

FEASIBILITY STUDY OF MULTIMODAL TRANSPORTATION OF CASSAVA PRODUCTS IN THAILAND: SYSTEM DYNAMICS MODELING

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Abstract

Thailand is one of the world's top export countries, sharing 72% of the global shipment, mainly in the agricultural and industrial products. Being a major logistics hub in ASEAN, Thai government has initiated several projects to support the transportation of people and goods. Road transportation is a major mode of goods transportation in Thailand. However, it incurs the highest logistics cost compared with water and rail modes. The use of multimodal transportation is, therefore, considered to lower the logistics cost and reduce the environmental problems. This study examines the feasibility of multimodal transportation of cassava products in the long-term utilizing the system dynamics modeling approach. Six saving elements, including 1) saving in labor cost, 2) saving in fuel cost, 3) saving in carbon dioxide tax, 4) saving in truck rental cost, 5) saving in reimbursement cost, and 6) saving in accident cost, and four cost elements, including 1) handling cost, 2) tariff cost, 3) product return cost, and 4) product damaged cost, are considered in the dynamics model. The simulation results reveal that at the initial years, the net cash flow is negative due to high investments in double track system. Once the project continues, the savings increase. It is found that the project is feasible when it is continued for 10 years at the internal rate of return of 13.69%. The sensitivity analysis results also show that the saving in truck rental cost and the product damaged cost are two key elements in the multimodal transportation, as they highly affect the internal rate of return of the project. The developed dynamics model of multimodal transportation of cassava products can be used as a guideline for transportation companies and government to plan for their multimodal transportation to reduce logistic costs and achieve benefits in the long term.

Keywords: Cassava, feasibility, multimodal transportation, system dynamics modeling, Thailand

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1.0 INTRODUCTION

The agricultural product industry is the one of main export industries of Thailand. According to BOI [1], cassava is one of Thailand's most important economic crops, with the supply of 67% of the global market or 33 million tons in 2016. Cassava can be processed into various products, such as chip, pellet, and starch, which represent 55 % of the total products [2]. The highest cultivated area of cassava in Thailand is in the

Northeastern, accounting for 52.3 % of the total cultivated area. With that, 32.86% of the total yield in the Northeastern provinces is in Nakhon Ratchasima province [3]. Thailand is turning into a major logistics hub in the ASEAN, setting up the production base and sales network in Indochinese Peninsula. To develop the country's transportation infrastructure, the Ministry of Transport comes up with the Infrastructure Development Plan (2015-2022) by integrating all platforms, including rail, air, road, and water transportations into multimodal transportation to reduce logistics and transportation cost [4].

Despite being the major mode of transportation in Thailand, road transportation is the most expensive mode among the three modes, including road, rail, and ship, with an average logistics cost of two to three times higher, see Table 1 [5]. Moreover, road transportation now faces various problems, such as traffic congestion, high fuel prices, air pollution, and high accident rates. Better transportation is required to reduce logistics and transportation cost. It is expected that the use of multimodal transportation will help reduce logistics and transportation costs, and diminish problems, such as traffic congestion, high fuel prices, air pollution, and high accident rate caused by the road transportation.

Table 1 Logistics Cost of Transportation in Thailand [5]

Mode	Logistics Cost (baht/ton-km)
Road	1.72 – 2.02
Water	0.64 – 0.65
Rail	0.93 – 0.95

With the government's dual track system project around the country, it is expected that cassava products will gain benefits of using the combination of road and rail transport to reduce the logistics and transportation costs. This research study, therefore, aims to examine the trend of multimodal transportation of cassava products, specifically truck-train modes, utilizing the system dynamics (SD) modelling approach. Main savings and costs of multimodal transportation of cassava products are extracted and used for the dynamics model development. The internal rate of return (IRR), achieved from the developed dynamics model, are used to examine the feasibility of the project. It is expected that the study results provide a guidance to the cassava and transportation industries to effectively plan for cassava transportation to achieve high competitiveness in the global market.

2.0 METHODOLOGY

The research flow of this study is summarized in Figure 1. Literature review of cassava transportation is reviewed to identify possible modes of transportation i.e., truck and train modes. The origin and destination i.e., Nakorn Ratchasima province to Laemchabang port used in this study is also highlighted. Previous studies on transportation are conducted to identify saving and cost elements affecting multimodal transportation of cassava products in Thailand. Secondary and primary data are collected to be used for the dynamics model development. Secondary data are collected through journal papers, conference papers, and company reports, while primary data are achieved from in-depth interviews. Interviewees include

representatives from cassava and logistics companies, with at least 5-year working experiences. The developed dynamics model of multimodal transportation of cassava products is used to examine the trend of multimodal transportation of cassava products in Thailand in the long term.

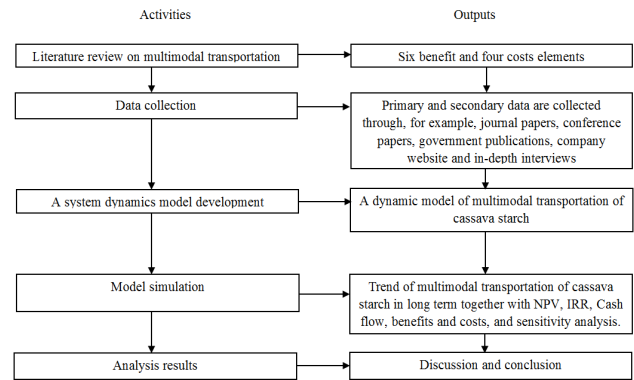


Figure 1 Research flow of this study

3.0 LITERATURE REVIEW

3.1 Double Track System Project

According to Unique [6], there are five major groups of Thai government infrastructure projects, including 1) development of inter-city rail network, 2) enhancing Thailand's air transport competitiveness, 3) development of transportation in Bangkok and its vicinity, 4) development of water transport network, and 5) improvement of highway network to link important local production hubs with markets in neighboring countries. The double track system is one of the inter-city rail network projects. It is planned throughout the country to promote social stability, augment economic stability, promote transport security and safety, and boost competitiveness [7]. Sixteen sub-projects of the double track system are planned (see Figure 2). Among those, seven routes are already commenced, with almost 106 billion baht in investment. It is expected that when the double track system finishes, more of multimodal transportation will be initiated, thus reducing logistics cost in the long-term.

The Jira Road Railway Station – Khon Kaen route has container yards (CYs) in Nakorn Ratchasima and Khonkaen provinces. These container yards serve as the transferred link between the truck and train modes in Northeastern part of Thailand. This is beneficial, especially for the agricultural products that require large space for the transferring process, such as cassava, rice, and rubber.

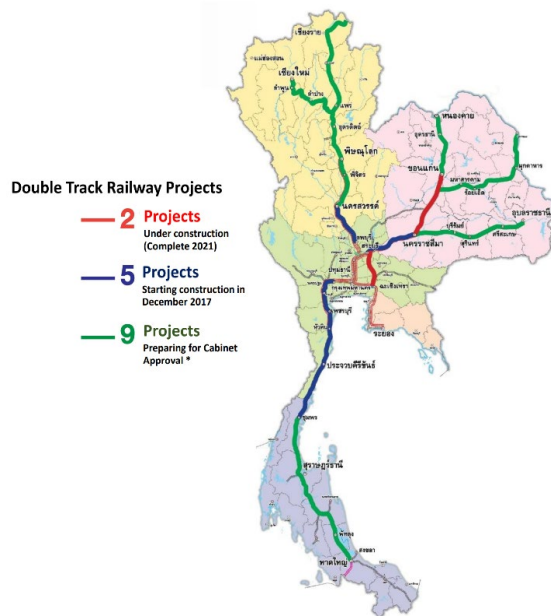


Figure 2 Double track system project [7]

3.2 Multimodal Transportation Of Cassava Products In Thailand

Multimodal transportation is the coordinated use of two or more modes of movement in transferring goods. It can be a combination of truck, rail, air, or ship modes. It provides convenient and economical connections of various modes to make complete journey from origin to destination. Cassava products are usually low price and low value, and that the shipment of these products using multimode is encouraged to reduce transportation cost.

Several studies have been conducted in multimodal transportation of cassava products in Thailand. Timaboot and Suthikarnnarunai [8], for example, presented a concept of designing the new distribution network of cassava supply chain in Thailand using rail as a major mode of transportation. Uabharadorn [9], on the other hand, discussed key areas of multimodal transport and logistics services, such as demand of freight transport, logistics costs, modal shift, effect of transport costs on trade, and the government policy and action plans towards the development of multimodal transport and logistics services and the areas of improvement. Suksawat Na Ayudhya [10] utilized the goal programming approach to address an intermodal routing decision problem with the case study of tapioca product.

In this study, the multimodal transportation is considered using the combination of truck and train modes. The origin of the study is at the major cassava growing area, which is at Nakorn Ratchasima province in the Northeastern part of Thailand. The destination is at Laemchabang port, which is the major export port of Thailand located in the Eastern part of Thailand. The products are to be delivered using the truck mode from the origin to Jira Road Railway Station, where the CY is provided for temporary storage. They are then transferred to the trains and are continued to Laemchabang port for final exporting process.

3.3 Saving And Cost Elements Of Multimodal Transportation Of Cassava Products

Several research studies have been conducted to extract key saving and cost elements of multimodal transportation. In this study, six saving and four cost elements are extracted from the literature and are used for the dynamics model development (see Tables 2 and 3). Santisirisomboon et al. [11], for example, mentioned that by using multimodal transportation, the company can reduce CO₂ emission and CO₂ tax. Ministry of Road Transport and Highways [12] stated that the use of multimodal transportation helps reduce chances of accident occurrences, thus reducing the accident and reimbursement costs. The use of multimodal transportation also requires fewer trucks, leading to lower truck driver and fuel costs [13].

Table 2 Saving Elements

Saving Element	Data Used	Value	Unit
Saving in labor cost	• Driver wage	18,000	baht/month
Saving in fuel cost	• Fuel price	27.31	baht/liter
Saving in CO ₂ tax	• CO ₂ tax rate	500	baht/ton CO ₂
	• CO ₂ emission for truck	107.37	g-CO ₂ /ton-km
	• CO ₂ emission for train	13.37	g-CO ₂ /ton-km
Saving in truck rental cost	• Truck rental price	22,500	baht/day
Saving in reimbursement cost	• Reimbursement for minor injury	50,000	baht/person
	• Reimbursement for major injury	200,000	baht/person
	• Reimbursement for death	200,000	baht/person
Saving in accident cost	• Truck accident rate	3.5	time/year
	• Probability of minor injury of road accident	96.69	percent
	• Probability of major injury of road accident	2.74	percent
	• Probability of death of road accident	0.57	percent

Note: References include [19], [18], [17], [13], [12], and [11].

Table 3 Cost Elements

Cost Element	Data Used	Value	Unit
Handling cost	• Crane cost	17,500	baht/time
	• Lift on and lift off cost	475	baht/time
Tariff cost	• Tariff cost	246-279	baht/ton
Product return cost	• Train delay time	2	hour/day
	• Product return rate	1	%
	• Train capacity	570	ton/train
Product damage cost	• Product damage rate	4.18	%

Note: References include [16], [15], [14], and [13].

Four costs related to the use of multimodal transportation are, on the other hand, extracted and utilized in the dynamics model development in this study (see Table 3). NESDB [14], for example, mentioned that handling cost is one of major logistics administrative cost. Kavirathna et al. [15] added that handling charge is significant in the transshipment processes. State Railway of Thailand [16] stated that tariff costs incurred when train mode is used. Seo et al. [13] mentioned that handling and tariff cost caused by mode changing is one of the major costs of

multimodal transportation. Products can also be damaged during mode changing. The reliability of rail and ship modes in Thailand is still low compared with the truck mode; this sometimes causes delay and product return.

The above six savings and four costs are used for the development of the dynamics model of multimodal transportation of cassava products in Thailand.

4.0 DEVELOPMENT OF THE DYNAMICS MODEL OF MULTIMODAL TRANSPORTATION OF CASSAVA PRODUCTS

4.1 System Dynamics Modeling

Several methods can be used to examine the multimodal transportation. In this study, the SD modelling approach is used to develop a dynamics model of multimodal transportation of cassava products. This approach can be used to guide policy and system design in numerous fields. Doan and Chinda [20] mentioned that SD can be used to deal with dynamic changes, in which a change can cause other changes over time.

SD modeling is used in various research, such as business, construction, economy, policy, environment, medicine, and transport. Many researchers utilize the SD approach in their studies, including the transportation studies. Perez-Lespier [21], for example, developed an SD model to understand disruptions that affect the efficiency of the multimodal transportation system in USA. Rawal and Devadas [22], on the other hand, utilized the SD modeling to analyze the impact of road transportation and develop plausible policy decision for sustainable development in Kanyakumari district. Yu et al. [23] analyzed the impact of different transportation levels and the proportion of road and railway investment on the land transportation systems in a port city in Tianjin, China.

This study utilizes the SD modelling approach to develop the dynamics model of multimodal transportation of cassava products for several reasons.

- SD modeling looks at the policies as well as the processes: SD enables policies to be included in the model as well as processes, so that any problems with the policies can be addressed.
- SD modeling considers the problem as a whole and includes cause-effect interrelationships between system variables.
- SD modeling includes both qualitative and quantitative analyses, thus providing a good basis for decision-making.

The iThink software is used to develop the dynamics model of multimodal transportation of cassava products in this study. It contains visualized symbols, such as converter, flow, connectors, and stocks. Converter stores the information about the state of the system. Flow, on the other hand, changes the state that affects a stock at any point of time. Connectors interpret the relationships between two variables. Stock accumulates the influences it receives over time [20].

4.2 Dynamics Model Of Multimodal Transportation Of Cassava Products

The dynamics model of multimodal transportation of cassava products consists of 11 sub-models: six saving, four cost, and net cash flow sub-models (see Figure 3). Data in Tables 2 and 3 are used to develop equations of the dynamics model of multimodal transportation of cassava products. Saving in labor cost sub-model, for example, calculates the labor cost saving each year by comparing the labor cost used in single (i.e., truck) mode and labor cost when multimodal transportation (i.e., truck and train modes) is used.

4.3 Saving in Labor Cost Sub-Model

Labor cost is considered in terms of truck drivers in the delivery process (one truck driver per truck). Seo et al. [13] mentioned that multimodal transportation requires less trucks, as truck driving distance is shortened from origin to the nearest train station. This results in less truck drivers required in the operation and lower labor cost per year, see Figure 3 and Equations 1 and 2.

$$LCS = TSPY \times LCPY \quad (1)$$

$$TSPY = TTPY - TMPY \quad (2)$$

Where LCS = Saving in labor cost (baht/year)

TSPY = Less trucks required per year (trucks)

LCPY = Labor cost per year (baht/truck/year) (one truck requires one driver)

TTPY = Trucks required per year using road mode (trucks)

TMPY = Trucks required per year using multimode (trucks)

4.4 Saving in Fuel Cost Sub-Model

Fuel cost consists of fuel price, fuel consumption rate, and travel distance. When the multimodal transportation is implemented, less trucks are required, as travel distance is reduced i.e., from origin to train station (instead of origin to Laemchabang port), resulting to less fuel cost (considering the same fuel consumption rate), see Equations 3 and 4 [13].

$$FCS = FCTPY - FCMPY \quad (3)$$

$$FCMPY = FCMLBPY + FCMCYPY \quad (4)$$

Where FCS = Saving in fuel cost (baht/year)

FCTPY = Fuel cost per year using truck mode (baht/year)

FCMPY = Fuel cost per year using multimode (baht/year)

FCMLBPY = Fuel cost per year to Laemchabang port using multimode (baht/year)

FCMCYPY = Fuel cost per year to container yard using multimode (baht/year)

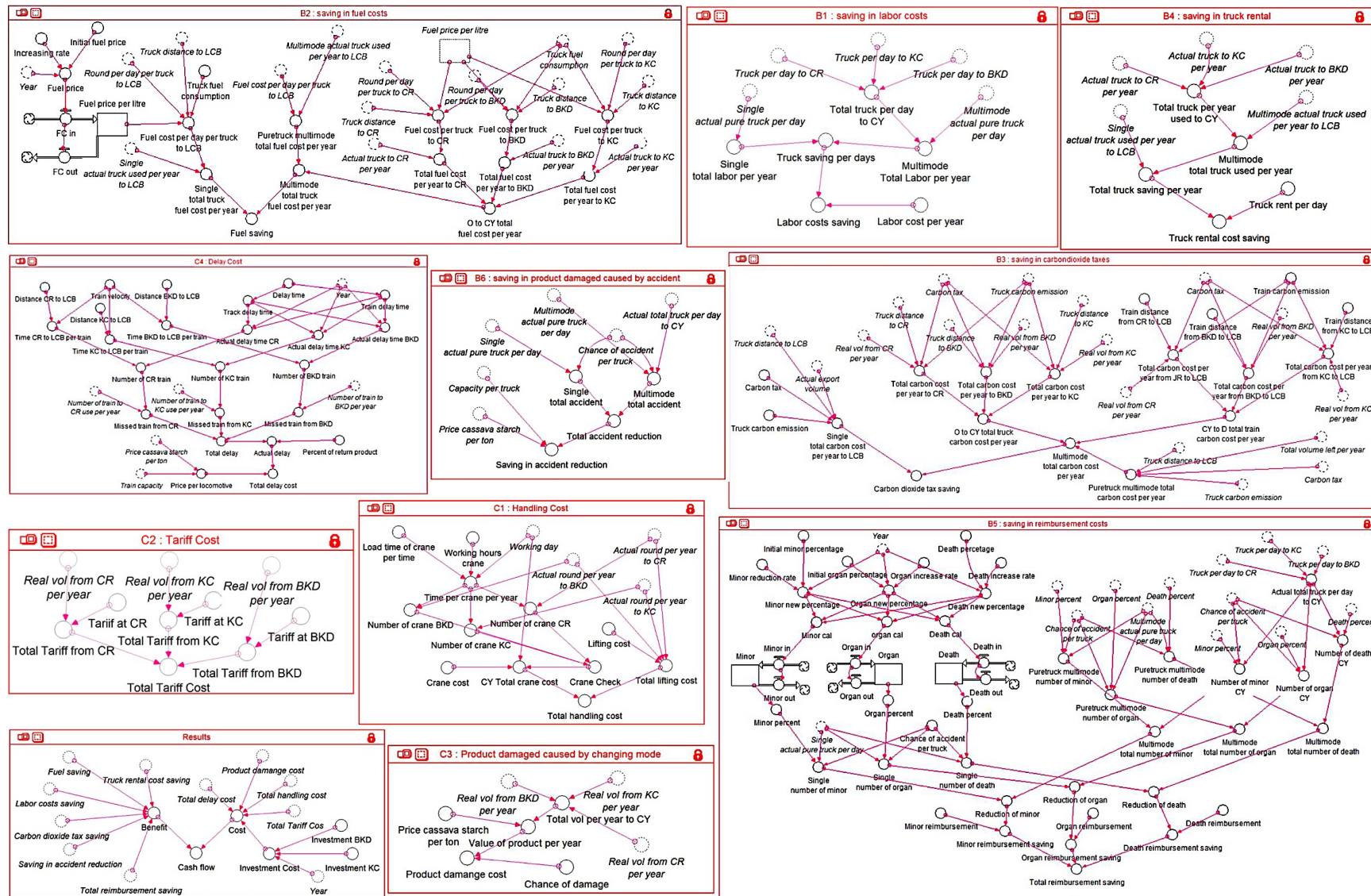


Figure 3 The dynamics model of multimodal transportation of cassava products

4.5 Saving in Carbon Dioxide Tax Sub-Model

Train mode releases less CO₂ than truck mode by around eight times [17, 11]. The use of multimodal transportation, thus, helps the company reduce CO₂ emission and CO₂ tax (see Equations 5 and 6).

$$CTS = CTPY - CTMPY \quad (5)$$

$$CTMPY = CTMLBPY + CTMCYPY + CTMRPY \quad (6)$$

Where CTS = Carbon dioxide tax saving (baht/year)

CTPY = Carbon dioxide tax per year using truck mode (baht/year)

CTMPY = Carbon dioxide tax per year using multimode (baht/year)

CTMLBPY = Carbon dioxide tax per year to Laemchabang port using multimode (baht/year)

CTMCYPY = Carbon dioxide tax per year to container yard using multimode (baht/year)

CTMRPY = Carbon dioxide tax per year using train in multimode (baht/year)

4.6 Saving in Truck Rental Cost Sub-Model

In this study, trucks in the transportation are rent to avoid maintenance problems. When multimodal transportation is utilized, trucks are reduced, as travel distance is shortened, leading to less truck rental cost (see Equation 7) [15, 13].

$$RCS = TSPY \times RCPY \quad (7)$$

Where RCS = Saving in truck rental cost (baht/year)

TSPY = Less trucks required per year (trucks)

RCPY = Truck rental cost per year (baht/truck/year)

4.7 Saving in Reimbursement Cost Sub-Model

Three levels of road injury are considered in this study: minor, loss of organs, and death [19, 12]. Based on Ministry of Road Transport and Highways [12], the probabilities of injury in minor, loss of organs, and death are 96.69 %, 2.74 %, and 0.57 % of total accident occurrences, respectively. The use of multimodal transportation is expected to reduce the reimbursement cost from less road accidents (see Equation 8).

$$RBS = RBMPY + RBOPY + RBDPY \quad (8)$$

Where RBS = Saving in reimbursement cost (baht/year)

RBMPY = Saving in reimbursement cost from minor injuries (baht/year)

RBOPY = Saving in reimbursement cost from losses of organs (baht/year)

RBDPY = Saving in reimbursement cost from deaths (baht/year)

4.8 Saving in Accident Cost Sub-Model

Accidents not only imply a direct cost, but also reduce the competitiveness of exports. Accidents, when occurred, cause product damage. In this study, less accidents result in less products damaged (see Equation 9).

$$ACS = ACRPY \times TCap \times CVP \quad (9)$$

Where ACS = Saving in accident cost (baht/year)

ACRPY = Accident reduction per year (times/year)

TCap = Truck capacity (tons/time)

CVP = Cassava price (baht/ton)

4.9 Holding Cost Sub-Model

Crane, lift-on, and lift-off costs are included in this study to transfer from truck to train modes. Crane charge is considered based on working hours, total load, and load sizes. The charge ranges from 15,000-20,000 baht per time. Lift-on and lift-off equipment are equipped with cranes to load and unload cargoes, and they cost between 350-500 baht per time [15, 14] (see Equation 10).

$$HLC = CRCPY + LLCPY \quad (10)$$

Where HLC = Handling cost (baht/year)

CRCPY = Crane cost (baht/year)

LLCPY = Lift on and lift off cost (baht/year)

4.10 Tariff Cost Sub-Model

Tariff cost incurs when train mode is used. The cost ranges from 246-279 baht/ton [16]. In this study, CYs at the train stations are used to deliver cassava products to Laemchabang port (see Equation 11).

$$TFC = TFCRPY + TFKCPY + TFBDPY \quad (11)$$

Where TFC = Tariff cost (baht/year)

TFCRPY = Tariff cost from Chira Station to Laemchabang port (baht/year)

TFKCPY = Tariff cost from Kutchik Station to Laemchabang port (baht/year)

TFBDPY = Tariff cost from Ban Kradone Station to Laemchabang port (baht/year)

4.11 Product Return Cost Sub-Model

In this study, product return cost is calculated based on amount of products that cannot be delivered on time due to the delay, and the returned chance [13]. According to State Railway of Thailand [16], the average delay time of the train is around 2 hours. NESDB [14] mentioned that the returned chance of cassava products is around 1% of the total export volume (see Equation 12).

$$PRC = 0.01 \times CVPY \times CVR \quad (12)$$

Where PRC = Product return cost (baht/year)

CVPY = Cassava shipment per year (trains/year)

CVR = Cassava cost per train (baht/train)

4.12 Product Damaged Cost Sub-Model

The use of multimodal transportation requires transshipments that may cause product damaged. This may affect the decision to utilize the multimodal transportation. According to NESDB

[14], the product damaged chance of cassava products is 4.18% of the total shipment volume (see Equation 13).

$$PDC = 0.0418 \times CVPY \times CVR \tag{13}$$

Where PDC = Product damaged cost (baht/year)
 CVPY = Cassava shipment per year (trains/year)
 CVR = Cassava cost per train (baht/train)

4.13 Net Cash Flow Sub-Model

Total saving (TS), achieved from the multimodal usage, is the sum of the six saving elements. Total cost (TC), similarly, is the sum of the four costs. This leads to the net cash flow (NCF) in each period, by having total saving subtracts total cost (see Equations 14-16).

$$NCF = TS - TC \tag{14}$$

$$TS = LCS + FCS + CTS + RCS + RBS + ACS \tag{15}$$

$$TC = HLC + TFC + PRC + PDC \tag{16}$$

Where NCF = Net cash flow (baht/year)
 TS = Total saving (baht/year)
 LCS = Saving in labor cost (baht/year)
 FCS = Saving in fuel cost (baht/year)
 CTS = Carbon dioxide tax saving (baht/year)
 RCS = saving in truck rental cost (baht/year)
 RBS = Saving in reimbursement cost (baht/year)
 ACS = Saving in accident cost (baht/year)
 TC = Total cost (baht/year)
 HLC = Handling cost (baht/year)
 TFC = Tariff cost (baht/year)
 PRC = Product return cost (baht/year)
 PDC = Product damaged cost (baht/year)

5.0 RESULTS

5.1 Simulation Results

The dynamics model of multimodal transportation of cassava products is simulated, and the results are as shown in Table 4 and Figure 4. In this study, the Internal Rate of Return (IRR) are used to determine the feasibility of the project based on six savings and four costs (see Equations 14-16). The IRR is the discount rate that makes the net present value of a project zero (see Equation 17).

$$0 = \sum_{t=0}^N \frac{NCF_t}{(1 + IRR)^t} \tag{17}$$

Where NCF = Net cash flow (baht/year)
 IRR = Internal rate of return (%)
 t = period
 N = total period

According to Chileshe et al. [25], the IRR of at least 12% is commonly used in public projects to measure the feasibility. The simulation results show that in the initial year (year 0), the dual track project is invested to initiate the multimodal transportation to increase the efficiency of train mode. This

costs around 1.3 billion baht in investment, causing negative cash flow at the beginning of the project. Once the dual track is fully operated in CY stations (in years 5, 8, 11, and 14, respectively), savings increase due to higher efficiency of multimodal transportation. It is found that the IRR of the project is higher than the minimum acceptable rate of 12% at the end of year 10 (see Figure 4). This is consistent with Yachiyo Engineering and Japan International Consultants for Transportation [26] that it takes 13 years for the high-speed railway project in Indonesia to be feasible. The IRR reaches 20% when the project is continued for 17 years.

Table 4 Simulation Results

Year	Total Saving (Baht)	Total Cost (Baht)	Net Cash Flow (Baht)	IRR (%)
0	0	1,342,448,000	-1,342,448,000	-
1	448,214,599.98	307,062,232.42	141,152,367.56	-89.49
2	448,735,226.22	307,062,232.42	141,672,993.80	-61.83
3	449,510,691.04	307,062,232.42	142,448,458.62	-41.05
4	450,641,662.98	307,062,232.42	143,579,430.56	-27.22
5	904,179,601.07	584,369,345.25	319,810,255.81	-11.02
6	908,460,554.59	584,369,345.25	324,091,209.34	-2.43
7	913,833,406.13	584,369,345.25	329,464,060.88	3.02
8	1,354,562,216.12	865,351,948.56	489,210,267.57	8.11
9	1,364,106,771.63	865,351,948.56	498,754,823.07	11.41
10	1,373,122,397.02	865,351,948.56	507,770,448.46	13.69
11	1,615,396,467.87	1,012,710,252.91	602,686,214.96	15.58
12	1,622,525,387.03	1,012,710,252.91	609,815,134.12	16.94
13	1,627,785,839.03	1,012,710,252.91	615,075,586.12	17.94
14	1,789,403,113.08	1,112,329,352.62	677,073,760.46	18.76
15	1,792,159,371.08	1,112,329,352.62	679,830,018.46	19.37
16	1,793,994,023.03	1,112,329,352.62	681,664,670.41	19.85
17	1,795,201,809.21	1,112,329,352.62	682,872,456.59	20.21
18	1,795,994,783.51	1,112,329,352.62	683,665,430.88	20.50
19	1,796,518,104.86	1,112,329,352.62	684,188,752.24	20.72
20	1,796,868,135.80	1,112,329,352.62	684,538,783.18	20.90

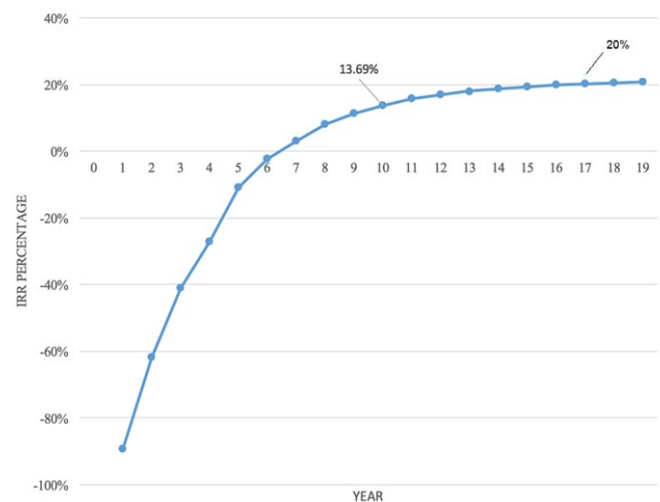


Figure 4 IRR of the project

Figures 5 and 6 show the saving and cost elements of the multimodal transportation of cassava products. Saving in truck rental cost is the most important saving element, while product damaged cost is the highest cost. By using fewer trucks, the company can also reduce the fuel and accident costs; however, products may be damaged during the transshipment processes.

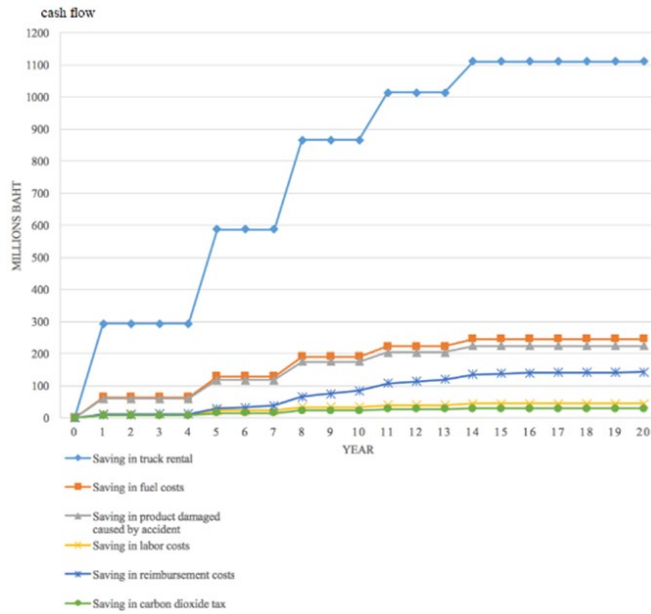


Figure 5 Simulation results of saving elements

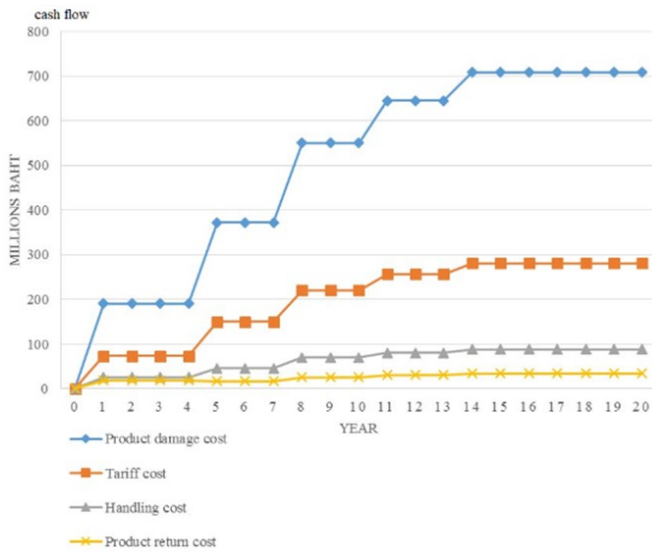


Figure 6 Simulation results of cost elements

5.2 Sensitivity Analysis

Sensitivity analysis is used to determine how sensitive a model is to changes in the value of the parameters of the model, and to changes in the structure of the model. Hekimoğlu and Barlas [27] mentioned that parameters of SD models are subject to uncertainty, therefore, sensitivity analysis is crucial for evaluating the reliability of model outputs. If changes in value of parameters do not change model behaviour, then the model is non-sensitive, stable, and reliable.

In this study, the saving in truck rental cost and product damage cost elements are performed with sensitivity analysis to test the sensitiveness of the model. This is because they contribute the highest saving and cost, respectively (see Figures 5 and 6).

5.3 Changes in Truck Rental Cost

Truck rental cost used in the dynamics model development is set at 22,500 baht per truck. However, this truck rental price might be fluctuated; this might cause changes in the model results. In the sensitivity analysis, therefore, is performed when the truck rental cost is changed from the lowest of 15,000 baht per truck to the highest of 30,000 baht per truck [28].

The dynamics model of multimodal transportation of cassava products is run with three truck rental price scenarios: 15,000 (lowest rental price), 22,500, and 30,000 (highest rental price) baht per truck, respectively. The simulation results are illustrated in Table 5 and Figure 7. The results confirm the non-sensitive model, as only the magnitude of the model changes, not the behavior of the model. This is consistent with [27] that non-sensitive model only changes magnitude of the results, not the behavior of the model. It is also found that when the truck rental cost is 15,000 baht, the minimum IRR of 12% is achieved after 20 years, while higher rental costs of 22,500 and 30,000 baht bring the acceptable IRR within 10 and 7 years, respectively. This confirms that higher truck rental cost brings higher savings when multimodal transportation is utilized.

Table 5 IRR Values When the Truck Rental Cost is Changed

Year	IRR (%)		
	Truck Rental Cost of 15,000 Baht	Truck Rental Cost of 22,500 Baht	Truck Rental Cost of 30,000 Baht
1	-96.79	-89.49	-82.18
2	-80.29	-61.83	-47.91
3	-63.32	-41.05	-25.70
4	-49.96	-27.22	-12.13
5	-31.75	-11.02	2.89
6	-22.01	-2.43	10.71
7	-15.43	3.02	15.45
8	-9.09	8.11	19.76
9	-4.79	11.41	22.47
10	-1.65	13.69	24.28

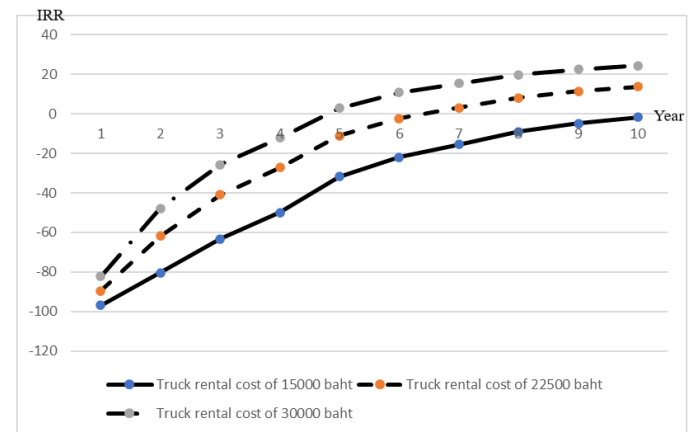


Figure 7 Sensitivity analysis when the truck rental cost is changed

5.4 Changes in Product Damaged Cost

According to State Railway of Thailand [16], percentage of product damage ranges from 2.37% - 4.18%. Low percentage of product damage through, for example, effective handling

equipment and skilled labor reduces the product damage cost. In this study, the developed dynamics model of multimodal transportation of cassava products is tested with three possible percentages of product damage: 2.37%, 3.28%, and 4.18%, respectively. The simulation results are as shown in Table 6 and Figure 8. The results confirm the non-sensitive model, as only the magnitude of the model changes, not the behavior of the model. It is found that high percentage of product damage causes high product damage cost. With high percentage of product damage, it takes longer time for the IRR to achieve its minimum acceptable value of 12%.

Table 6 IRR Values When the Percentage of Product Damage is Changed, Causing Different Product Damage Costs

Year	IRR (%)		
	2.37% of Product Damage	3.28% of Product Damage	4.18% of Product Damage
1	-83.33	-86.41	-89.49
2	-49.95	-55.66	-61.83
3	-27.90	-34.15	-41.05
4	-14.28	-20.39	-27.22
5	0.83	-4.78	-11.02
6	8.73	3.46	-2.43
7	13.57	8.58	3.02
8	17.99	13.31	8.11
9	20.78	16.34	11.41
10	22.66	18.40	13.69

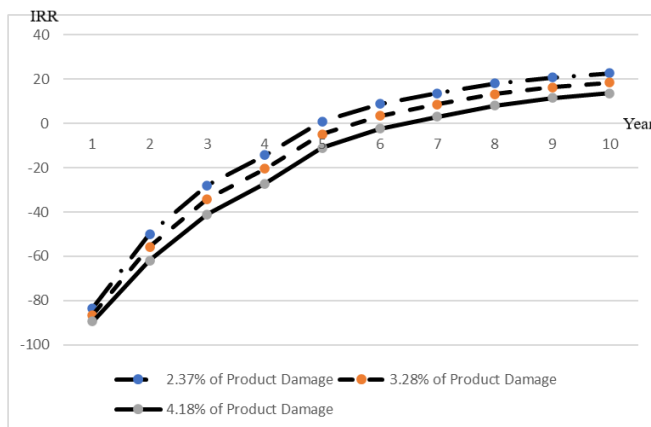


Figure 8 Sensitivity analysis when the percentage of product damage is changed

6.0 CONCLUSION

Being the second largest cassava producer in the world, Thailand aims to increase the export amount to neighbouring and other countries around the world. Attempting to reduce the logistics and transportation costs, the government initiates various projects to support the multimodal transportation. Wongsanguan [5] mentioned that the use of multimodal transportation (i.e., combination of road, rail, and water modes) reduces the logistics cost when compared with the single truck mode. This study develops the dynamics model of multimodal transportation of cassava products utilizing the system dynamics modelling approach. The model consists of six saving and four cost elements. Data are collected through several transportation literature to develop the equations for

the dynamics model. The simulation results reveal that the project becomes feasible at the end of year 10 with the internal rate of return of higher than the minimum of 12%. The results also show that the saving in truck rental cost and the product damaged cost are the most important saving and cost elements, respectively. Attention must be paid for these two elements when planning for multimodal transportation in the long-term.

This study contributes to the existing body of knowledge and the transport industry in the following ways:

- No previous research has been performed to consider the long-term effect of the use of multimodal transportation of agricultural products in Thailand. The developed dynamics model in this study can be used to examine the cause and effect of the project in the long-term.
- Six saving and four cost elements give a good representation of multimodal transportation of agricultural products in Thailand.
- The study results provide the NPV and IRR values to be used to examine the feasibility of the project. This is useful for the cassava and logistics companies to plan for the multimodal transportation in the long-term.
- Truck rental cost and product damage cost are found the most important factors in multimodal transportation. Government should provide a better infrastructure, for example, double track system and effective CYs and handling system to encourage the use of multimodal transportation.
- Sensitivity analysis can be performed with different factors to effectively plan for multimodal transportation strategies and policies for the company.

This research study was conducted using data from cassava firms in Thailand, which is considered a developing country. A comparative study, thus, may be performed between developed and developing countries to investigate the differences in food safety standard and implementation. Other modes of transportation, such as inland water combining with road transport, rail combining with inland water transport, could also be performed to compare the study results.

The developed dynamics model can be used as a guideline for the agricultural and transport industries and government to effectively plan for the multimodal transportation in the long-term.

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