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Optimizing the distribution channel for Rattan seeds (*Calamus manan*) in Katingan Forest in Central Kalimantan of Indonesia

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Abstract

Finding the best distribution route, distance, and cost for rattan seed supplies is the goal of this study. Farmers made up the study's population. interview-based data collecting. An obtained first solution is required to perform data processing. The first solution's outcomes are then transferred to obtain a new route by exchanging the point matrices for each route. Depending on how many possible moves (permutations) there are on each path, the number of iterations varies. One move is thought to be equivalent to one iteration in this instance. Every iteration involves a check to determine if the move attribute being utilized is present in the tabu list or not. Based on the research results, it was found that the length of the existing (initial) distribution route was 8245.89 km, and the proposed new route length was 6917.85 km, or a saving of 16%. There is a grouping of six transport routes based on the level of proximity between villages, where the rattan seeds will then be transported to the forest. The distribution cost calculation formulation can be used for other commodities that have the same characteristics as rattan.

Keywords: Distribution routes, Distance, Costs, Rattan seeds.

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1. Introduction

Rattan (Palmae family vines) is a vine that hangs from the thick stands of wood trees in the forest [1]. Rattan is known as a green product because its natural properties are an indicator of the ecological health of the forest [2]. Currently, Indonesia is the largest producer of rattan in the world; it is one of the livelihoods of the Dayak tribe. Socio-cultural rattan cultivation is part of the daily life of the Dayak tribe in the Katingan forest, Central Kalimantan, where this area is the largest producer of rattan seeds in Indonesia [3]. Currently, the need for rattan seeds has started to increase after the upstreaming of the rattan industry. Finished goods are starting to be in demand, such as rattan crafts and rattan furniture. The demand for rattan seeds is starting to increase, so it is necessary to maintain the condition of the forest, as its function means it is necessary to cultivate and maintain it by the community traditionally and take rattan seeds from cultivation sites in the sub-district city or cultivation sites that are quite far from the Katingan forest [4]. The number of requests for rattan seeds upstream is quite large, but the problem is that the route is quite difficult, the weather conditions are unpredictable, and with many limited modes of transportation, the seed planting places are scattered in the forests, making this distribution difficult and affecting the condition of the supply of seeds for rattan cultivation in the forest [5]. This research area focuses on areas that have abundant sources of rattan seeds and are targets for rattan cultivation so that forest conditions are maintained. Rattan seed distribution is part of forest conservation and rehabilitation efforts as well as sustainable natural resource management activities. Rattan is a plant that is widely used in the craft industry, especially for making furniture, baskets, and other woven items [6]. Therefore, it is important to maintain the rattan population so that it does not become extinct and can be used sustainably. To meet the growing need for rattan in the future, it is estimated that we will not be able to provide it in sufficient and sustainable quantities, so it is necessary to overcome this by carrying out rattan development on a large scale through rattan cultivation and rattan multiplication [7]. The problem in transportation is determining whether an area has economical, efficient, and feasible transportation services so that it can meet the transportation needs of the community. The operations and routes of transportation modes are an interesting research object to study. The efficiency of a transportation system in a particular mode will depend greatly on the route it takes. Routes are prepared by considering the interests of users and operators so that optimal routes are obtained that are expected to meet the goals and interests of related parties who need them. Route determination is an important activity in the distribution process. In distribution problems, determining routes often requires complex stages, especially if the paths that must be traversed are quite numerous and difficult [8].

The problem of the rattan seed distribution supply chain is sought to be resolved by comparing several pieces of literature and examining several matches that are felt to be the closest and most appropriate to be able to solve it. Optimization methods from various literature become references for solving transportation route and route problems. Optimization methods will provide emphasis and coordination in the supply chain for perishable products and products that can last a long time. In this research, the supply chain system that will be studied is the route transportation system for rattan seeds. The route that must be faced provides a fairly difficult picture using multi-modal means of transport, namely Jukung boats and diesel trucks. Research on supply chain distribution with optimization results was completed using the Vehicle Routing Problem (VRP) method to determine the shortest route, minimum total cost, transport capacity, and short travel time. Several previous researchers have extensively used distribution supply chain solution models for optimization problems to produce solutions to supply chain problems for single optimization and supply chain problems with limited vehicles. Previous research used the vehicle routing problem as an optimization model using a mathematical programming approach, a model based on the equations of the system being studied [9]. The vehicle routing problem aims to complete a collection of routes from the central distributor to the demand points that must be served in order to produce a minimum total distance and costs incurred. The vehicle's carrying capacity also referred to as the capacitated vehicle routing problem (CVRP) should be taken into account in future study on the vehicle routing problem. Research using this problem will have the aim of minimizing travel costs and minimizing route length. The most basic version of the problem defines the captured vehicle routing problem as the CVRP vehicle routing problem. The customer's requirement to serve from a distinct depot serves as an example of the CVRP dilemma. Q is ready to deliver the items for each customer who requests a certain number of goods, qi, and the vehicle capacity. Vehicles can only carry so much cargo, thus they have to occasionally return to the depot to be reloaded. It is not feasible to separate customer shipments in CVRP. As a result, the CVRP solution consists of a set of locations that each client will visit once, with a maximum movement demand of Q. Theoretically, CVRP is represented by the following expression: The depot, represented by c0 in the network model, is served by the other nodes, which are the clients. Every node has qi, which is a set amounts of items that need to be delivered. The transit time between ci and cj is represented by the value tij, which is assigned to each arc. Finding a group of tours with the shortest possible overall travel time is the aim. Depot c0 serves as the starting and finishing point for each tour. Node ci (i = 1,…..,n) must be visited exactly once. The quantity of items to be delivered along the route cannot exceed the vehicle capacity Q [10]. This problem modeling is a mathematical formula that will serve as both the foundation for the program's preparation and the initial step in solving the problem. In order to convey all products as needed with the lowest feasible transportation costs, the model required for this writing problem must calculate the best distribution route based on the identified limitations, particularly the fleet's capacity. The product sent is rattan seeds with a distribution channel, so the rattan seeds are distributed starting from the rattan seeding place in the district city to the village, where the farmer or collector is then distributed to the Katingan forest in the Katingan Hulu area. For this problem, the distribution of rattan seeds is limited to the sub-district level because, at the sub-district level, there are many places where farmers cultivate rattan to maintain the sustainability of the forest so that it remains sustainable [11]. The land transportation route is the one that will be modeled for the distribution of rattan. Use the truck transportation mode for land transit routes. The vehicle routing issue with capacitating constraints is the mathematical model that will be used in this study, and the Tabu Search Algorithm will be employed to find the optimal solution. The preparation of mathematical models for vehicle routing problems considers several elements that are crucial in distribution planning. In this context, the index i refers to the member in the consumer set that needs to be served, while j represents the possible visits or calls that can occur to consumer i. The v index refers to the availability of vehicles such as trucks or L300 klotoks used to run these distribution routes. Various important parameters, such as C_{ij}, show the cost or distance required from one point or node to another node in the journey. Then, K_v represents the maximum capacity that can be transported by vehicle v, and d_i represents the level of demand from consumers at each node i [9]. The variable X_{ijv} describes the specific route taken by vehicle v from node i to node j, while $X_{i\ j}^v$ represents a binary variable indicating whether the path or arc from node i to node j is traversed by vehicle v (value 1) or not (value 0). Integrating these elements into a mathematical model allows for optimal planning in the distribution of goods or services. By considering travel costs, vehicle capacity, and consumer demand, this model helps find the best solution for determining efficient routes and minimizing overall distribution costs. This strategy can be used in various industries, including logistics, transportation, and delivery services, to increase operational efficiency and customer satisfaction [12]. In the mathematical model for the problem of distributing rattan seeds from cultivation sites to farmers in the forest, the main objective function is to minimize the travel routes used by vehicles. This aims to optimize delivery efficiency by finding the shortest or most efficient routes from rattan cultivation centers to farmers' locations in the forest. The main focus of the objective function is to reduce the cost of vehicle travel required in the distribution process. By identifying the best routes, both in terms of distance and travel time, you can reduce fuel use, optimize time, and reduce overall operational costs [13]. Meanwhile, the main constraint function in this problem is vehicle capacity. This constraint stipulates that each vehicle has a maximum capacity limit that it can transport. Taking these constraints into account, route planning needs to ensure that vehicle capacity does not exceed the specified limits [14]. This ensures that the delivery of rattan seeds to farmers in the forest meets the maximum capacity of the vehicle so that there is no overloading, which has the potential to harm the efficiency and safety of the distribution process [15]. Integration between the objective function to minimize vehicle travel routes and the constraint function to pay attention to vehicle capacity is the key to preparing mathematical models.

By considering both travel efficiency and vehicle capacity availability, this model can help in finding optimal solutions for the effective and economical distribution of rattan seeds to farmers in the forest.

2. Materials and methods

The distribution of rattan seeds is an important step in preserving natural resources and promoting the sustainability of forest ecosystems and the downstream rattan industry. The steps are as follows: Identify the type of rattan species by conducting a survey of local rattan types in the forest so that they match their natural habitat. Obtain rattan seeds from mature rattan plants that have grown to bear fruit. Rattan fruit is collected from natural forests and then made into new rattan seeds in cultivation sites or specially created rattan gardens. Prepare the seeds before distribution; this can include the drying process, selecting quality seeds, and separating them from fruit flesh or other fibers. The distribution of rattan seeds uses the vehicle routing problem method with limited transport capacity. The results of interviews with farmers, collectors, and community leaders show that these rattan seeds will be distributed when farmers or collectors harvest rattan using ¾ trucks, which usually transport the rattan harvest. These trucks are usually empty when they leave for the place closest to the forest and wait for the raw materials that rattan comes from. Now, when the truck leaves, it is filled with rattan seeds. Providing land that will be used for planting rattan seeds by carrying out preparatory steps first by clearing the land of weeds or other unwanted vegetation. Planting rattan seeds on prepared land. This planting process must pay attention to planting depth, distance between plants, and surrounding environmental conditions. Care and monitoring are carried out after the rattan seeds are planted. Good and regular care needs to be carried out to ensure the healthy growth of the rattan by watering, fertilizing, and protecting it from pests and diseases. Collaboration with several related parties, such as government agencies, environmental organizations, and local communities, on distribution issues to ensure the success of cultivation projects and the sustainability of forest management. Rattan cultivation certainly has an important role in preserving Indonesia's forests. There are several reasons why it is necessary to cultivate rattan because it will contribute to forest conservation, even though there are still many illegal logging activities and the conversion of forests into oil palm plantations. Several things about the importance of rattan cultivation include: Rattan cultivation carried out in rattan gardens or special cultivation sites can reduce pressure on primary forests. This provides an economic alternative for local communities; rattan cultivation can reduce illegal logging practices and the conversion of forests into agricultural land or more destructive plantations, such as oil palm plantations. Rattan is a natural resource that is of high value and important in Indonesia. Cultivating rattan will certainly be an opportunity to protect and preserve various types of rattan species that are threatened with extinction due to overexploitation in their natural habitat, namely forests. It is hoped that rattan cultivation activities will provide additional income for local communities, especially in areas that have potential for rattan cultivation. This will improve community welfare and reduce economic pressure, which will encourage communities to carry out activities that destroy forests. Rattan cultivation activities must be carried out in accordance with the principles of sustainable forestry so that they become a good example for other and broader sustainable forestry practices. This activity includes forest management, replanting, and sustainable protection of natural habitats. Including rattan cultivation in the economic program is necessary in order to reduce the economic risks associated with one main source of income. This will make society more resilient to sudden economic changes and help sustain society in the long term. The type of soil in rattan cultivation is mostly inceptisol, which is formed from igneous, sedimentary, or metamorphic rocks that are acidic or alkaline and suitable for use in rice fields and dry land farming, and some is entisol, which is formed from all types of soil parent materials that generally cover the land in the form of grasslands, tidal swamps, and ponds. In the area to the south, the soil type is histosol, which is organic soil (peat), and forests are good for plantations, agriculture, and settlements. Based on the problem and existing data, a mathematical model is created to determine the desired distribution pattern. The form of the model that is prepared refers to the desired goals and the constraints contained in the problem of the conditions that occur. The model that will be created is a mathematical function that provides a quantitative expression of the interaction between different components. With reference to the previously discussed mathematical model, the data processing goal of this study is to ascertain the best distribution route, distance, and cost for allocating the supply of rattan seeds by the application of the Tabu Search algorithm approach. The distance between the sub-district area and capital, the distance between the sub-district capital and district capital, and capacity are the input data needed for data processing in order to determine the first solution. The goal of this first solution work step is to determine an initial delivery route based on the supply of rattan seed's distribution pattern. Later on, this first answer will be used as input to find the optimal path, which will subsequently be refined by combining the suppliers nearest positions. This is done in an effort to reduce the truck's trip distance. Then, based on the groupings, the distance between these sites is computed; nevertheless, in order to ensure that the total demand transported does not surpass the truck's carrying capacity, consideration and limitation of the volume to be transported from each supplier must be made. Next, every point is examined, and if there are any connections, scheduling is done to ascertain the route the car will take on its trip. The output of this first work phase is a preliminary distribution route, which serves as the basis for the preliminary solution of the subsequent work phase, which involves the application of tabu search. The distribution route is the path that will be taken for travel. The entire truck travel distance and the shipment expenses are calculated from the current trips. It is necessary to have an initial solution in order to process additional data. The first solution's outcomes are then transferred to obtain a new route by exchanging the point matrices for each route. Delivery volume and distance matrix data are also needed. The distance between the rattan-producing areas in Katingan district was used to calculate the shipping route distance data that was entered. The initial solution delivery route data that will be optimized needs to be entered into each work process.

The current best solution is the distance from this first solution; if a shorter distance is found later, it will be replaced. Depending on how many possible moves (permutations) there are on each path, the number of iterations varies. One move is thought to be equivalent to one iteration in this instance. Every iteration involves a check to determine if the move attribute being utilized is present in the tabu list or not. If there is, then the move must not continue with the next process, whereas if the move used is not on the tabu list, then the resulting solution must be checked to see whether the demand capacity matches the truck's carrying capacity or not. If it does not meet, then the move cannot continue to the next process, but if it does, then that solution can be the chosen solution. If the chosen solution has a better distance than the best solution in the current iteration, then that solution becomes the new best solution and will be the current solution that will be processed in the next iterations. The move attributes will be recorded in the tabu list, so that for the next iteration, the move will not be carried out. The output from the results of the work carried out is a new trip or the best new route solution with a total distance traveled that is more optimal than the total distance traveled from the initial solution, or it could be that the initial solution is the best solution because the distance results from the move made to the moved point do not produce a more optimal distance from the initial solution, so that the initial solution is the best solution.

3. Results and discussion

The best final solution for the distribution of rattan seed supplies has been successfully broken down into six optimal distribution routes. These routes have been selected based on in-depth analysis to ensure maximum efficiency in the process of distributing rattan seeds to farmers in the region. The preparation of these six distribution routes is the result of an evaluation of a number of important factors. These factors include travel distance, the needs of each village, and the capabilities of the vehicles used to transport rattan seeds. Through careful research, these distribution routes are designed in such a way as to minimize travel costs, optimize travel time, and take into account the maximum capacity of the vehicle. The division of the final solution into six distribution routes allows for more efficient and effective distribution of rattan seeds. Thus, it is hoped that this solution can support the development of rattan cultivation in the region in a more sustainable way and strengthen the availability of seed supplies for farmers. The results of this best solution are an important basis for increasing the distribution of rattan seed supplies in a more organized and optimal manner. The first distribution route has been laid out in great detail to ensure a well-planned journey. The total distance covered on this route has been carefully calculated, reaching a total length of 53.03 kilometers. This detail includes a number of trip segments with detailed lengths for each section of the route, for example, 9.86 kilometers, 3.92 kilometers, 14.01 kilometers, 9.52 kilometers, 11.22 kilometers, and 4.5 kilometers, respectively. This structured route planning is the key to making travel more efficient and reducing the total distance traveled. This is expected to support efforts to distribute rattan seeds in a more efficient and organized manner. By considering strategic travel sequences and the length of each route segment, this effort aims to contribute to increasing efficiency in the distribution of rattan seeds to farmers in the region. On the second distribution route, the total distance traveled on this route is calculated at 2686.5 kilometers. This journey consists of several segments with detailed route lengths for each section, such as 1343 kilometers, 11.3 kilometers, 4.2 kilometers, and 1328 kilometers, respectively. This route has been carefully prepared to optimize travel and determine the most efficient route for rattan seed distribution. By paying attention to the planned sequence of trips and the length of each route segment, it is hoped that this distribution route can support the efficient distribution of rattan seeds to farmers in the region. Optimizing travel on this route is expected to be a significant effort to increase the efficiency of rattan seed distribution as well as help develop the agricultural sector in the area. On the third distribution route, the total distance traveled on this route is calculated at 1394.02 kilometers. This journey consists of several segments with detailed route lengths for each section, such as 28 kilometers, 34.13 kilometers, 8.3 kilometers, and 1323 kilometers, respectively. This distribution route has been planned in detail to optimize travel and minimize the total distance traveled. This effort is expected to support efficiency in the distribution of rattan seeds to farmers. By planning a structured travel route and considering the length of each route segment, it is hoped that this distribution route can contribute to increasing efficiency in distributing rattan seeds to farmers in the region. On the fourth distribution route, the total distance traveled on this route is calculated at 38.2 kilometers. This distribution route consists of several segments with detailed route lengths for each section, such as 15.6 kilometers, 9.5 kilometers, 9.6 kilometers, and 3.5 kilometers, respectively. The preparation of this route has been carried out carefully to optimize the trip and minimize the total distance traveled. This is expected to support efficiency in the distribution of rattan seeds to farmers. On the fifth distribution route, the total distance traveled on this route reaches 28.8 kilometers, which is divided into several travel segments with detailed lengths for each route: 5.2 kilometers, 11.7 kilometers, 1.8 kilometers, 5.3 kilometers, and 4.8 kilometers. The preparation of this route has been carried out carefully to ensure orderly and efficient travel planning, with a focus on route optimization and efforts to minimize the total distance traveled. The sixth distribution route was carefully designed, representing an important journey. The total distance traveled on this route is calculated at 2717.3 kilometers, consisting of several travel segments with route lengths of 1323 kilometers, 47.3 kilometers, 10 kilometers, and 1337 kilometers, respectively (Figure 2). y has a code that refers to the area where rattan seeds are cultivated, according to the regional and production codes of the initial solution presented previously. This route planning has been prepared in detail with the aim of optimizing the travel route, considering each rattan seed distribution point. It is hoped that this distribution route will make a positive contribution to increasing the efficiency of rattan seed distribution to farmers in the region. By developing structured travel routes and considering the location of each distribution point, it is hoped that this effort can strengthen the agricultural sector and encourage sustainable economic growth. The estimated transportation costs for each kilometer of distance during the distribution process are assumed to be IDR 929.00.

This assumption is based on a fuel price of IDR 6,500.00 per liter with a vehicle fuel consumption ratio of 1:7. Therefore, the cost of traveling for each kilometer is calculated based on the calculation of fuel consumption and the price of the fuel, which is equivalent to IDR 929.00 per kilometer. In addition, in anticipation of possible unexpected costs during the distribution process, an additional 30% has been added to the previous transportation costs. Thus, the total cost for each kilometer of travel or distribution is calculated to be IDR 1,207.00. This additional 30% aims to accommodate possible additional costs that may arise during the distribution process, such as other operational costs or sudden, unexpected needs. By considering these costs, companies or distribution organizers can more accurately calculate and allocate the costs required during the rattan seed distribution process. The price of rattan seeds at the transportation stage from the sub-district capital to the forest is set at IDR 2,000.00. However, the price of rattan seeds can vary based on the type of rattan in question. To calculate total costs, including distribution costs, a formula described by previous research is used. This formula considers costs arising from the distribution process and is expected to become a reference for covering costs incurred during the distribution process. In the context of this study, farmers and collectors will be responsible for any costs that arise. This is because they use the same transportation to transport the harvested rattan raw materials. The formula presented is the basis for calculating total distribution costs. This formula can be applied not only to the distribution of rattan seeds but can also be used for other commodities that have similar characteristics in the distribution process, especially when they are distributed from the forest. By using this formula, it is hoped that farmers and collectors can better calculate the total costs associated with the distribution of rattan seeds or other commodities. This helps in more efficient financial management and more precise planning in the distribution process to or from the forest.

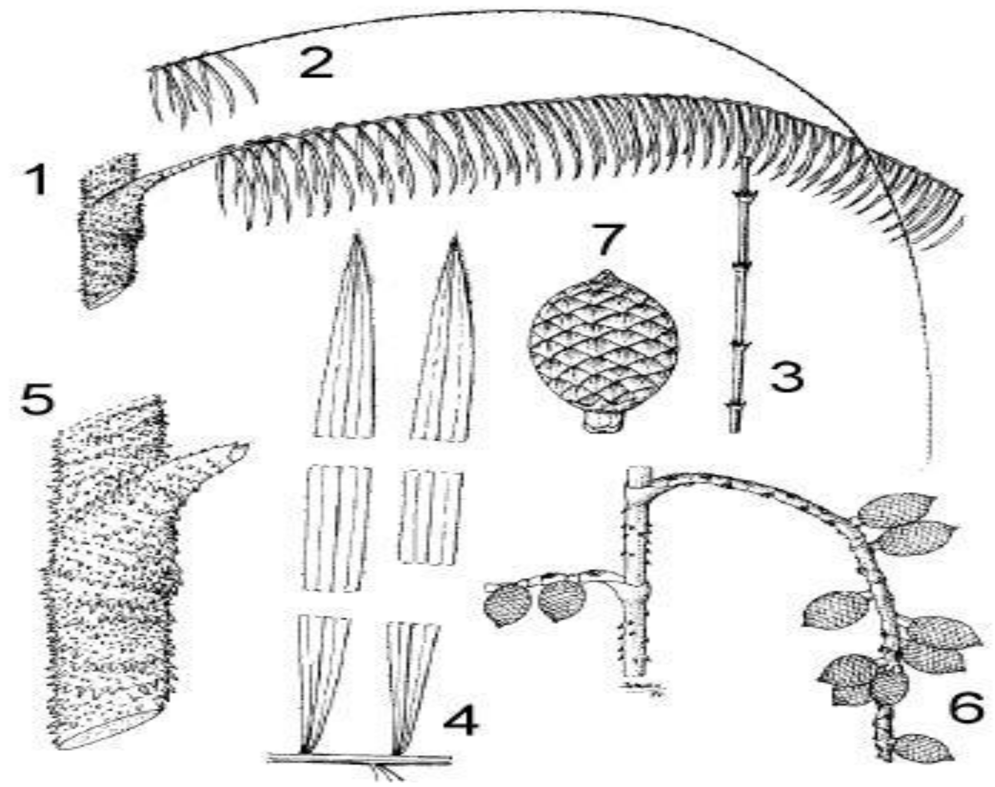

Figure 1. Rattan seeds (Calamus manan) meding and falling in forest adabted from CABI liberary (2019) [16].

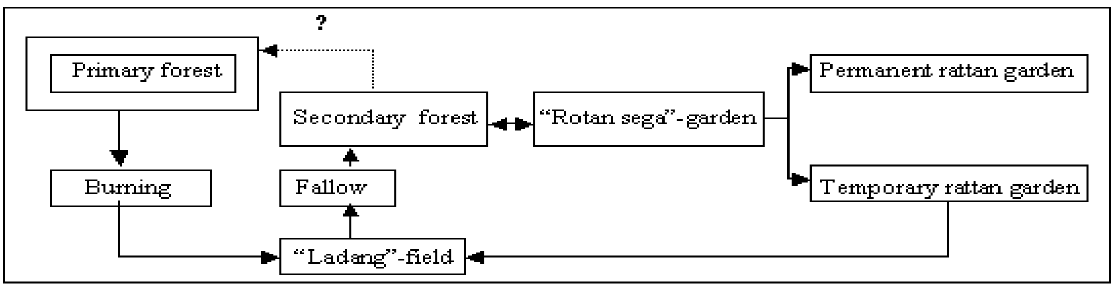

Figure 2. Land use for distribution of rattan seeds. *image is adapted from Arifin & Mitlöhner (2003) [17].

4. Conclusions

The length of the existing distribution route (initial) is 8245.89 kilometers, but through proposed route changes, the length of the new route is planned to be 6917.85 kilometers. With this change, there is a savings of 16% in the total length of distribution routes. This plan describes a strategy for grouping into six transport routes, which is based on the level of proximity between the villages where the rattan seeds will be transported. In addition, the distribution cost calculation formulation used in this context can be optimized for other commodities that have similar characteristics to rattan. This makes it possible to use the same distribution cost calculation formula to calculate distribution costs for other commodities that have a similar distribution process, especially in the context of transportation from villages to forests. The implementation of the transportation route grouping strategy based on the proximity of the villages where the rattan seeds are located is expected to provide greater efficiency in the distribution process. Thus, the application of a distribution cost calculation formula that can be adapted for various types of similar commodities is expected to help business actors manage distribution costs more efficiently and make the overall distribution process more effective.

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