N	N	G	G	0.033	0.591
5	A, B	A	A	A	B	B	B	0.034	0.150
6	A, B	A	A	A	B	B	B	0.034	0.150
7	E, B, T, F	E	E	B	B	T	F	0.019	0.577
8	E, B, T, F	E	E	B	B	T	F	0.019	0.577

The association results in Table 1 illustrate the relationship between each item in the transaction. The first association formed involved three-item, namely "A" and "K" as the predecessor category and "H" as the follower category. The first association relationship produces a support value of 4.8%, meaning that purchases of goods "A" and "K" have appearances of 49 out of 1,015 total transactions and will trigger purchases of line "H" with a confidence level of 77.6% in one transaction.

In this study, there is no minimum limit for the value of support and confidence because it is necessary to identify more associations that will use as the basis for composing the composition of the items in the storage pods.

From the identification of product associations, it was found that products with a high order frequency level will place in pod number one, then followed by other products with a frequency level below it on the next pod number. Pods will place according to the classes based on the ABC classification results. The arrangement of pod placement can see in Figure 5.

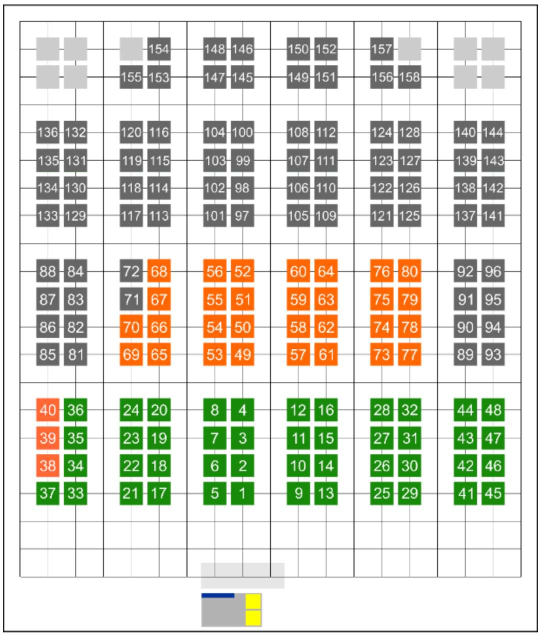

Figure 5. Pod Storage Location

Information:

= pod Class A (37 unit)

= pod Class B (33 unit)

= pod Class C (88 unit)

From Figure 5 above, it can be seen that pods entering class A are placed close to the order-picking station, then followed by pods class B and C in rows two and three. This arranged layout will then be used as the basis for performing numerical simulations at a later stage.

Numerical Simulation

At this stage, the simulation model carried out in the product order fulfillment system will be explained along with the scenarios developed.

Order Fulfillment Model

The input of this simulation is order data which contains information about pod numbers, the product ordered, the number of products ordered, and order number. To minimize the number of kiva robot trips, the order fulfillment process is carried out using an order batching system. The use of an order batching system in the process of picking up goods at order picking stations will allow products at different transaction numbers to be collected simultaneously in one trip [12]. Further research is needed to be able to determine the optimal number of batching orders because the greater the number of batching orders used, it will speed up the product picking process at each operating period and vice versa [12]. In this study, the number of batching orders used was 10 orders. This amount is used by considering the number of transactions in the simulation, which amounts to 50 transactions and can describe an order batching system that can update the list when one of the transactions in it has been completed.

In fulfilling the order, the kiva robot will process the order based on the pod closest to the initial location. Pods will be brought to the order-picking station for the picking process. After the picker finishes picking up the item, the pod will be returned to its original location and the robot kiva prepares to accept the next assignment. Orders that have been completed will be replaced with new orders, so the order list always contains 10 orders. In doing its job, Kiva robot uses the breadth-first search (BFS) algorithm to determine the route to be passed.

There are three scenarios considered in this study. Detailed information for each scenario can be seen in Table 2 below.

Table 2. Numerical Simulation Scenario

Scenario	The number of Kiva robots	Number of Order Picking Stations
1	3	1
2	4	1
3	3	2

Simulation Process

The initial stage in the numerical simulation process of order fulfillment is to determine which products will be processed by the kiva robot. Kiva robot will process the products stored in the closest pod from the kiva robot's initial node. At the beginning of the simulation process, the order fulfillment kiva robot will be placed in coordinates adjacent to the order-picking station. The breath first search (BFS) algorithm is used to determine the route that must be taken by the kiva robot. The following is a simulation process of order fulfillment in this study:

1. Determine the nearest pod that will be taken by the robot kiva based on the order list.
2. Determine the route taken by the robot kiva using the BFS algorithm by entering the initial coordinates of the robot kiva and the final coordinates to be addressed. The output generated by the BFS algorithm will be stored and recorded in Ms. Excel.
3. After knowing the movement time of the kiva robot on each trip, it will be recorded the time the kiva starts working, the arrival time, service time, waiting time, and the time the kiva ends work.

   The recording of the kiva robot movement functions to determine the assignment sequence for each robot kiva and determine the order of the process of picking up goods at the order-picking station. The order of the assignment of the robot kiva is determined from the time in the column "Kiva End Time". Kiva who has a shorter time will be given the task first compared to another kiva.
4. Pods that have been processed will be marked on the coordinates of the storage area so that there are no errors in the order fulfillment process on the next trip. Order information recording is carried out.
5. If all orders in one of the transactions have been completed, the order list will update the order list so that the total order list becomes 10 orders.
6. The order list will stop updating when order number 50 has entered the order list.
7. Repeat steps one through six until all the products on the order list have been processed.

Simulation Result

This section describes the simulation results for the three considered scenarios. In running the order fulfillment simulation, several assumptions must be fulfilled. These assumptions are shown in Table 3.

Table 3. Simulation Assumtion

Asumsi	Information	
Kiva *speed*	1,3	m/s
Turning time (90°)	1,83	s
Turning time (180°)	3,66	s
Process time	14	s/2 item
Lifting up time	7	s
Lifting down time	7	s
Node length	1,96	m

Order fulfillment simulations are carried out for scenario 1, scenario 2, and scenario 3. Some of the data being compared is the average queue time, total order fulfillment time, total trips per robot kiva, travel distance, total travel time, total work time, total waiting time per kiva robot, and charging cycle. The following figure 6 is a comparison of the product pick-up time for all scenarios.

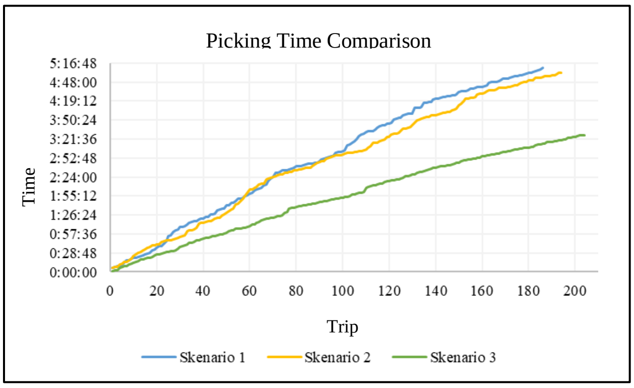

Figure 6. Order Picking Simulation Result

Economic Analysis

This section will explain the feasibility test of using the kiva robot as a material handling tool from an economic point of view. The strategy to be tested is scenario 3, as the best strategy in the order fulfillment process.

Out Flow

The following is a breakdown of the Kiva robot investment costs.

Table 4. Investment Cost

Details	Total	Cost/unit	Total Cost
Kiva robot	3	Rp 147.975.000	Rp 443.925.000
Charging device	3	Rp 4.439.250	Rp 13.317.750
Pod	158	Rp 1.500.000	Rp 237.000.000
RFID sticker	380	Rp 29.447	Rp 11.189.869
AGV system installation	1	Rp 14.797.500	Rp 14.797.500
	Total		Rp 720.230.119

Meanwhile, the following is a breakdown of overhead costs.

Details	Period	Total	Cost/period
Maintenance kiva	1 tahun	1	Rp 4.439.250
System maintenance	1 tahun	1	Rp 17.757.000
Penggantian baterai	2 tahun	3	Rp 48.343.432
Gaji pegawai	1 tahun	6	Rp 335.789.136
Asuransi	1 tahun	6	Rp 13.431.565
Konsumsi	1 tahun	6	Rp 32.400.000

Besides, there are also variable costs that must be incurred by the company. These costs will show in Table 5.

Table 5. Variable Cost

Details	Period	Total	Cost/period
Biaya pengisian baterai	1 tahun	3	Rp 1.957.624

In Flow

In this case, the estimated savings are obtained by comparing the operational costs of PT XYZ's warehouse with the estimated cost of implementing the kiva robot. Details of PT XYZ warehouse operational costs will show in Table 6 below.

Table 6. Direct Labour Cost PT XYZ

Details	Total	Cost/unit	Cost/year
Gaji pegawai	12	Rp 4.663.738	Rp 671.578.272
Asuransi	12	Rp 186.550	Rp 26.863.131
Konsumsi	12	Rp 195.000	Rp 64.800.000
	Total		Rp 763.241.403

Decision Criteria Evaluation

The evaluation of the decision criteria is used to determine the investment feasibility of implementing the kiva robot which is calculated by considering the economic aspects. The methods used to perform economic analysis are Net Present Value (NPV), Rate of Return (ROR), Benefit-Cost Ratio (BCR), and Payback Period (PP). The following is the result of the decision criteria evaluation.

Table 7. Economic Analysis Result

Method	Result	Terms	Conclusion
NPV	Rp 671.801.045	NPV > 0	OK
ROR	19,27%	IRR > MARR	OK
BCR	1,21	B/C > 1	OK
PP	3,5 tahun	PP < 10 tahun	OK

Sensitivity Analysis

In this section, a sensitivity analysis will be conducted to determine the effect of the kiva robot speed on order picking productivity and charging costs per year. The results of the sensitivity test will show in Table 8 below.

Table 8. Sensitivity Analysis Result

Speed (m/s)	Time (h)	Order Fulfilled	Charger Cycle	Cost/year	Prod.
0,6	16	176	2	Rp 559.321	-24,14%
0,8	16	197	3	Rp 838.982	-15,09%
1	16	215	5	Rp 1.398.303	-7,33%
1,2	16	228	6	Rp 1.677.964	-1,72%
1,3	16	232	7	Rp 1.957.624	-
1,4	16	236	7	Rp 1.957.624	+1,72%
1,5	16	240	8	Rp 2.237.285	+3,45%
1,6	16	243	8	Rp 2.237.285	+4,74%

After the sensitivity analysis process is carried out, it is known that order picking productivity can increase by 1.72% if the kiva accelerates the speed up to 1.4 m / s and at the same cost. Then if the kiva robot increases the speed to the maximum limit of 1.6 m/s, the productivity of order picking can increase up to 4.74% with the charging cost to Rp. 2,237,285. If the kiva speed is slowed down to 1.2 m/s, there will be a decrease in productivity of 1.72% but the costs incurred will be lower, which is Rp. 1,677,964 per year.

Based on the results of data processing related to the calculation of charging costs per year. It can be elaborated on how the required costs affect the overall investment plan. The following table 9 is a recapitulation of the NPV, PP, IRR, and BBC values.

Table 9. Economic Analysis for Sensitivity Analysis Result

Speed (m/s)	PP	NPV	ROR	BCC
1,3	3,5	Rp 671.801.045	19.27%	1,21
1,4	3,5	Rp 671.801.045	19.27%	1,21
1,5	3,51	Rp 670.397.484	19.23%	1,21
1,6	3,51	Rp 670.397.484	19.23%	1,21

From the results above, it can be concluded that the calculation results of the NPV, ROR, and BCC methods have met the specified minimum requirements. However, when using a speed of 1.6 m / s, the company's savings will decrease by IDR 1,403,561 to IDR 670,397,484. Meanwhile, the BEP period showed similar results, from 3.5 years (3 years 6 months) to 3.51 years (3 years 6 months 3 days). Thus, it can be concluded that maximizing the kiva robot speed to obtain higher productivity is feasible to implement.

CONCLUSIONS

Based on the results of research on the implementation of the use of the kiva robot as a material handling tool in e-commerce warehouses, the following conclusions are obtained:

1. Based on the calculation of storage area requirements, the area required for warehouse order picking activity operations using Kiva Robot requires an area of 615.01 m^2. It is 5.96% smaller than the warehouse area of PT XYZ of 654.02 m^2.
2. Based on the simulated order picking scenario analysis, it is found that scenario 3 with 3 units of robot kiva and 2 areas of order picking station is the scenario that produces the best value. Scenario 3 takes 3 hours 27 minutes 27 seconds to complete 50 orders, 31.89% and 31.28% faster when compared to scenario 1 and scenario 2.While the average waiting time for kiva robots at stations in scenario 3 is 10 seconds for station A and 13 seconds for station B, 90.15% and 93.82% better when compared to the average waiting time for scenario 1 and scenario 2.
3. Economic analysis shows that the implementation of the use of the kiva robot as a material handling tool in PT XYZ's warehouse is feasible. Evidenced by the results of the calculation of the net present value (NPV) which produces a positive value of Rp. 671,801,045, the value of the rate of return (ROR) is 19.27% which is greater than the minimum attractive rate of return (MARR) of 15%. Calculation of the benefit-cost ratio (BCR) of 1.21 which is greater than 1 as the minimum requirement and the value of the payback period (PP) for 3 years and 6 months, shorter than the investment life of 10 years.
4. Based on the results of the sensitivity analysis, the productivity of order picking activity can be increased by 4.74% by accelerating the movement of the robot kiva from 1.3 m/s to 1.6 ms. Increasing the kiva ro bot speed will affect the charging cost per year to Rp. 2,237,285, an increase of 14.29% of the cost generated in scenario 3. The increase in the kiva robot speed is worth considering because it has an NPV value of Rp. 670,397,484, an IRR value of 19, 23%, the BCC value was 1.21, and the PP duration was 3 years 6 months 3 days.

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