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Simple Multi-Attribute Rating Technique for Warehouse Location Selection (Case Study: PT. PPT)

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ABSTRACT: Indonesia's Manufacturing Industry, encompassing processing and non-oil and gas processing, grew in Q3 of 2022, contributing 17.88% and 16.10% to GDP. Transportation and storage played a significant part, with a 15.93% year-on-year growth in Q1 2023, highlighting the sector's importance. PT. PPT is a sub-holding of one of Indonesia's companies. The company manages to trade PP/PE significantly from more sources (import, local producer, or local trader). This research will determine and analyze the criteria for the selection of warehouse locations for PT. PPT analyzes the weight of each criterion at each location in the warehouse location selection process for PT. PPT and obtain the priority location for PT. PPT to build a new warehouse. This research aims to guide and help the decision makers to choose and find a suitable location based on the Centre of Gravity (CoG) analysis conducted by a third-party consultant. The five locations resulting from the Centre of Gravity (CoG) as alternatives will be analysed with Kepner-Tregoe Analysis in the decision-making process, using Situation Appraisal defined in Business Issues. The author then employs a Rich Picture and Fishbone Diagram to assess the scenario or the process of select the new warehouse. The decision analysis was carried out in eight stages using the one of Multi-Criteria Decision Making (MCDM) method, which is the Simple Multi-Attribute Rating Technique (SMART). Lastly, using the preceding analysis, undertake a Potential Problem Analysis. The major criterion is the distance to the customer, which aligns with the company's emphasis on customer satisfaction. Demand growth affects warehouse capacity, with more growth necessitating a larger facility. Distance from suppliers reduces delivery lead time, and the size of the land must accommodate demand growth and product capacity for PT. PPT.

KEYWORDS: CoG, Kepner-Tregoe, MCDM, SMART, Warehouse Location

INTRODUCTION

Manufacturing Industry is one of the largest contributing sectors to Indonesia's GDP. In the third quarter of 2022, the growth of the processing industry and non-oil and gas processing industry grew by 4.83 and 4.88 per cent (y-on-y) respectively. Even though it was lower than Indonesia's economic growth which reached 5.72, the contribution of the Processing Industry to Indonesia's GDP during the third quarter of 2022 increased compared to the previous quarter to 17.88 per cent and the contribution of the Non-Oil and Gas Processing Industry also increased to 16.10 per cent [1]. Increasing competitive pressures and performance requirements cause logistics activities to become more important, and companies need logistics to gain a competitive advantage and build sustainable customer relationships. In recent years, this need felt by companies has increased their commitment to logistics and supply chain management. One of the key activities of logistics and supply chain management is storage. Storage includes all movements of goods in the warehouse or distribution, including receipt, storage, order collection, accumulation, sorting, and distribution [2]. Viewing economic growth from the production side, in the first quarter of 2023 all industries showed positive performance, especially Transportation and Storage, which continued to lead by 15.93% (YoY). In conclusion, Transportation and Storage are important factors in the industrial sector in Indonesia [3].

BUSINESS ISSUE

Table 1 below shows the cost structure of PT. PPT. It described the cost the company spends for each item to carry out its warehousing operations. Many costs cannot be controlled by the company, such as Tank Storage, Custom Clearance, and Surveyor Cost because it is based on customers' request. However, the cost that can be controlled is the warehouse cost which is the highest controllable cost for the company. This makes the company consider doing efficiency of the warehouse's cost.

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Table 1. Cost Structure of PT. PPT

Cost Structure	*Amount*	*Remark*
Tank Storage	12.300.000.000	Uncontrollable
Custom Clearance	5.392.000.000	Uncontrollable
Warehouse	**3.072.000.000**	**Controllable**
Trucking From Port	2.675.000.000	Controllable
Trucking From Warehouse	1.398.000.000	Controllable
Surveyor	489.000.000	Uncontrollable

Moreover, based on the increasing product stock in the Jakarta Warehouse of PT. PPT, it is evident that there is a growing number of products that should be stocked in the warehouse every year. However, the current warehouse cannot accommodate the growing product stock. Currently, the warehouses of PT. PPT are located in Kelapa Gading, Plumpang and Cikarang. The separate locations and the limited capacity of the current warehouse in Jakarta, lead to overcrowding and inefficiencies in inventory management. Another factor that needs to be taken into consideration is the status of the warehouse. It is rented to a third party and takes a lot of cost to spend.

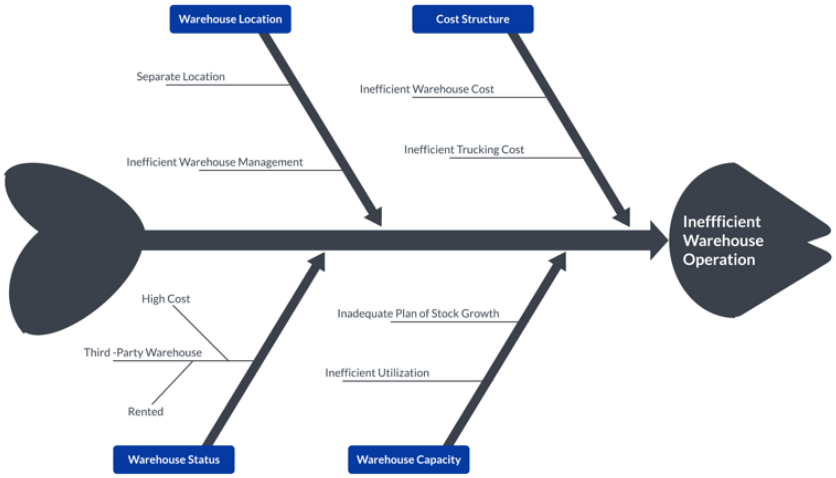

Figure 1. Fishbone Diagram

Figure 1 describe the overall problem that happened in PT. PPT. Therefore, to effectively manage the inventory, accommodate the increasing product stock, and minimize warehouse costs, the company must determine a suitable warehouse location that can accommodate the growing demand, ensure efficient operations, and have a reasonable cost. Several possible locations have already been determined by a third-party consultant. The location that will be chosen is the four nearest locations from the Centre of Gravity (CoG) calculation, and one location that can be considered as an ideal warehouse location.

The centre of Gravity (CoG) Method is a method for calculating geographic coordinates for a potential single new facility while minimizing expenses. This method is based on the principle that the optimal location for a particular facility or activity is at the centre of mass or gravity of all relevant points, where the main objective is to reduce the total transportation costs or travel distance [4]. Candidate locations consist of assets owned by the holding company and properties for sale (vacant land/warehouses) around the CoG point. The calculation results show that the Centre of Gravity (CoG) is in Rawa Buaya, Cengkareng, West Jakarta.

In PT. PPT, many stakeholders are involved in this new warehouse location decision-making, including the Sales and Marketing, Director, Supply Chain, Investment Committee, Customer, and Third-party Consultant. The rich picture raises several questions and concerns related to the business. Each stakeholder has their own set of concerns and priorities, and the rich picture in Figure 2 helps to identify and visualize these issues.

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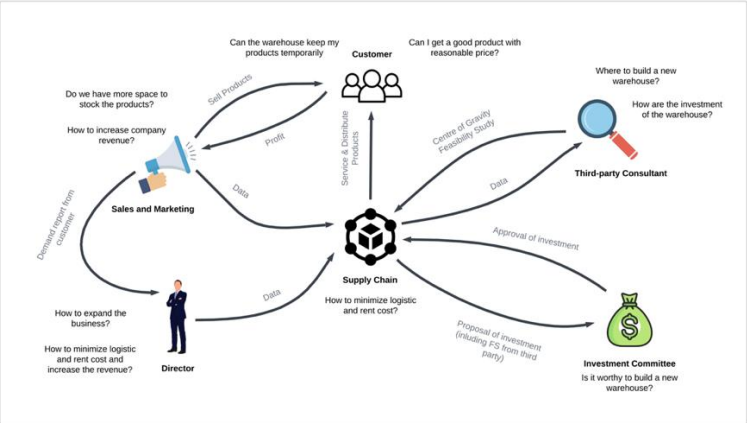

Figure 2. Rich Picture

This research will determine and analyze the criteria for the selection of warehouse locations for PT. PPT, analyzes the weight of each criterion at each location in the warehouse location selection process for PT. PPT, and obtain the priority location for PT. PPT to build a new warehouse. The research is focused on identifying an optimal warehouse location within Jakarta to accommodate the storage needs of the company's polymer or dry products. The research is conducted from July to November 2023.

CONCEPTUAL FRAMEWORK

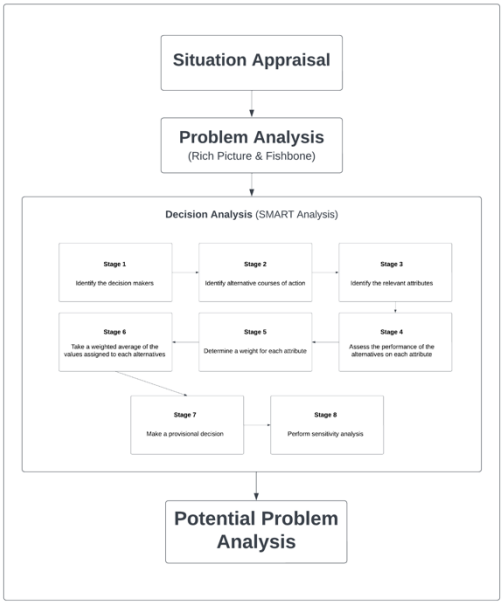

Figure 3. Conceptual Framework

The conceptual framework for determining the location of a new warehouse involves considering various factors that can impact its design, operational performance, energy consumption, and sustainability [5]. The decision-making process will be performed by using Kepner and Tregoe Analysis, with Situation Appraisal defined in Business Issue. Then, the author uses a Rich Picture and Fishbone Diagram to analyze the problem, situation, or the process of selecting the new warehouse. Decision Analysis was conducted with the Simple Multi-Attribute Rating Technique (SMART) with 8 stages. This method is used in this research due to ease of use in practice to perform simple decision-making. SMART is one of the methods for decisions involving multiple criteria or objectives

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with a finite set of alternatives. The performance of each alternative is expressed in grades on numerical scales, which are evaluated through a direct-rating procedure [6]. Lastly, Potential Problem Analysis can be performed by using the previous analysis.

RESEARCH METHODOLOGY

A. Research Design

Research designs are study strategies and procedures that range from broad assumptions to methods of data gathering and analysis. This plan involves multiple decisions, which do not have to be made in the order in which they make sense to me and are presented below. The ultimate choice entails determining which design should be employed to investigate an issue. This decision should be informed by the researcher's worldview assumptions, procedures of inquiry (called strategies), and specific methods of data gathering, analysis, and interpretation. A research design is also chosen based on the nature of the research topic or issue being addressed, the researchers' own experiences, and the research's readers [7].

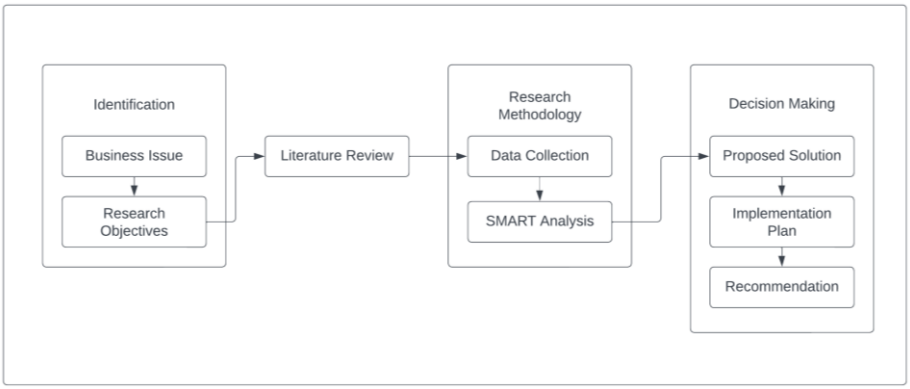

Figure 4. Research Design

B. Data Collection Method

Primary Data

The interviews will be examined throughout the qualitative phase to discover reoccurring themes, topics, and criteria that are important to the company. These criteria will be retrieved to develop a structured questionnaire for the quantitative phase that follows. The qualitative data will allow to determine the root causes of company problems and drive the development of survey questions geared to analyze these parameters more thoroughly.

In the second phase of the data collection method, quantitative data will be gathered through the distribution of questionnaires to the company's employees. These questionnaires will be designed to measure the weight and rating of each previously identified criterion. The company will rate the criteria according to their perceived importance and relevance, providing numerical data for each criterion. This phase enables the transformation of qualitative insights into quantitative data for further analysis.

Secondary Data

Secondary data, on the other hand, is derived from prior accessible sources. Secondary data for the research comes from two main sources: current literature and company data. The literature review enables to incorporation of pertinent ideas, concepts, and findings from earlier field research. This provides a broader context for understanding company difficulties and determining criteria. Company data, such as historical data of existing warehouses supplement primary data by providing a historical perspective on the company's difficulties and the efficacy of previous solutions.

RESULT AND DISCUSSION

A. Analysis

Stage 1: Identify decision maker(s)

In an uncertain environment, decision-makers have to deal with various alternatives and criteria. Furthermore, numerous people are involved in the decision-making process [8]. The decision-makers of this research are:

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Table 2. Decision Makers

No	Job Title
1	Supply Chain Manager
2	Sales Manager
3	Marketing Manager
4	Sales Branch Manager Polymer
5	Third-Party Consultant

Each job title's function and responsibilities in the vital decision-making process of identifying the optimal location for a new warehouse are critical and complicated. These decision-makers are tasked with creating a thorough and strategic plan to discover and eventually select the most advantageous and best location for the new warehouse. The chosen location must not only match existing operational needs but also be positioned to support future growth and changing market dynamics.

As a result, the decision-maker in these positions holds the significant duty of guaranteeing the success of the organization's supply chain and distribution network, creating the groundwork for efficient and seamless operations, and improving overall business performance.

Stage 2: Identify alternative courses of action.

The alternatives for the research are already decided based on the *Centre of Gravity* that the Third-Party Consultant has determined. The alternatives are:

Table 3. Alternatives for SMART Analysis

Alternative	***Location***
Alternative. 1	Jalan Daan Mogot 16 Kalideres
Alternative. 2	Jalan Daan Mogot 1 Grogol Petamburan
Alternative. 3	Meruya Utara, Jl. Safir 5
Alternative. 4	Jl. Perintis Kemerdekaan, Pulo Gadung
Alternative. 5	Rawa Buaya, Jl. Daan Mogot

Stage 3: Identify the relevant attributes.

The relevant attributes in the alternatives are called the “Decision Criteria”. The relevant attributes have two main attributes, *Cost* and *Benefit*. The criteria were developed based on the discussion with PT. PPT. In order to facilitate more effective comparison and analysis, the author, after collaborating with PT. PPT decided to further subdivide the main attribute of *Benefit* into more specific sub-attributes. Initially, *Benefit* was presented as a single, broad category. However, to conduct a more detailed evaluation, it was deemed necessary to break it down into its constituent components. This resulted in the creation of two distinct sub-attributes: *Market* and *Location*.

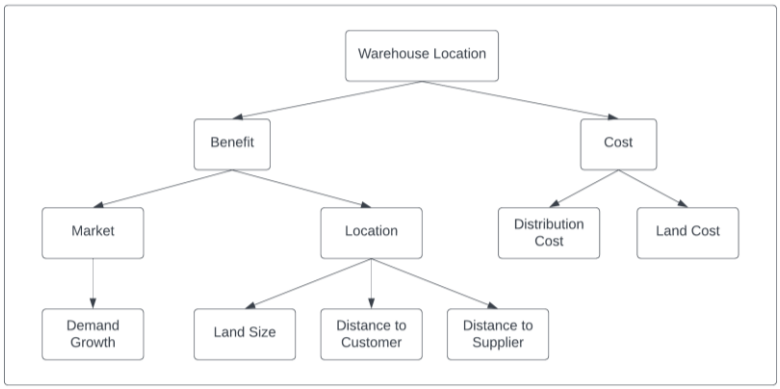

Figure 5. Relevant Attributes

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The *Market* attribute is broken down into *Demand Growth*, one of the important determinant factors. Future market growth will result in increased demand and, as an outcome, economies of scale [9]. In this research, *Demand Growth* is needed to determine the capacity or building size of a new warehouse. For *Location*, the size of the land is important since it affects the available space for inventory storage and overall warehouse operations. Maintaining a balance is critical, ensuring enough land to fulfil current and future needs without wasting money on wasted areas. Distance to Customer is an important issue that influences delivery times and costs. The optimal location of warehouses near large consumer bases allows for rapid and effective product distribution. Similarly, the distance to suppliers has a significant impact on incoming transportation costs. Choosing a warehouse location close to important suppliers helps save transportation costs, which contributes to overall operational efficiency.

Stage 4: Assess the rating of the alternatives on each attribute.

In stage 4, Table IV.6 outlines how each decision-maker ranked the alternatives based on their relative importance. The assigned weights show the individual's preference for each alternative. Below is the weight of Land Size from each decision-maker.

Table 4. Land Size

Alternative / Decision Maker	*Supply Chain Manager*	*Sales Manager*	*Marketing Manager*	*Sales Branch Manager Polymer*	*Third-Party Consultant*	*Average*
Alternative 1	**100**	**100**	**95**	**100**	**100**	**99**
Alternative 2	60	65	60	65	90	68
Alternative 3	55	70	65	60	80	66
Alternative 4	65	75	70	70	70	70
Alternative 5	100	95	100	95	100	98

Based on Table 4, Alternative 1 is the most preferred Land Size among others with an average rating of 99. The Third-Party Consultant and Sales Branch Manager Polymer gave Alternative 1 a weight of 100, indicating that it was the top choice of the consultant. The Marketing Manager gave 95 to Alternative 1, which shows that they prefer it, but not as strongly as the Third-Party Consultant and Sales Branch Manager Polymer. In conclusion, the analysis shows that Alternative 1 is the most advantageous alternative due to its status as a Holding Company asset. The key reason Alternative 1 received the greatest average weight is its relationship with The Holding Company, which allows for more cost-effective land purchase and has a large land size.

Table 5. Distance to Customer

Alternative / Decision Maker	*Supply Chain Manager*	*Sales Manager*	*Marketing Manager*	*Sales Branch Manager Polymer*	*Third-Party Consultant*	*Average*
Alternative 1	75	90	95	80	90	86
Alternative 2	80	85	90	85	95	87
Alternative 3	**100**	**95**	**100**	**95**	**100**	**98**
Alternative 4	25	30	45	50	70	44
Alternative 5	60	70	75	75	80	72

The ratings of many decision-makers regarding the distance of each choice from customers are elaborated in Table 5. The analysis reveals that Alternative 3 becomes the highest average rating (98), indicating that decision-makers agree that it is the closest to the customers. Alternative 2 receives the second-highest average rating (87), followed by Alternatives 1 (86) and 5 (72), and Alternative 4 receives the lowest average rating (44).

Customers' closeness is important in a variety of industries and commercial scenarios. Shorter delivery distances result in lower transportation costs and logistical improvements, which contribute to overall operational efficiency, and allows for faster deliveries and on-site support can also provide rapid and accessible customer service. As a result, the significance of distance of customers is

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diverse, embracing elements that go beyond the specific nature of the items and connecting closely with the dynamics of customer behaviour, cost-effectiveness, and service excellence.

Table 6 Distance to Supplier

Alternative / Decision Maker	*Supply Chain Manager*	*Sales Manager*	*Marketing Manager*	*Sales Branch Manager Polymer*	*Third-Party Consultant*	*Average*
Alternative 1	70	70	80	75	85	76
Alternative 2	75	85	85	80	75	80
Alternative 3	30	35	50	45	70	46
Alternative 4	**95**	**90**	**100**	**90**	**100**	**95**
Alternative 5	45	45	40	55	60	49

Table 6 shows the average ratings given by different decision-makers for each rating in terms of distance to suppliers. Alternative 4 receives the greatest average rating (95), indicating that decision-makers believe it is the closest choice to suppliers. Alternatives 2 and 1 come in second and third, with average scores of 80 and 76, respectively. Alternatives 5 and 3, on the other hand, obtain the lowest average ratings (49 and 46), indicating that they are seen to be further away from suppliers.

The importance of distance to suppliers for PT. PPT is dependent on several factors. Production lead times are one factor to consider, as being closer can minimize lead times and improve production efficiency, especially in scenarios needing frequent deliveries or just-in-time inventory management. Shorter distances to suppliers, like customer closeness, can reduce transportation costs and logistics. Moreover, physical closeness improves communication, collaboration, and quality control with suppliers, resulting in stronger partnerships. Furthermore, distance to suppliers offers greater flexibility and responsiveness to unanticipated supply chain disruptions or changes in demand.

Table 7. Demand Growth

Alternative / Decision Maker	*Supply Chain Manager*	*Sales Manager*	*Marketing Manager*	*Sales Branch Manager Polymer*	*Third-Party Consultant*	*Average*
Alternative 1	**100**	**100**	**100**	**100**	**100**	**100**
Alternative 2	50	40	30	60	45	45
Alternative 3	50	45	35	65	45	48
Alternative 4	80	60	65	70	65	68
Alternative 5	**100**	**100**	**100**	**100**	**100**	**100**

Table 7 analyses the average ratings given to each choice by various decision-makers in terms of their potential for demand growth. Alternative 1 and Alternative 5 had the highest average rating (100), suggesting that decision-makers believe it has the greatest potential for considerable demand increase. Alternatives 4 come in third position, with an average rating of 68. Alternatives 2 and 3, on the other hand, earn the lowest average scores (48 and 45), indicating projections of considerably weaker demand growth.

Future company plans are critical since a site with strong potential demand growth relates to aggressive expansion plans, assuring adequate warehouse capacity for future needs. To avoid shortages of products, increased demand could require more effective inventory management systems and bigger storage space. Additionally, increased demand can result in economies of scale, thereby lowering overall operational costs per unit. Choosing a location with high development potential also helps to justify the investment in a new warehouse.

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Stage 5: Determine a weight for each attribute.

Table 8. Weight from each attribute

No	*Criteria*	*Original Weight*
1	Land Size	74
2	Distance to Customer	92
3	Distance to Supplier	86
4	Demand Growth	88
Total Weight		342

Above, Table 8 defines the weights attributed to four critical criteria that must be considered while evaluating a new warehouse location. Distance to the supplier is given a weight of 86, indicating its third-highest relevance and underlining the importance of the closeness of the supplier in prospective locations. With the second-highest weight of 86, demand growth takes priority emphasizing its critical importance for good warehouse operations. The lowest weight is Land Size with 74, emphasizing its relevance in the choosing process. The distance of the customers is given the highest weight, 92, emphasizing the importance of considering the closeness to the customers. The cumulative weight for all four criteria amounts to 342, emphasizing the necessity of a comprehensive evaluation of potential warehouse locations. The weights are assigned based on the specific importance of each criterion, tailored to meet the unique operational needs. Below, the swing attribute in Figure 6 provides further insight into this comprehensive assessment.

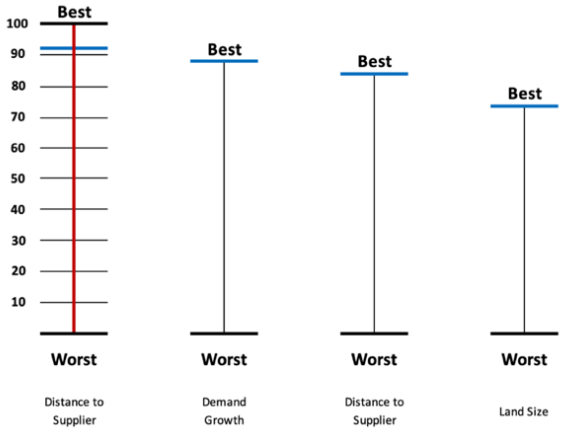

Figure 6. Swing Weight of Attributes

The original weights showed the overall importance of each component, but normalizing them to a scale of 0 to 1 reveals a more comprehensive picture. With a normalized weight of 0.27, distance to the customer takes the highest importance, closely followed by demand growth at 0.26. Land size and distance to suppliers are weighted at 0,25 and 0,22, showing the criteria are also important or influence the decision-making process. The following Figure 6 and Table 9 explain a clear and comparable structure for evaluating potential warehouse locations, preventing any single factor from overshadowing the others and allowing for a more balanced analysis.

Table 9. Normalized Weight

No	*Criteria*	*Original Weight*	*Normalized*
1	Land Size	74	0,22
2	Distance to Customer	92	0,27
3	Distance to Supplier	86	0,25
4	Demand Growth	88	0,26
Total		342	340

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Stage 6: Weighted average of the values assigned to the alternative.

The aggregate benefit for each alternative was calculated using a weighted average of individual ratings for Land Size, Distance to Customer, Distance to Supplier, and Demand Growth. The normalised weights, which add up to one, indicate the relative importance of each criterion in the overall decision-making process.

Table 10. Aggregate Benefits

Alternative/criteria	*Land Size (0,23)*	*Distance to Customer (0,25)*	*Distance to Supplier (0,23)*	*Demand Growth (0,28)*	*Aggregate Benefit*
Alternative 1	**21,55**	**23,27**	**19,22**	**25,88**	**89,9**
Alternative 2	14,80	23,54	20,24	11,65	70,2
Alternative 3	14,36	26,52	11,64	12,42	64,9
Alternative 4	15,24	11,91	24,03	17,60	68,8
Alternative 5	21,33	19,48	12,39	25,88	79,1

Breaking down Table 10, Alternative 1 has the highest aggregate benefit score (89.9), confirming it as the most desirable choice when all criteria are combined. Alternative 5 comes in second with a score of 79.1, followed by Alternatives 2 (70.2), Alternative 4 (68.8), and Alternative 3 (64.9).

The analysis reveals that Alternative 1 performs better in Land Size and Demand Growth, demonstrating a well-rounded choice with significant future growth potential. Alternative 5 scores well on Demand Growth but needs to catch up on other factors, making it less competitive than the top two options. Alternative 4 has the greatest benefit in Distance to the Supplier but has a low benefit to others. Alternative 3, on the other hand, outperforms in Distance to the Customers but falls short in Land Size, Demand Growth and Distance to the Supplier, making it an effective choice for preferring customer proximity over long-term scalability. However, alternatives 3 and 2 have lower overall scores due to specific flaws, such as the comparatively small area of Alternative 2's land and Alternative 3's distance to suppliers.

Stage 7: Make a provisional decision.

Before finalizing the selected criteria, the provisional decision aims to provide decision-makers with all the details. Columns in Table 11 breakdown include Benefits, which highlight potential benefits, and Total Cost, which reflects the expected expenses connected with each criterion.

Table 11. Provisional Decision

Alternative	*Benefit*	*Total cost*
Alt 1	89,9	3.248.347.246
Alt 2	70,2	566.087.349
Alt 3	64,9	1.602.259.011
Alt 4	68,8	28.270.579.301
Alt 5	79,1	108.256.190.645

A more detailed examination of Table 11 shows deeper observations. Alternative 1 is the preferred alternative, with a high benefit score of 89.9 and a relatively low total cost of Rp. 3.248.347.246. Meanwhile, Alternative 2 offers a significant benefit (70.2) at a low cost of Rp. 566.087.349. Alternative 3 strikes a reasonable balance, with a low benefit (64.9) and a cost of 1.602.259.011. Alternative 4, while providing a moderate benefit of 68.8, does it at a substantially lower cost of Rp. 28.270.579.301. Finally, Alternative 5 has a remarkable benefit (79.1) but a relatively large cost of Rp. 108.256.190.645. This provisional decision helps decision-makers navigate the selection process by clarifying the trade-offs between benefits and costs associated with each possibility.

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For each of the alternatives, the aggregate value of benefits has been plotted compared to the cost in Efficient Frontier (Figure 7). The cost scale has been 'reversed around,' so that the lower (and therefore preferable) costs are on the right. This helps to make this graph comparable to others later. Clearly, the higher an alternative ranks on the benefits scale and the lower it ranks on the cost scale, the more appealing it is.

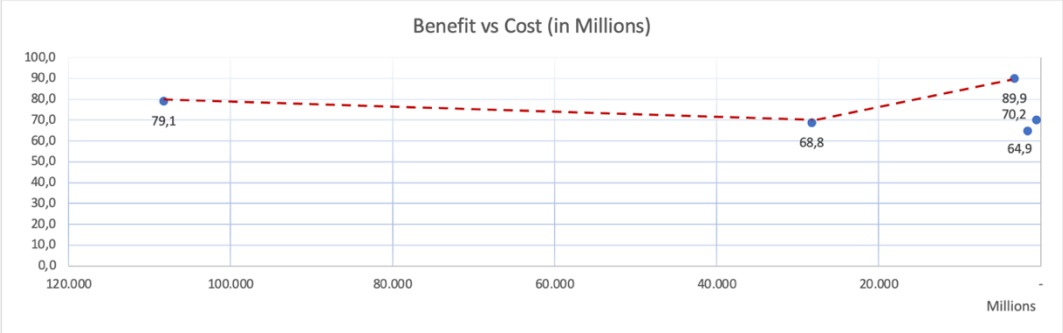

Figure 7. Efficient Frontier

From the graph, Alternative 5 has higher benefits. Similarly, Alternative 1 not only has lower costs but also higher benefits compared with other alternatives. While Alternative 4 has a moderate cost but has a relative benefit. Thus, the only locations which are worth considering are Alternative 5, Alternative 4, and Alternative 1. The choice between the three alternatives on the efficient frontier will depend on the relative weight the decision-makers attach to costs and benefits.

Table 12. Comparison of Provisional Decision

		Alt 1		***Alt 4***	
		3.248.347.246	*89,9*	*28.270.579.301*	*68,8*
Alt 5	*108.256.190.645*			79.985.611.344	10,32
	79,1			7.752.311.248	
Alt 4	*28.270.579.301*	25.022.232.054	21,15		
	68,8	1.182.919.757			

Consider shifting from Alternative 4 to Alternative 5, as seen in Table 12 where the benefits rise from 68.8 to 79.1, a 10.32-point increase. The shift comes at an additional cost of Rp. 79,986,611,344. The result, the cost per incremental value point is Rp. 7,752,311,248 (Rp. 79,986,611,344/10.32). A similar analysis of shifting from Alternative 4 to Alternative 1 finds a significant gain in benefits of 21.15 points for Rp. 25,002,232,054. In this scenario, the cost per extra value point is Rp. 1,182,919,757 billion (Rp. 25,002,232,054/21.15).

To make a well-informed choice, PT. PPT must weigh the importance of each extra value point. Alternative 4 becomes the favored option if this number is less than Rp. 1,182,919,757. Alternative 1 should be chosen if the owner believes it is worthwhile to pay more than Rp. 1,182,919,757 for each extra value point. Similarly, if the PT. PPT values an extra point at less than Rp. 7,752,311,248, Alternative 4 remains preferable; otherwise, if it is worth paying more than Rp. 7,752,311,248 for each extra value point, Alternative 5 is the preferred option. Table IV.15 below shows about the summary of extra value point:

Table 13. Extra Value Point

Extra Value Point	***Alternative Chosen***
< 1,182,919,757	Alternative 4
≥ 1,182,919,757	Alternative 1
< 7,752,311,248	Alternative 4
≥ 7,752,311,248	Alternative 5

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In contrast to the basic application of the Simple Multi-Attribute Rating Technique, in which the value of an extra value point is determined equally, the scenario with Alternative 1 presents a unique case. In this case, Alternative 1's great value combined with its low cost distinguishes it from the typical method. The unique aspect is the detailed rating of each alternative, in which not only the incremental benefits but also the accompanying costs are thoroughly considered. The value associated with each extra point requires an evaluation of lower-level qualities inside the value tree. PT. PPT is entrusted with determining an attribute for which they can assign a monetary value to the improvement from worst to best, assuming no other changes.

In this research, the company estimates the value of increasing the size of a warehouse from the lowest to the largest land area while keeping all other criteria constant. The company is willing to pay an additional USD 1,800,000 or Rp. 28,618,200,000 yearly to upgrade the land size of a warehouse from the smallest equal to the best, under unchanging conditions, expressing a preference for evaluating the improvement in land size. This equals to a Rp. 28,618,200,000 billion valuation for a 100-point increase in the land size criteria. Given that the normalized weight of land size contributes to 22% of the total weight assigned to criteria, a 100-point increase on the representation scale equals a 22-point rise in the extra value of a warehouse's benefits.
Land Size Weight: 0,22 (22 points)

$$Extra\ value = \frac{IDR\ 28{,}618{,}200{,}000}{22}$$

$$= IDR\ 1{,}314{,}890{,}270$$

Based on the calculation above, it can be concluded that PT. PPT will have an extra value of IDR 1,314,890,270. Then, Alternative 1 will be suitable for the new warehouse location of the company.

Stage 8: Sensitivity Analysis

A sensitivity analysis is required to assess the robustness of the solution. This method of analysis displays the effect of varying the weights assigned to choice criteria on the total aggregate score. In fundamentals, the sensitivity analysis assesses the solution's robustness to changes in individual criteria while also providing insights into prospective outcomes under extreme situations in one criterion, offering light on the interrelated dynamics with other criteria.

Table 14. Original Rating Average

Alternative / criterion	*C1*	*C2*	*C3*	*C4*
A1	99	86	76	100
A2	68	87	80	45
A3	66	98	46	48
A4	70	44	95	68
A5	98	72	49	100

Table 14 presents the original rating average derived from Stage 4, alongside the original and normalised weights obtained in Stage 5 on Table 15. With the comprehensive data gathered from the preceding stages, the next step involves conducting a sensitivity analysis

Table 15. Original Weight and Normalized Weight

No	*Criteria*	*Original Weight*	*Normalized*
1	Land Size	74	0,22
2	Distance to Customer	92	0,27
3	Distance to Supplier	86	0,25
4	Demand Growth	88	0,26

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In this scenario, demand growth or Market is purposefully set to zero, as seen in Table 16, making it functionally detached with a weight of 0.00. Despite its existence in the table, its absence of weight suggests that demand growth has no impact on the overall assessment in this calculation.

Table 16. Original Weight and Normalized Weight with Market = 0

No	*Criteria*	*Original Weight*	*Normalized*
1	Land Size	74	0,22
2	Distance to Customer	92	0,27
3	Distance to Supplier	86	0,25
4	Demand Growth	0	0,00

The next step is to compute the aggregate benefit for each alternative with demand growth (market) = 0. This is accomplished by multiplying each criterion's score by its matching normalized weight. The products for all criteria are then added together to produce a score for each alternative. Importantly, this score is based only on the importance of the criteria, removing the influence of demand growth, which has been purposely eliminated in this case.

Table 17. Aggregate Benefit with Market = 0

Alternative / criterion	*C1*	*C2*	*C3*	*C4*	*Aggregate Weighted Value*
A1	**21,5**	**23,3**	**19,2**	**0**	**64,0**
A2	14,8	23,5	20,2	0	58,6
A3	14,4	26,5	11,6	0	52,5
A4	15,2	11,9	24,0	0	51,2
A5	21,3	19,5	12,4	0	53,2

As seen in Table 17 with Market = 0, has a slight impact on the weighted value of each alternative. Alternative 1 is stable in the first position or the highest weighted value, even though it has a significant decrease from the situation. Similar to Alternative 5, which has experienced the same amount of decline, which make Alternative 5 dropped position from second to third. In contrast to Alternative 2, it witnessed a minor dip, putting it in second place when it was previously in third. It is possible to conclude that Alternative 1 is sufficiently stable in the condition Market = 0.

Table 18. Original Weight and Normalized Weight with Location = 0

No	*Criteria*	*Original Weight*	*Normalized*
1	Land Size	0	0
2	Distance to Customer	0	0
3	Distance to Supplier	0	0
4	Demand Growth	88	0,26

The Location attribute is then purposely set to zero in Table 18, meaning that only Demand Growth can influence the rating number. Alternatives 1 and 5 in Table 19 have the same amount of average weighted value. It is caused by the fact that all decision-makers chose the same number of ratings (100). Decision makers feel that both solutions can meet the capacity of strong demand growth.

Table 19 Aggregate Benefit with Location = 0

Alternative / criterion	*C1*	*C2*	*C3*	*C4*	*Aggregate Weighted Value*
A1	**0**	**0**	**0**	**25,9**	**25,9**
A2	0	0	0	11,6	11,6
A3	0	0	0	12,4	12,4
A4	0	0	0	17,6	17,6
A5	**0**	**0**	**0**	**25,9**	**25,9**

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Following the analysis of both Market = 0 and Location = 0 situations, the next important phase is to perform a sensitivity analysis. The analytical procedure attempts to assess the robustness of the selected new warehouse location by investigating how modifications in the weights of the choice criteria affect the aggregate score.

Table 20. Sensitivity Analysis

Alternative / criteria	*Aggregate Benefit (Location)*	*Aggregate Benefit (Original)*	*Aggregate Benefit (Market)*
A1	64,0	89,9	25,9
A2	58,6	70,2	11,6
A3	52,5	64,9	12,4
A4	51,2	68,8	17,6
A5	53,2	79,1	25,9

Figure 8, the sensitivity analysis has been calculated. It is shown how the value of benefits for the different alternative locations varies with changes in the raw weight. As seen in Figure 8, Alternative 1 still has the highest value among other alternatives. Alternative 2 is the second highest when Location = 0, but it is no longer the second highest when Market = 0, it is from 58,6 to 11,6 which makes Alternative 2 the lowest. Meanwhile, Alternative 5 has the third highest in 53,2 when Location = 0, and it is positioned the highest when Market = 0 in the sensitivity analysis (25,9) similar to Alternative 1. From the analysis above, it is concluded that Alternative 1 is the best location to build a new warehouse for PT. PPT.

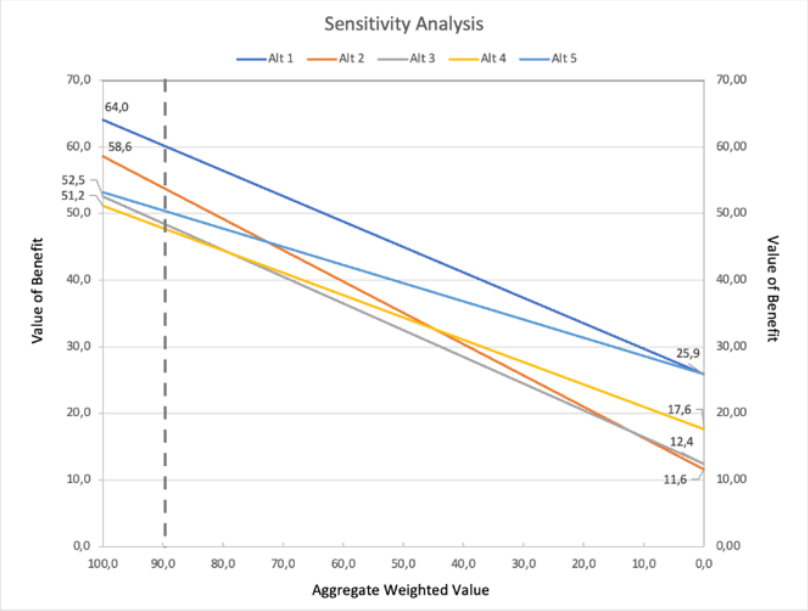

Figure 8. Sensitivity Analysis

B. Potential Problem Analysis

Strategic warehouse location selections are critical in enhancing supply chain efficiency in the current dynamic business context. As PT. PPT is looking for a new warehouse location, so it is critical to perform a thorough investigation of the potential problems connected with the chosen alternative. Alternative 1 has emerged as the preferable alternative in this analysis, delivering a variety of benefits. However, a thorough research of potential issues is required to provide a well-informed and resilient implementation. This analysis will go deeper into the complexities of Alternative 1, providing light on the predicted barriers and proposing tactical approaches for dealing with these issues. The potential problem analysis for alternative are:

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Table 21. Potential Problem Analysis

Potential Problem	*Consequence*	*Possible Cause*	*Preventive Action*	*Contingent Action*
Ownership status	Termination of prolongation contract and move out from the property	Change of regulation in Holding Company	Letter of Appointment for long term status	Consider to buy a land or consider other alternatives
Inefficient of the land size utilization	Waste space and inefficiency of operation	Poor space planning, lack of inventory management, inadequate warehouse layout	Implement inventory and land management systems, make a plan to optimize warehouse layout for the efficient flow of goods	Building up by using vertical space
Supply Chain Disruption	Delays in product deliveries, customer dissatisfaction, reputational damage	Ineffective delivery process, poor communication, inadequate performance monitoring	Implement regular communication channels, conduct ongoing performance reviews	Using 3PL (third-party logistics) provider, implement contingency plans
Ineffective marketing and sales strategies	Stagnant demand, missed sales targets, reduced revenue	Lack of market research, poor targeting, ineffective messaging	Conduct market research, identify and target key customer segments, develop marketing campaigns, invest in sales training	Revise marketing and sales strategies, seek external marketing expertise if needed

There are some advantages to PT. PPT if the company choose Alternative 1 as their new warehouse location:

1. **Cost-Effectiveness**
   Alternative 1's key advantage is its low total cost when combined with its large land size. This results in a substantial profit for PT. PPT. The spacious land's reduced acquisition or rental cost offers perfect budget flexibility. Extra investment can be widely deployed to other critical aspects of the organization.
2. **Strategic Location Balancing**
   According to the Centre of Gravity calculation, Alternative 1 is in a moderately central location in terms of supplier and consumer distance. The balanced location guarantees effective delivery routes for incoming goods from suppliers as well as shipments to customers. While not the absolute closest to either, this middle ground reduces overall shipping costs and lead times, establishing an appropriate balance between supplier and customer convenience.
3. **West Jakarta's Advantage**
   Alternative 1's specific location within West Jakarta offers PT. PPT has several distinct benefits. Firstly, it provides easier access for on-site monitoring. This proximity allows for regular physical inspections of the warehouse and its operations, ensuring optimal efficiency and adherence to quality standards. Secondly, West Jakarta's extensive network of major highways facilitates swift and efficient deliveries to customers and timely product receipt from suppliers. This infrastructure advantage minimizes lead times and transportation costs, further enhancing the operational effectiveness of the warehouse.

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CONCLUSION AND RECOMMENDATION

C. Conclusion

Currently, PT. PPT want to do an efficient cost of warehousing operations. One of the controllable costs that can be managed by the company is Warehouse Cost, which is the largest cost that the company has. Moreover, there is a growing number of products that should be stocked in the warehouse every year. The company wanted to increase its revenue to cover the costs associated with the expanding product stock in the warehouse. However, the current warehouse cannot accommodate the growing product stock. This research aims to guide and help the decision makers to choose and find a suitable location based on the Centre of Gravity (CoG) analysis. From the analysis, the author found the conclusions and answered the research questions:

The criteria for selecting the location of the warehouse are:

1. *Land Size*
   It highlights the physical space available for the warehouse, which reflects its ability to accommodate product storage needs. A larger area of land enables versatility and efficient storage management, hence enabling the company's potential expansion.
2. *Distance to Customer*
   This criterion focuses on the warehouse's proximity to the end customers. The strategic position close to customers ensures timely deliveries, improves customer happiness, and lowers transportation costs, all of which are critical supply chain concerns.
3. *Distance to Supplier*
   It refers to the warehouse's geographical proximity to the supplier. By providing a rapid and adaptable supply chain, a closer distance reduces lead times, streamlines the delivery process, and contributes to overall operational efficiency.
4. *Demand Growth*
   The demand growth criterion evaluates the expected rise in product demand over time. A location that is aligned with prospective demand growth is critical for guaranteeing that the warehouse can efficiently fulfil the market's developing needs and the company's expanding product portfolio.

From the weight, it can be concluded that the priority of each criterion is to select the new warehouse location. Based on SMART Analysis, the weight of criteria are:

Table 21. Potential Problem Analysis

No	*Criteria*	*Original Weight*
1	Land Size	74
2	Distance to Customer	92
3	Distance to Supplier	86
4	Demand Growth	88

Distance to the Customer is the criterion that has the highest weight among others (92) and emerges as a paramount consideration. From the justification of the company, prioritizing customer satisfaction has aligned with the company's core business. Demand Growth directly influences to determine the capacity of the warehouse (88). The more demand growth per year, the size of the warehouse would be bigger. Distance to Suppliers (86) is the critical criterion to minimize the lead time of the delivery process. Lastly, PT. PPT has to consider Land Size (74) that is suitable to accommodate the demand growth or the capacity of the products.

The priority location of the new warehouse is Alternative 1, located in Jalan Daan Mogot 16, Kalideres. Alternative 1 has significant benefits for PT. PPT, particularly in terms of cost-effectiveness and strategic location balance. Alternative 1's combination of reasonably priced overall cost along with substantial land size adds greatly to maximizing profitability while enabling budget flexibility for essential organizational components. Moreover, the Centre of Gravity estimate placed Alternative 1 in an approximate central position for both suppliers and customers. This balanced location enables efficient delivery routes, which reduces overall shipping costs and lead times. Furthermore, the specific location within West Jakarta provides distinct advantages, including easier

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on-site monitoring for optimal efficiency and adherence to quality standards, as well as access to an extensive number of major highways. These advantages collectively position Alternative 1 as a favourable choice for PT. PPT's new warehouse location.

D. Recommendation

The recommendation that suitable for PT. PPT from the Business Solutions and Implementation Plan are:

1. Renting a new warehouse and considering other alternatives to reduce the difficulties associated with inefficient land usage while also providing flexibility in supporting increasing demand or shifting inventory requirements.
2. Acquiring experienced warehouse staff with a proven track record or instituting a complete training program for current employees to strengthen its workforce and establish the required skills to get through the hurdles involved in the establishment and management of a new warehouse through these actions Also, PT. PPT can acquire Third-Party Logistics (3PL) to minimize the lead time and easier to manage and control the process of operation.
3. To prevent the flood, PT. PPT can conduct a detailed risk assessment relevant to floods, taking into account historical data, climate patterns, and the warehouse's vulnerability, invest in infrastructure upgrades that will increase the warehouse's resilience to flooding, and also have insurance against water damage. This includes examining and upgrading insurance coverage to protect against potential losses and business interruptions caused by flooding.

For future research, comparative studies with other decision-making models are strongly recommended to do a deeper understanding of the applicability and effectiveness of different models in diverse contexts. It is to assess the strengths and weaknesses of the simple multi-attribute rating technique in comparison to alternative methodologies.

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