A Decision Support System for Reducing Transport Period of Wood Chips

D. Rotkanok, T. Angskun, and J. Angskun

***Abstract*—Wood chips business is one of the fastest growing agriculture products in Thailand. However, there are some problems in its transport system. Under the obligation by the department of forestry and the insufficiency of unloading areas, a long period of waiting time for loading and unloading products have been occurred; as a result, the total transport period of wood chips has been extended. Thus, a decision support system (*DSS*) for reducing transport period of wood chips in order to increase the turnover of business is designed. The paperalso provides a model of the*DSS* for wood chip transport management which helps to reduce (1) waiting time at original nodes; (2) waiting time at terminal nodes; and (3) travel time for transport by using the opportunity costs concepts. The model can help utilize trucks efficiently by reducing overall transport periods up to 63 percent per month. In addition, this proposed model can be even adapted to the other similar transport systems such as timbers.**

***Index Terms*—Decision support system, transport period, wood chips.**

I. Introduction

Transport in Thailand has been gradually growing every year but truck transport has played a major role due to the statistics provided by the department of land transport [1].The department of land transport reported that the number of truck licenses was 93 percent greater than the other licenses during 2011.However, truck transport in Thailand is normally operated by small and medium business enterprises which are facing the problems of competitive logistics cost. In addition, World Bank also announced that the Logistics Performance Index (LPI) of Thailand was lower than the other countries in the region [2].Logistics cost in Thailand consists of 3 main aspects: transport cost, inventory cost, and management cost [3].Thus, this paper is to design a decision support system to help truck transport companies in Thailand manage their logistics system and alsoto reduce transport cost, especially time cost.

Since Thailand is a well-known country for its agriculture products, this research then focuses on wood chips which is one of the fastest growing agriculture products that has a high volume of export and also domestic consumption. Wood chips are vast demanded in paper industry, power plants, and plywood or particle board industry. The number of demands for wood chips in Thailand is now above 6.5 million tons per year [4]. However, there are only few researches about this product in comparison with the other agriculture products such as rice, sugar cane, or cassava.

The transport of wood chips, displayed in Fig. 1, starts from sellers who are called as *original nodes* to buyers who are named as *terminal nodes*. A seller can sign a purchasing contract with several buyers; therefore, a third party logistics provider (TPL) who acts as a middle man has intervened into the system. This provider signs a transport contact with the original node and thus all transport from original nodes to terminal nodes is under their responsibility. However, a transport contract can be signed with several original nodes and various terminal ones, thus the provider have to engage with truck companies to help them satisfy their customers. As a result, trucks are able to load wood chips at several original nodes and also to unload products at various terminals. This can be illustrated in Fig. 2.

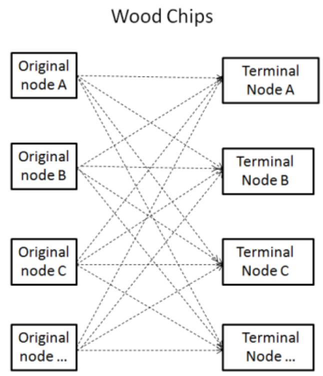

Fig. 1. Wood chip transport

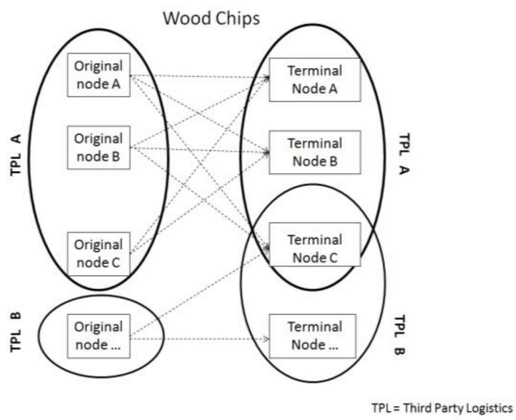

Fig. 2. Wood chip transport intervened by third party logistics

The concerned issues of wood chips that have a major impact on high cost of transport are their production line and inadequate infrastructures. The production line of wood chips has to wait for raw materials that depend on labors intensive

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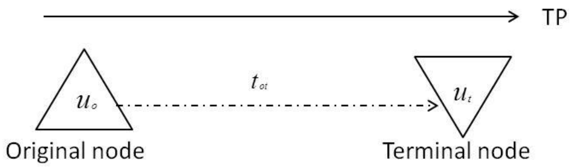
because the regulation from Thai forestry department that does not allow any electric machines to cut trees producing wood chips. Additionally, the humidity level of wood chips can be lost after its production; therefore, wood chips are rarely produced in the high volume. As a result, the supply of wood chips at the original node is lower than the demand of wood chips. Thus, many trucks have to wait for loading wood chips at the original nodes. In the meanwhile, there is an excess in supply of wood chips at the terminal nodes due to insufficient infrastructures such as inventory areas; thus, a period of waiting time for unloading at terminal nodes is also occurred.

The length of transport period can results in the high total cost of logistics. A long period of usage time at original and terminal nodes, and travel time between these two nodes are the factors that can decelerate a transport period as shown in Fig. 3.



TP = *Transport Period* $(u_o + t_{ot} + u_t)$

u_o = *Usage Time at Original Node*
(*Waiting Time for Loading and Loading Time*)

t_{ot} = *Travel Time from Original to Terminal Nodes*

u_t = *Usage Time at Terminal Node*
(*Waiting Time for Unloadingand Unloading Time*)

Fig. 3. Transport period.

The related literatures on truck transport have been currently renowned for many scholars, especially in the field of strategic management. Silverman *et al*. [5] and Yang and Regan [6]studied about truck management in the US, whereas Lumsden [7] did a research into the efficiency of truck transport by concerning about its dimensions and masses.Leonardi and Baumgartner [8] also studied about the energy efficiency of trucks and Pootakham and Kumar [9] published a comparison between pipeline and truck transportMoreover, Gunnarsson [10] designed a routing vehicle for truck in Europe. In addition, Ta *et al*. [11] explored truck allocation for loading oil sands by using queuing theory and non-linear regression to illustrate the relationship between the number of trucks and the number of loading goods. Later, Sahoo [12] structured the research of Ta *et al*.[11]into a model. Furthermore, Nichollse*t al*. [13] conducted a research on the impact of timber transport on provincial road. However, none of research has been investigated into dispatch areas, especially in wood chip transport.

Hence, this paper aims to design a decision support system (*DSS*) to reduce atransport period of wood chips. A model of *DSS* is also created to assist in truck management for wood chip transport. The proposed model is designed by using the opportunity cost concepts and also weighted arithmetic mean. The proposed model will be implemented as a center system to display the demand and supply of wood chips from original to terminal nodes. Thus, truck companies can efficiently manage their resources by decreasing the waiting time at original and terminal nodes, and also the travel time via the developed model. This proposed model can also be implemented into the other products which are concerned about transport period reduction. The structure of this paper is as follows: the model development is proposed in Section 2 and then the model construction is described in Section 3. Next, the model implementation is demonstrated in Section 4 before the model evaluation is presented in Section 5. Finally, the conclusion is drawnin Section 6.

II. Model Development Framework

The model development framework of a decision support system for reducing transport period of wood chips is depicted in Fig. 4. The framework consists of 3 aspects: inputs,process and output. Inputs are involved in the data that are used for developing the model. The inputs are the data obtained from: original nodes, travel data, terminal nodes, and trucks. The data of original nodes and terminal nodes are mainly about location and time usages for loading and unloading respectively. However, the travel data involve in the distance, time and cost between original nodes and terminal nodes. Last, truck data are about the number of truck plates, revenue, cost and driver profiles.

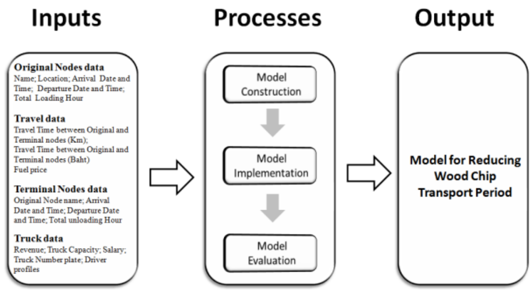


Fig. 4. Model development framework.

The inputsare precededto the model development process in order to construct and implement the proposed model as discussed in the next sections.

III. Model Construction

The proposed model is constructed by the concept that all time related to a transport period of wood chips have different impact on it. Typically, the transport period of wood chips (*TP*) is the summation of a usage time at an original node (u_o), a travel time from an original node to a terminal node (t_{ot}), and a usage time at a terminal node (u_t) as shown in Equation 1.

$$TP = u_o + t_{ot} + u_t \tag{1}$$

However, the route selection for wood chip transport does not convince that the minimum *TP*value is the best route. It is due to the face that the cost of each time is not equivalent. The waiting time affects wage cost and revenue, whereas the travel time affects truck cost. Thus, the model construction aims to analyze the different impact of each time on a transport period as the weight of time. The model construction process includes six steps as follows.

A. First Step: Average Usage Time Acquisition at Original Nodes

The first step is to find an average time usage of each truck at original nodes. An arrival time and a departure time at original nodes of each truck are recorded to find the total usage time before diving it with the number of trucks. The average of usage time at the original nodes is represented as$Avg(u_o)$.

B. Second Step: Average Usage Time Acquisition at Terminal Nodes

The second step is similar to the first step but this step requires the arrival and departure time at terminal nodes. Thus, the average of usage time at the terminal nodes is represented as $Avg(u_t)$.

C. Third Step: Average and Minimum Travel Time Acquisition between Nodes

The third step is to find an average travel time and a minimum travel time from original to terminal nodes. This step is implemented by retrieving the data of travel time from Google Map. The average and minimum of travel time from original to terminal nodes is represented as $Avg(t_{ot})$ and $Min(t_{ot})$, respectively.

D. Forth Step: Average Travel Distance Acquisition

The forth step is to find an average of travel distance between nodes. A travel distance between nodes can also be investigated via Google Map. The average of travel distance from original to terminal nodes is represented as $Avg(d_{ot})$.

E. Fifth Step: Opportunity Cost Computation

The fifth step is to compute the opportunity costs of usage times at nodes and travel time between the nodes into financial terms using the following cost assumptions:

1) *Revenue (R) is 470 Baht/Tons*
2) *Oil Price (OP) is 30 Baht/Liter*
3) *Petrol Consumption (PC) is 2.5 Km/Litrer*
4) *Truck Capacity (TC) is 30 Tons*

Theopportunity costs of a usage time at original nodes (C_o) and at terminal nodes (C_t) are computed based on the revenue variables. While theopportunity cost of travel timebetween nodes (C_{ot}) is based on oil price and revenue. The results of the opportunity costs are presented in Table I.

F. Sixth Step: Weight Derivation

The usage time and travel distance are weighted to explore the impact on a transport period. The weight derivation of each factor (w_o, w_{ot} , and w_t) can be depicted in Equation 2, 3, and 4, respectively.

$$w_o = \frac{C_o}{C_o + C_{ot} + C_t} \tag{2}$$

$$w_{ot} = \frac{C_{ot}}{C_o + C_{ot} + C_t} \tag{3}$$

$$w_t = \frac{C_t}{C_o + C_{ot} + C_t} \tag{4}$$

The weights of usage time at original and terminal nodes, and travel time between the nodes are shown in Table I under the cost assumptions in the fifth step.

In conclusion, an equation of weighted transport period (TP_w) for wood chips can be derived as Equation 5 and 6.

$$TP_w = w_o u_o + w_{ot} t_{ot} + w_t u_t \tag{5}$$

$$TP_w = 0.31 u_o + 0.50 t_{ot} + 0.19 u_t \tag{6}$$

where $u_o$is a usage time at an original node, u_t is a usage time at a terminal node andt_{ot} is atravel time from an original node to a terminal node.

TABLE I: MODEL CONSTRUCTION PROCESS FOR ANALYZING WEIGHTS OF USAGE TIME AND TRAVEL TIME

Step	Related Variables	Value	Unit
First	$Avg(u_o)$	5.18	Hours
Second	$Avg(u_t)$	3.23	Hours
Third	$Avg(t_{ot})$	8.02	Hours
	$Min(t_{ot})$	7.10	Hours
Forth	$Avg(d_{ot})$	434.48	Kilometers
Fifth	*Revenue : round (Rr)= R * TC*	14,100.00	Baht
	Revenue : hour (r)= Rr/ T_{ot}	1,758.10	Baht
	$C_o = r * Avg(u_o)$	9,106.98	Baht
	$C_t = r * Avg(u_t)$	5,678.68	Baht
	C_{ot} = $Avg(d_{ot})$/PC*OP + $(r * (Avg(t_{ot}) - Min(t_{ot})))$	14,651.86	Baht
Sixth	w_o	0.31	
	w_{ot}	0.50	
	w_t	0.19	

IV. MODEL IMPLEMENTATION

In this research, the model is implemented in a real operation of a wood chip transport organization which has two original nodes namedKasetwisai and Benjaluk, and three terminal nodes namedSrirachaHabour, Siracha Silo, and Kerry Siamseaport. The travel distance and traveltime fromeach original node to each terminal node are illustrated in Table II.

TABLE II: TRAVEL DISTANCE AND TRAVEL TIME FROM ORIGINAL TO TERMINAL NODES

Travel Distance and Travel Time from an Original Node to a Terminal Node			Terminal Node					
			Sriracha Habour		Sriracha Silo		Kerry Siam Seaport	
			Distance	Travel Time	Distance	Travel Time	Distance	Travel Time
Original Node	Kasetwisai	Pakchong	547 Km	7 hrs 10 mins	549 Km	7 hrs 13 mins	575 Km	7 hrs 27 mins
		Kabinburi	510 Km	7 hrs 13 mins	512 Km	7 hrs 17 mins	508 Km	7 hrs 21 mins
		Burirum	536 Km	7 hrs 38 mins	539 Km	7 hrs 41 mins	534 Km	7 hrs 46 mins
	Banjaluk	Aranyaprathet	579 Km	9 hrs 20 mins	577 Km	9 hrs 20 mins	575 Km	8 hrs 23 mins
		Kabinburi	580 Km	8 hrs 13 mins	583 Km	8 hrs 16 mins	578 Km	8 hrs 21 mins
		Parkchong	639 Km	8 hrs 30 mins	642 Km	8 hrs 33 mins	668 Km	8 hrs 47 mins

In addition, the operation of organization in each month is to run thirty-seven trucks for wood chip transport between those original nodes and terminal nodes. The information of thirty-seven trucks is applied to acquire a usage time at each original node (u_o) and a usage time at each terminal node(u_t). As previous described, the usage time at each original node means a time period since arrival until departure, i.e., the summation of waiting time for loading and loading time, as shown in Fig. 5. The usage time at each terminal is similar as shown in Fig. 6.

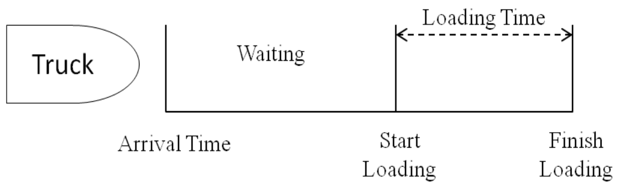


Fig. 5. Usage time at each original node

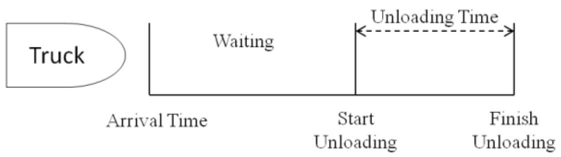


Fig. 6. Usage time at each terminal node

The waiting times for loading and unloading can be computed in the proposed model.Thus, at the first time of model usage, the usage times at original and terminal nodes means only the loading and unloading time.

The loading and unloading times vary on several factors such as the number of labors in picking up wood chips into trucks or taking down wood chips from trucks at that time.The loading time of each original node is derived from the minimum usage time at the original node of the thirty-seven trucks, whereas the unloading time of each terminal node is derived from the minimum usage time at the terminal node of the thirty-seven trucks. The results of usage times (u_o, u_t) of each nodearedisplayed in Table III.

TABLE III: USAGE TIMES AT ORIGINAL AND TERMINAL NODES

Original Nodes		Terminal Nodes		
Kasetwisai	Benjaluk	Sriracha Habour	Sriracha Silo	Kerry Siamseaport
37 mins	1 hrs 3 mins	60 mins	1 hour 5 mins	48 mins

According to Table III, the usage time of original node at Kasetwisai is 37 minutes,which is longer than Benjaluk; whereas the shortest usage time at terminal nodes is at Kerry Siamseaport spending48minutes. The minimum usage time of each node is replaced in $w_o$and wt_t in Equation 5.

A weighted transport period (TP_w)is computed in order to search for the best route for running each truck. Table IV presents a computation of the weighted transport period to search for the best route as an example. Although the shortest transport period for wood chips is 8 hours 46 minutes which travels from Kasetwisai to KerrySiam Seaport via Kabinburi route,the proposed model provides a better selection which is to travel from Kasetwisai to SrirachaHabour via Parkchong route wherethe transport period is 8 hours 47 minutes due to the lower weighted transport period as shown in Table IV.

TABLE IV: AN EXAMPLE OF THE WEIGHTED TRANSPORT PERIOD COMPUTATION OF ONE TRUCK IN SEARCHING FOR THE BEST ROUTE

(Truck No. Plate) Arrival Time	Original Nodes	Travel		Terminal Nodes	Transport Period	Weighted Transport Period
(70-1234) 11:38	Kasetwisai $\boxed{u_o}$	Route	$\boxed{t_{ot}}$	Sriracha Habour $\boxed{u_t}$	$\boxed{TP}$	$\boxed{TP_w}$
		Pakchong	7 hrs 10 mins		8 hrs 47 mins	237.87
		Kabinburi	7 hrs 13 mins	1 hr	8 hrs 50 mins	239.37
		Burirum	7 hrs 38 mins		9 hrs 15 mins	251.87
		Route	$\boxed{t_{ot}}$	Sriracha Silo $\boxed{u_t}$	$\boxed{TP}$	$\boxed{TP_w}$
		Pakchong	7 hrs 13 mins		8 hrs 55 mins	240.32
	37 Mins	Kabinburi	7 hrs 17 mins	1 hr 5 mins	8 hrs 59 mins	242.32
		Burirum	7 hrs 41mins		9 hrs 23 mins	254.32
		Route	$\boxed{t_{ot}}$	Kerry Siam Seaport $\boxed{u_t}$	$\boxed{TP}$	$\boxed{TP_w}$
		Pakchong	7 hrs 27 mins		8 hrs 52 mins	244.09
		Kabinburi	7 hrs 21 mins	48 mins	8 hrs 46 mins	241.09
		Burirum	7 hrs 46 mins		9 hrs 11 mins	253.59
	Benjarak $\boxed{u_o}$	Route	$\boxed{t_{ot}}$	Sriracha Habour $\boxed{u_t}$	$\boxed{TP}$	$\boxed{TP_w}$
		Aranyaprathet	9 hrs 20 mins		11 hrs 23 mins	310.93
		Kabinburi	8 hrs 13 mins	1 hr	10 hrs 16 mins	277.43
		Parkchong	8 hrs 30 mins		10 hrs 33 mins	285.93
		Route	$\boxed{t_{ot}}$	Sriracha Silo $\boxed{u_t}$	$\boxed{TP}$	$\boxed{TP_w}$
		Aranyaprathet	9 hrs 20 mins		11 hrs 28 mins	311.88
	1 hr 3 mins	Kabinburi	8 hrs 16 mins	1 hr 5 mins	10 hrs 24 mins	279.88
		Parkchong	8 hrs 33 mins		10 hrs 41 mins	288.38
		Route	$\boxed{t_{ot}}$	Kerry Siam Seaport $\boxed{u_t}$	$\boxed{TP}$	$\boxed{TP_w}$
		Aranyaprathet	8 hrs 23 mins		10 hrs 14 mins	280.15
		Kabinburi	8 hrs 21 mins	48 mins	10 hrs 12 mins	279.15
		Parkchong	8 hrs 47 mins		10 hrs 38 mins	292.15

V. MODEL EVALUATION

The proposed model is evaluated by comparing transport periods between the current routes running trucks in one month and the designated route by the model. The proposed model leads to the reduction in transport periods over 63 percent per month. The comparison is depicted in Fig. 7.

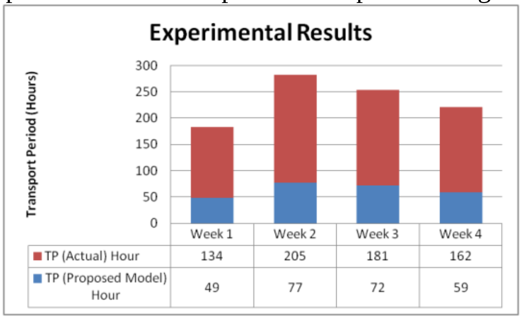


Fig. 7. A comparison of the transport periods between the current routes and the designated routes by the proposed model

VI. CONCLUSION

This paper provides a model of a decision support system to assist truck service providers reduce a transport period of wood chips. The proposed model has also a financially benefit to a transport business in wood chips due to the decrease in time cost. A framework of the proposed model is divided into three parts as: inputs, process and output. Inputs involve in relevant data about truck and activities at original and terminal nodes before processing to a model construction and implementation. The proposed model is constructed with five steps and processed by the actual data from a truck service provider in Thailand. Over 63 percent of a transport period for wood chips is reduced via the proposed model.

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