



**SUCCESSFUL MULTIMODAL TRANSPORTATION OF
BLOCK RUBBER IN THAILAND**

BY

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DISSERTATION

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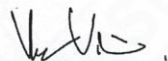
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BLOCK RUBBER IN THAILAND

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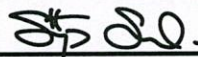
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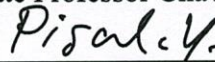
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ABSTRACT

Agricultural production is essential to the economic growth of Thailand. For decades, Thailand remains a strong agricultural competitor as it is one of the world's leading exporters of agricultural products. However, the strong competitors, such as Indonesia and Malaysia have come up with the plan for competing with cheaper price. In order to move ahead with sustainable growth, the country has embarked on the Free Trade Agreements policy with several countries, thus, bringing the preferential tariffs that lead to a growth in bilateral trade and export opportunities. In this regard, the country must produce better quality of agricultural products, and deliver to the doors in competitive prices to maintain its competitiveness.

In the past, transportation of agricultural products in Thailand relied mainly on road because of its extensive network and convenience. However, with the limited loads, traffic congestion, air pollution problem, and higher fuel prices, this transportation mode becomes less effective. In general, agricultural products has low selling price per unit and low value. The most effective transportation mode for them is the mode that can carry in large volume which is multimodal transportation. The government, then, attempts to develop and promote multimodal transportation,

especially rail and water modes, to reduce the costs and increase the transportation network efficiency.

To promote the use of multimodal transportation, it is necessary to understand key factors influencing the multimodal transportation effectiveness. These factors also have influences on each other, making it hard to plan for the long-term plans. Thus, it is necessary to summarize key challenges and limitations of multimodal transportation. Moreover, relationships among those criteria must be examined, so that the effective development plan could be established. This study, therefore, examines key factors influencing the multimodal transportation of agricultural products in Thailand, as well as their interrelationships.

Based on a number of literatures, five key factors influencing multimodal transportation of agricultural products in Thailand are hypothesized, together with 20 associated items, including Multimodal Transportation, Operation, Multimodal Service Provider, Market, and Road Constraints. A questionnaire survey is, then, developed to collect data. The collected data are screened and performed by Exploratory Factor Analysis (EFA) to confirm key factors influencing multimodal transportation of agricultural products in Thailand with their associated items. The five key factors are then performed with the Structural Equation Modeling (SEM) to examine interrelationships among them.

The results reveal that an increase in road transportation issues grow a preference of transport service providers on multimodal transportation. When the transport service providers take their interests in multimodal transportation, the operation in multimodal service is also improved to fully utilized company resources and maximize efficiency. These lead to reduction in logistics costs and enhancement of company's green image, thus, increase of companies' competitiveness. Government may also support the multimodal transportation by improving multimodal transportation infrastructure to minimize resources and modal shift processes. The government policies will, in turn, stimulate the transport service providers in using multimodal transportation. This will, eventually, turns to a dynamic cycle of multimodal transportation overtime through continuous improvement in factors influencing multimodal transportation. These dynamic relationships can be further

studied by constructing the simulation model to compare costs of multimodal transportation and road transportation.

As mentioned above, Thailand is one of the world's leading exporters of agricultural products. Specifically, the growth of world natural rubbers demand increases by 3% in 2019 which leads to the growth in natural rubbers production and export in Thailand as it is also the world's leading natural rubbers exporter. The major exported type of natural rubber is block rubber as it is the main material for automobile production industry in China. Additionally, China has imposed a policy to stimulate domestic automobile market, leading to rise in demand for block rubber.

Thus, this study, then, develops a dynamic model of multimodal transportation of block rubber transportation in Thailand by using System Dynamics (SD) modeling. In this study, the block rubber demand and supply, transportation-related costs and capacity, as well as the government and company policies in multimodal transportation development, have been placed in the simulation model to introduce alternative modes of transportation and compare costs between road transportation and multimodal transportation usages. The sensitivity analysis and policy analysis are, then, performed to ensure that the uncertainty will not significantly affect the overall behavior of the model, as well as explain how to change policy to receive the satisfactory and optimized results in a specific time.

The results show that a focus on multimodal transportation development will give company a competitive edge over road-only transportation with the optimization of logistics and transportation costs. However, with the limited capacity of each mode, all modes are still needed in order to complete the transportation of total demand amount. The results also reveal that the road transportation is a good alternative when only using as a support transportation mode for multimodal transportation. Regarding the government policies, the results show that the current multimodal transportation development policies is already fit with the block rubber demand and market situation for next 20 years. It can be seen that the use of multimodal transportation can save up to one time the logistics cost of the traditional mode. The government, therefore, should support the use of multimodal transportation in the long term to achieve the highest benefit for the industry and the country as a whole. The support could be in various areas, such as infrastructure development and R&D of agricultural product

transportation. These may lead to market competitiveness and market enhancement in the global scale.

Keywords: Block rubber, Costs comparison, Decision making, Exploratory factor analysis, Multimodal transportation, Policy analysis, Sensitivity analysis, Structural equation modeling, System dynamics modeling, Transportation management



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Dear Myself,

Thank you for never giving up. And I am so proud of you for that.
You are always so worthy of love. I am sorry people had convinced you otherwise.
You have survived every single thing you thought you wouldn't.
There is so much greatness in you, just dying to be released.
From now on, go live your life to the fullest.

Dear My Mommybear,

Thank you for never giving up on me. You love me unconditionally.
You always give and forgive.
You even pray for the people who hurt me to have good lives because you believe that
when people satisfy with their lives, they will not hurt the others.
You have the purest heart, no one can compare to you.
I am a strong woman because you, a strong woman, raised me.
I promise I will spend my whole life loving and taking care of you.

Dear N'Atom,

When things break my heart into pieces,
you are always the only one who collect me up piece by piece.
Thank you for always believing that I am more than good enough, and I can do it.
That makes me brave.
I am blessed that I have you genuinely supporting me.
Your love and energy are so loud, and that silences all of my insecurities.
You are literally my bestie.
Love and support you till I die.

Dear Mom, Papa, J'Leiw, and Koh'Fong,

I am so glad that I have you guys.

Thank you for respecting who I am and helping me to flourish.

We are unbreakable and we will always be able to get through anything together.

I always carry your loves with me no matter where I go and what I do.

I promise I will make you guys proud of me every day.

Dear My Cats,

Thank you for always comforting me.

I want to especially thank Som-meow for keeping our promise.

I wish we would be humans and we could be the best friends in the next life.

Dear My Advisor, Assoc. Prof. Dr. Thanwadee Chinda

Thank you for all guidance that you have given me over the past six years.

Thank you for standing by me from the first day till the best day of my life.

You are and will always be a definition of "the great teacher" to me.

I will always root for you with all my gratitude and respect.

Dear My Friends,

Thank you for standing by me even when I have nothing to give you in return.

Our moments of laughter make me feel so alive.

Cheer-up things you said mean so much to me to live to fight another day.

I am appreciated that you are people whom I can show my kindness without caution.

Dear Anyone, who is Struggling,

I know what it feels like to be lost and invisible. But please just keep hanging in there.

All great things take time. Consistency is harder when no one is clapping for you.

You must clap for yourself during those times, you should always be your biggest fan.

Dear Everyone, Who Caused Me Hard Times and Miserableness,

You've lost me as a friend, but it doesn't mean you gained me as an enemy.

I am bigger than that. I still want to see you eat, but just not at my table.

And you will never know the damage you did to someone,
until the same thing is done to you. That's why karma is there.

Pimnapa Pongsayaporn

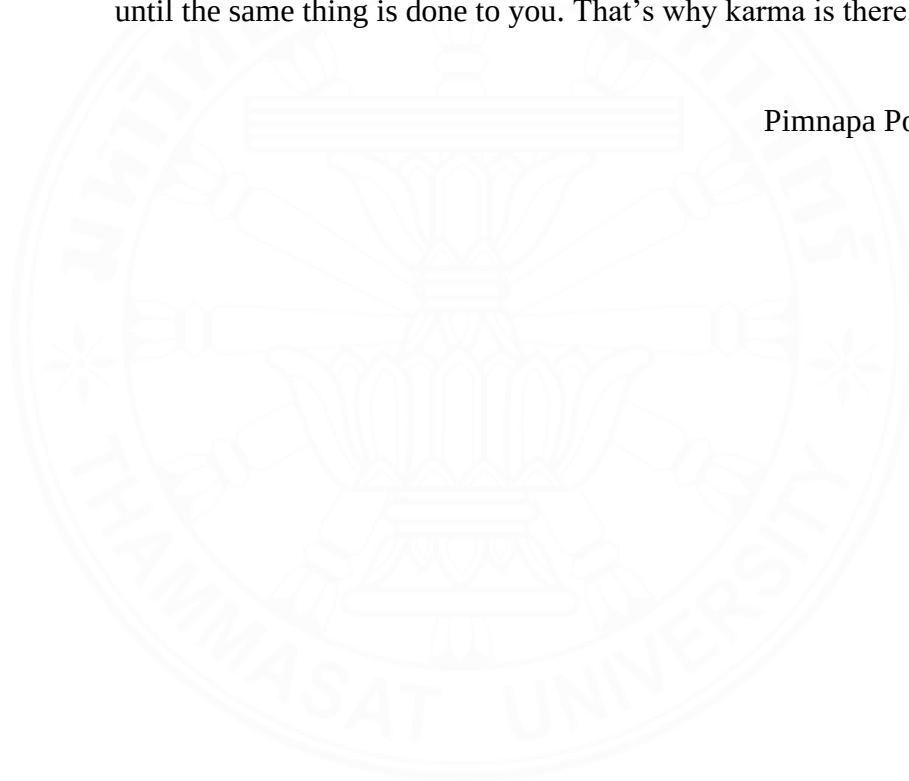


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LIST OF SYMBOLS/ABBREVIATIONS

Symbols/Abbreviations	Terms
ACD	Road Accident
ACY	Accessibility
AHP	Analytic Hierarchy Process
ASEAN	The Association of Southeast Asian
Nations	
BR	Block Rubber
CAP	Capacity
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CLMV	Cambodia, Laos, Myanmar, and
Vietnam	
CMIN/DF	Relative Chi-Square
CO ₂	Carbon Dioxide
CY	Container Yard
DOC	Documentation
DSN	Vehicle Design
EFA	Exploratory Factor Analysis
EMP	Skilled Employee
EQP	Transshipment Equipment
GDP	Gross Domestic Product
GOV	Government Policy
ICD	Inland Container Depot
IMG	Green Image
IOC	IOC
KMO	Kaiser-Meyer-Olkin
LAW	Road Law Enforcement
LC	Laem Chabang
LOG	Logistics Costs

Symbols/Abbreviations

MKT

NR

PAF

PCA

PUN

REL

RMSEA

Approximation

SD

SEM

SER

SPD

SPSS

Sciences

TEUs

TLI

TRF

TRK

TSC

VOL

Terms

Market Competitiveness

Natural Rubber

Principal Axis Factoring

Principal Components Analysis

Punctuality

Relationships

Root Mean Square Error of

System Dynamics

Structural Equation Modeling

Service Providers

Delivery Speed

Statistical Package for the Social

Twenty – Foot Equivalent Units

Tucker–Lewis index

Road Traffic

Tracking System

Transshipment Costs

Volume Flexibility

CHAPTER 1

INTRODUCTION

1.1 Research Background

Agricultural production is essential to the economic growth of Thailand (Ajiboye & Afolayan, 2009). For decades, Thailand remains a strong agricultural competitor as it is one of the world's leading exporters of agricultural products (Food and Agriculture Organization of the United Nations, 2018). Major export products are natural rubbers, rice, and cassava (USDA Foreign Agricultural Service, 2017). In particular, Thailand is the largest producer and exporter of natural rubber due to its geographical advantages, tropical climate, soil fertility, and effective cultivation methods (Thailand Board of Investment, 2019).

The major importer of Thai natural rubber is an automobile tire production industry in China which is the world's largest consumer of natural rubbers (Chanchaichujit, 2014). According to Kritchanhai and Chanpuypetch (2009), block rubber is the main raw material in tire production industry, thus, making it the most production and export type of Thai natural rubber.

However, strong competitors, such as Indonesia and Malaysia have come up with the plan for competing with cheaper price (Doner & Abonyi, 2013). In order to move ahead with sustainable growth, Thailand has embarked on the Free Trade Agreements policy with several countries, such as China, Japan, India, and Australia, thus, bringing the preferential tariffs that lead to the growth in bilateral trade and export opportunities (KPMG, 2018). In this regard, the country should produce better quality of block rubber, and deliver to the doors in competitive prices to maintain its competitiveness. According to Ajiboye and Afolayan (2009), an access to transportation infrastructure and logistics service is crucial as it strengthens market competitiveness. Consequently, the government decides to give precedence to transportation and logistics services development by promoting the transportation support policies (Thongkhaw, 2016).

In the past, the transportation of block rubber in Thailand relied mainly on road because of its extensive network and convenience. However, with increased issues,

including limited capacity, traffic congestion, air pollution problem, and higher fuel prices, this transportation mode becomes less effective. In general, block rubber have low selling prices per unit and low values, so that, their most effective transportation modes should be a combination of road, rail, and water transportation to gain benefits of heavy bulk shipment and reduced logistics costs (Tanachodrungsatis, 2014; Timaboot & Suthikarnnarunai, 2017). The government, then, attempts to develop and promote multimodal transportation, especially rail and water modes, to reduce logistics costs and increase transportation network efficiencies. Government policymakers executed a number of projects, for example, double-track railway development, water transportation network enhancement, and Eastern Economic Corridor development projects to encourage logistics providers to use alternative modes to reduce road congestion, save logistics cost, and lower environmental impacts, which lead to the sustainable transportation development and enhance the country's market competitiveness among Southeast Asian countries (Bui, 2011).

To promote the use of multimodal transportation, key multimodal factors should also be examined with their interrelationships to better understand the causes and effects of multimodal transportation implementation, so that the effective development plans and policies could be established. This study, therefore, confirms key multimodal factors influencing successful multimodal transportation of agricultural products in Thailand with their associated items by exploratory factor analysis (EFA). The multimodal key factors are then performed with the structural equation modeling (SEM) to examine causal relationships among them.

With the causal relationships among key multimodal factors, it may create a dynamic cycle of multimodal transportation development overtime through continuous improvement from both government and business sectors. These dynamic relationships can be further studied by constructing the simulation model to compare costs and benefits of multimodal transportation and road transportation.

Thus, this study then develops a dynamic model of successful multimodal transportation of block rubber in Thailand by using system dynamics (SD) modeling. In this study, the block rubber demand and supply, transportation-related costs and capacity, as well as the government and company policies in multimodal transportation development, have been placed in the simulation model to introduce alternative modes

of transportation and compare costs between road transportation and multimodal transportation usages. The sensitivity analysis and policy analysis are, then, performed to ensure that the uncertainty will not significantly affect the overall behavior of the model, as well as explain how to change policy to receive the satisfactory and optimized results in a specific time. This will turn into the benefit for both government and business sector to be competitive in the world market.

1.2 Research Needs and Research Aims

The primary objective of this research is to identify factors influencing multimodal transportation of block in Thailand, from block rubber production companies to export point, as well as to examine the causal relationships among key multimodal influencing factors. The main analysis of this objective is carried out using EFA and SEM methods. EFA method is used for sorting groups of key multimodal influencing factors which are summarized from previous studies. SEM method, then, is used to examine the causal relationships among key multimodal influencing factors.

With clarity of how the key multimodal influencing factors influence each other, it is possible to suggest the SD model to simulate the interaction of their causal relationships over a period of time. Moreover, the government policies and company's strategies are added to the model to evaluate the feasibility of multimodal transportation usage in the long-term. The recommendations for policymakers and transportation managers based on the simulation results are also presented to successfully increase the modal share of multimodal transportation, which is the long-term aim of this study.

1.3 Thesis Organization

The thesis is organized into nine chapters. The structure of each chapter is as follows:

Chapter 1 describes the background of block rubber transportation, as well as the government strategies supporting multimodal situation in Thailand. This chapter identifies the gaps between current situation and goal. The research needs and aims are identified in order to successfully develop multimodal transportation of block rubber in Thailand.

Chapter 2 outlines the adopted research methodology, including research framework and research design. This chapter also outlines concept of performing literature review, data collection and data screening, Exploratory Factor Analysis (EFA) method, Structural Equation Modeling (SEM) method, system dynamics modeling method, and application of SEM results in SD model development.

Chapter 3 reviews the literature on block rubber production and export in Thailand, transportation of block rubber in Thailand, items influencing multimodal transportation, statistical analysis methods used in multimodal transportation studies, and previous studies on multimodal transportation model development. The research methods to be used in this study are summarized based on the alignment with research aims and framework.

Chapter 4 clarifies the questionnaire survey development, data collection, and data screening processes to increase confidence in collected data.

Chapter 5 presents the EFA conducting by Statistical Package for the Social Sciences (SPSS, version 21) software to reduce the number of items into a smaller number of factors.

Chapter 6 proposes the SEM method to investigate the causal relationships among factors extracted from EFA method in Chapter 5.

Chapter 7 develops the dynamic model for multimodal transportation of block rubber in Thailand using SD modeling method.

Chapter 8 contributes the effective model design and formulation, addresses the current issues, and suggests future recommendations for government, related authorities, and business sectors. The policy analysis is also performed through the SD model to achieve the best policy to enhance the efficiency and competitiveness of multimodal transportation in Thailand.

Chapter 9 summarizes the major findings, contribution of this study, implication for government, related authorities, and business sectors, as well as limitations and recommendations for future research.

CHAPTER 2

RESEARCH METHODOLOGY

To achieve reliable findings and recommendations, the study must be well-designed with clear methodology for data collection and data analyses. This chapter outlines the research framework and research design of methods to be used in the study.

2.1 Research Framework

The primary objective of this research is to identify factors influencing multimodal transportation of block in Thailand, from block rubber production companies to export point, as well as to examine the causal relationships among key multimodal influencing factors using EFA and SEM methods, respectively. Through identification of group of factors and associated items as well as examination of the causal relationships, the EFA results and SEM model are developed based on collected data and subsequently justified through the references of previous studies. In SEM model development process, reliance on existing literature is highly recommended because of the establishment of theories which has already been justified (Hair et al., 2010).

The SEM results consist of complex direct and indirect relationships. Moreover, these relationships are continued to reinforce each other, thus, involving dynamic relationships that are changed through time. This study, therefore, further examine complex and dynamic relationships among key multimodal transportation influencing factors using the SD model to simulate the interaction of their causal relationships over a period of time. Moreover, the government policies and company's strategies are added to the model to evaluate the feasibility of multimodal transportation usage in the long-term. The study will eventually establish appropriate strategies for long-term multimodal transportation development.

The study provides robust implications for policymakers of government sector and transportation managers of business sector to plan for multimodal transportation that meets the current and future needs. The results are expected to prove that multimodal transportation is a solution to reduce the road transportation problems and

limitations, thus improving logistics costs and increasing transportation efficiency. These, in turn, raise companies' profitability and ability to compete in the global market.

2.2 Research Design

The research design (as shown in Figure 2.1) involves a review of the current situation of block rubber and multimodal transportation in Thailand, as well as the multimodal transportation literatures to identify the multimodal transportation influencing items and methods used in model development. The influencing items summarized from previous studies are then used in the questionnaire survey development to collect data and measure opinions or experiences of respondents on each item for further analyses. The data screening is then performed to increase confidence in collected data. The screened data is further analyzed using EFA and SEM methods. Following the data analyses, the SD model of multimodal transportation of block rubber in Thailand is constructed and tested to fulfil the research aims of the study. The government policies and company's strategies are also established in the model to analyze the long-term results of multimodal transportation according to these policies and strategies. Finally, the recommendations for government and business sectors to plan for multimodal transportation development that meets the current and future needs are summarized. The limitations of the study are explained, whereas the assumptions in order to improve the quality of findings are also presented.

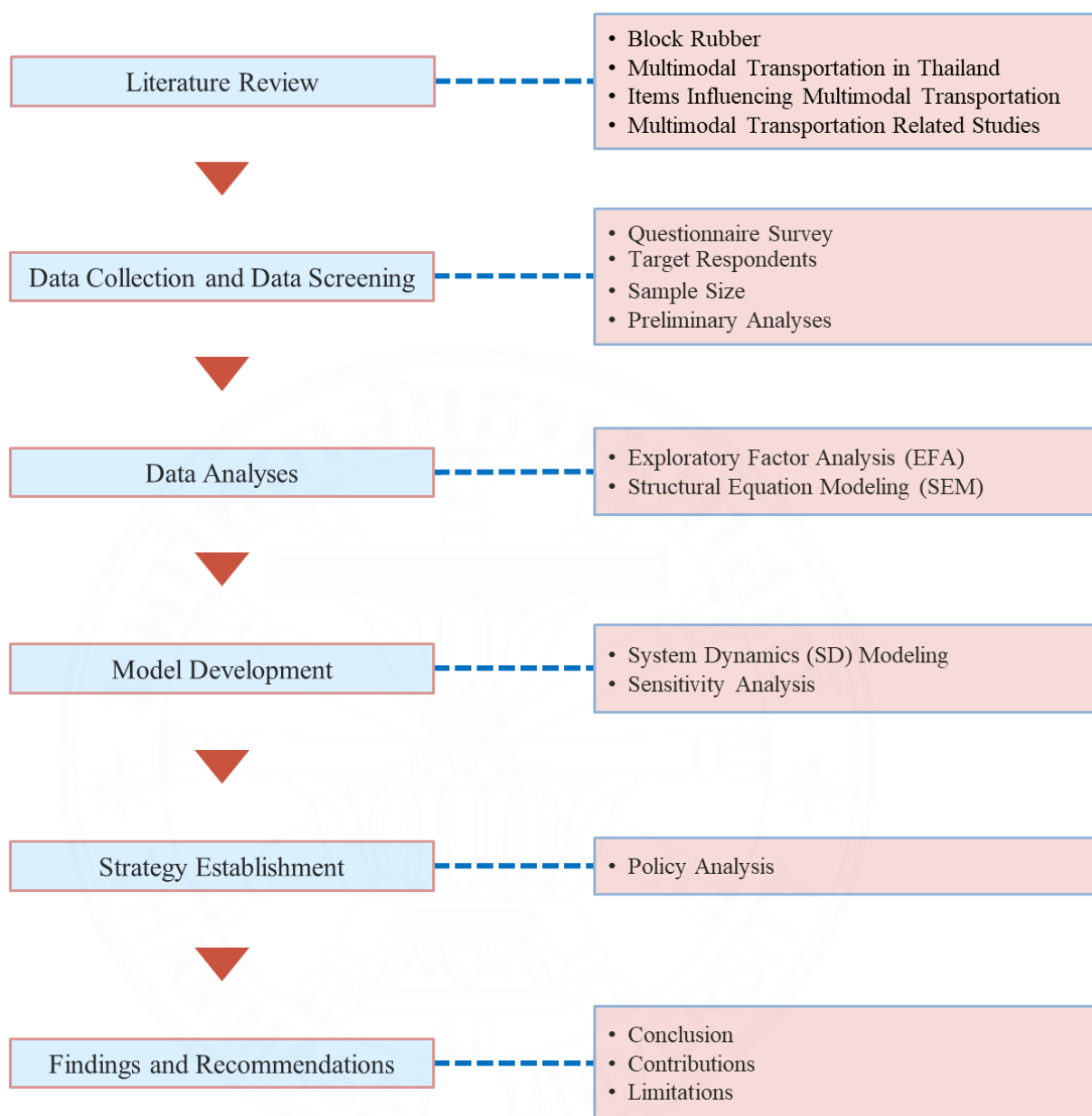


Figure 2.1 Research Design

2.2.1 Literature Review

The literature review begins with the background of block rubber situation in Thailand. Then, the transportation of block rubber in Thailand is presented to summarize the background and current situation of block rubber transportation from manufacturers to export point, as well as issues and potential of successful multimodal transportation. Items influencing multimodal transportation are then summarized from

previous studies, in both developed and developing countries, to be used in the questionnaire survey development. Multimodal transportation related studies are reviewed to study the appropriate statistical analysis methods used in multimodal transportation studies. Research on multimodal transportation model development are also considered to find the method that is suitable for simulating and quantifying the behavior of key multimodal influencing factors over a period of time, which is considered essential in understanding problems and implications for long-term success of multimodal transportation implementation.

2.2.2 Data Collection and Data Screening

With theoretical references from the literature, summarized items influencing multimodal transportation form a set of questions in questionnaire survey development to be used for data collection process. Data collection refers to gathering specific information aimed at revealing, improving, or refuting some facts (Kamuruchi, 2013). In this study, data collection aims at discovering respondents' level of agreement on each multimodal transportation influencing items based on their experiences, opinions, and perceptions.

According to Heljedal (2013), survey data collection can be accomplished through interview and mailed questionnaire survey. The interview is more appreciated for a smaller sample size, which mainly because of the resources and time requirement of performing an interview, while mailed questionnaire is more suitable for a large number of respondents. Both methods have different advantages and disadvantages. The mailed questionnaire survey normally suffers from low response rate and lack of interviewer involvement and possibilities for open ended questions. However, it is usually more cost effective, can be completed within a time frame that is convenient for the respondent, the respondent can stay anonymous, and the interviewer bias is avoided (Forza & Filippini, 1998).

Thus, this study collects data mainly by mailed questionnaire survey to obtain sufficient responses required for further analyses. However, the interview is also applied to support in examining more detailed answers in an open-ended question asking for suggestions and opinions regarding the possible use of multimodal transportation in Thailand.

The collected data is then screened to confirm its level of confidence. The study applies two statistical methods, including the outlier tests and normality test. Gao & Mokhtarian (2008) suggested that researchers should identify and remove significant outliers that most impact on normality of the data. According to Liu (2011), outliers in the collected data may create extravagant factors in EFA results. Thus, the 5% trimmed mean and standardized scores (z – scores) methods are used to detect outliers in the collected data. The 5% trimmed mean identifies items that are significantly influenced by extreme values. The standardized scores (z – scores) method, on the other hand, identifies responses that appear to be inconsistent with other responses in the data set. The 5% trimmed mean is a mean calculated by discarding a 5% of the lowest and the highest scores and then computing the mean of the remaining scores of each item (Walfish, 2006). If a difference between mean and 5% trimmed mean is not beyond the criteria of 0.20, it demonstrates an insignificant influence of any possible outliers on that item (Pallant, 2005). The standardized scores (z – scores) is used to identify the influence and presence of outliers on each response. A response is considered to be a potential outlier if its absolute standardized residual is greater than 3.29 at $p < 0.01$, two – tailed test (Tabachnick & Fidell, 2013).

The normality in distribution is then tested by examining skewedness and kurtosis (Yu & Richardson, 2015). Skewedness measures asymmetry of a distribution of a variable. The skew value of a normal distribution is zero. A skewed variable is a variable whose mean is not in the center of the distribution. Kurtosis, on the other hand, measures a peak of the distribution (Kim, 2013). The normality test helps increase confidence in collected data which will allow more accurate EFA results (Arifin, 2017).

2.2.3 Exploratory Factor Analysis (EFA) Method

The objective of factor analysis is to summarize data in which relationships and their patterns can be easily interpreted and understood (Yong & Pearce, 2013). It is commonly used to classify items into groups of items (i.e., factors) based on shared variances. There are two main factor analysis methods, including Confirmatory Factor Analysis (CFA) and Exploratory Factor Analysis (EFA). CFA aims to confirm existing hypotheses and relationships, whereas EFA focuses on discovering relationships and patterns among items by exploring the data sets and testing predictions (Child, 2006).

The researchers must indicate the number of factors a priori in CFA. With EFA, researchers normally decide on the number of factors by examining output from a principal components analysis in which eigenvalues are used (Newsom et al., 2005).

As Thai block rubber export is growing and multimodal transportation in Thailand is developing continuously according to the government policies aim at reducing road transportation issues and costs, a study of factors influencing multimodal transportation of block rubber in Thailand is crucial for block rubber production industry, multimodal transportation service providers, and government to be competitive in the world market. This study then summarizes items influencing multimodal transportation from previous studies in various fields, countries, and markets. Thus, EFA method is needed to explore the possible underlying factors of a set of measured variables or items in accordance with Thailand multimodal transportation conditions and situation.

According to Arifin (2017), steps of EFA method are proceeded as following:

- 1) Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity are conducted to determine if the data is suitable for EFA, and to confirm that the data has patterned relationships, respectively (Yong & Pearce, 2013).
 - The minimum value of KMO is 0.60 (Tabachnick & Fidell, 2007).
 - The Bartlett's Test of Sphericity should be significant ($p < 0.05$) (Tabachnick & Fidell, 2007).
- 2) The EFA is conducted to classify items into factors using SPSS software. Prior to performing the EFA, factor extraction and factor rotation methods must be selected based on research objectives and data set, and the number of factors required, and minimum factor loadings may also specify.
- 3) The Cronbach's alpha test is performed to measure the internal consistency reliability of each factor (group of items) (Tavakol & Dennick, 2011).
 - Cronbach's alpha is expressed as a number between 0 and 1.
 - The value of 0.70 is the minimum acceptable values of alpha (DeVellis, 2003).
- 4) Summarize the EFA results.

The EFA results form a baseline model for SEM model development. The factors and their associated items are then confirmed and examined causal relationships, as well as directions of relationships among them utilizing the SEM approach.

2.2.4 Structural Equation Modeling (SEM) Method

In this study, the SEM method is utilized to examine causal relationships among five key factors affecting multimodal transportation efficiency of agricultural products in Thailand. This method is an appropriate multivariate statistical analysis method that allows simultaneous analysis of multiple and interrelated dependences, as well as direct and indirect relationships among the variables (Hair et al., 2010). It also allows hypothesis testing of a theoretical model in a quantitative approach. It helps distinguish direct, indirect and total effects, and interprets the interaction effects in the context of a simultaneous equation model (Batista-Foguet et al., 2004).

Various software can be used to perform the SEM model development, such as LISREL and AMOS (Arbuckle & SPSS Inc., 1997; Jöreskog et al., 1988). This study applies AMOS version 21.0 software in constructing the multimodal transportation model to explain impacts of key factors on multimodal transportation efficiency in Thailand. The model is schematically drawn as path diagrams through the collaboration of four geometric symbols: a circle or oval representing latent variable, a square or rectangle representing observed variable, a single-headed arrow ($\rightarrow$) representing the impact of one variable on another, and a double-headed arrow ($\leftrightarrow$) representing the covariance between pairs of variables (Byrne, 2001; Khine, 2013).

To perform SEM model development, two main parts, namely measurement and structural models are considered (Kline, 2011). The measurement model, so-called the confirmatory factor analysis, is performed to confirm key factors, their associated items, and their relationships. The structural model, on the other hand, specifies directions of relationships among key constructs, as well as levels of influences (Blunch, 2008). The structural model can only be performed, using the same data set, after the best fit measurement model is achieved (Abdullah & Rosli, 2015). Steps of the SEM analysis are as shown in Figure 2.2.

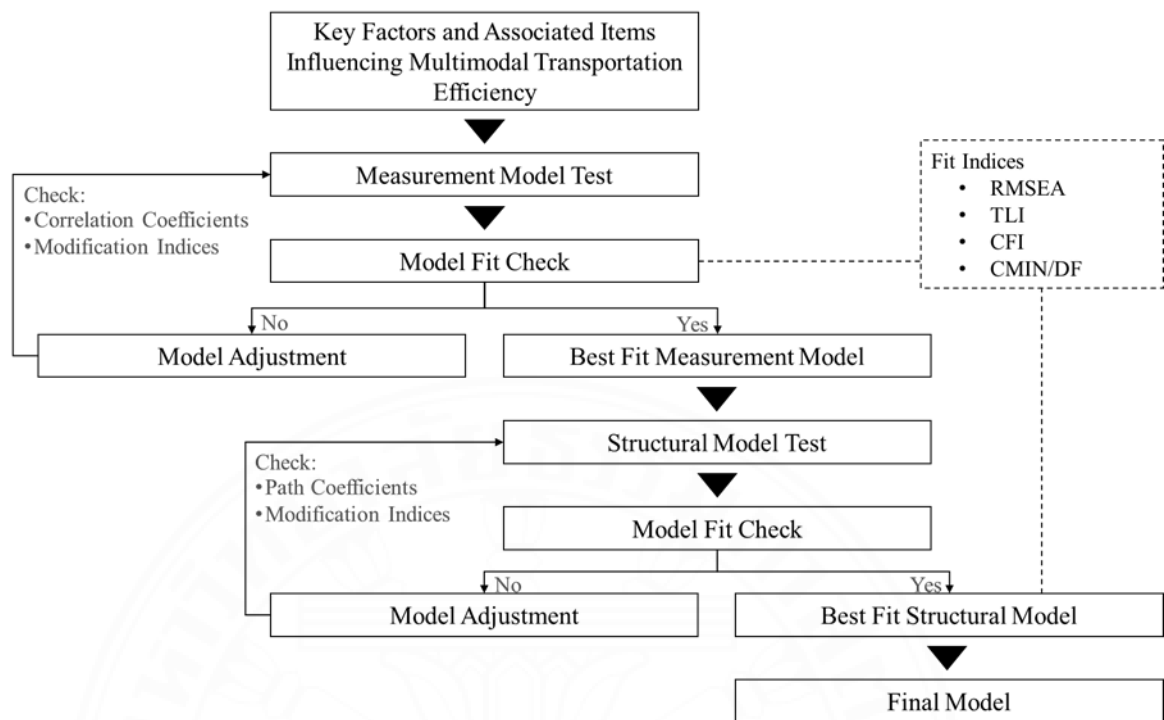


Figure 2.2 Steps of SEM Model Development

2.2.5 System Dynamics Modeling Method

System dynamics (SD) modeling is invented during the mid-1950s at the Massachusetts Institute of Technology (MIT) by Professor Jay W. Forrester (Forester, 1958). SD modeling can be described by the four dimensions (Forrester, 1961), including:

- Feedback is the core concepts of SD modeling.
- SD modeling is the experimental model approach to complex systems.
- System dynamics not only provides direct decision support for policy analysis, but also provides a means for understanding problems, which in turn informs the way policymakers navigate complex decision-making processes.
- SD modeling is constructed through digital computer and software to simulate realistic mathematical models.

According to Azhaginiyal & Umadevi (2014), SD modeling consists of four basic elements (as shown in Figure 2.3):

- 1) Stocks or levels are used to represent anything that accumulates.
- 2) Flows or rates represent activities that increase and decrease stocks.
- 3) Connectors are used to establish the relationship among variables in the model.
- 4) Converters transform input to output. It can be the variables that affect the system behavior.

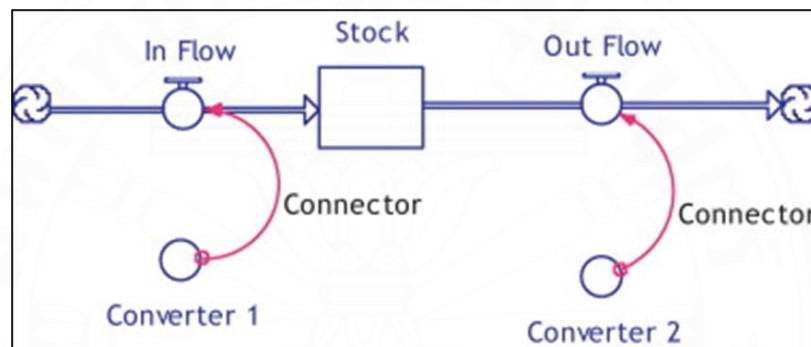


Figure 2.3 SD Modeling Basic Elements

In SD model development, the first phase is to recognize and define problems which lead to identification of problem boundary and model purpose. The system conceptualization is then conducted to identify key factors that affect the system. Next, SD model is constructed in order to describe the behavior of key factors. When the SD model development is completed, the sensitivity analysis must be performed to ensure that the uncertainties will not significantly affect the overall behavior of the model. If the sensitivity analysis shows that the SD model is significantly affected by the uncertainties, model adjustment must be performed until the model replicates system behavior. Finally, the policy analysis is performed by examining the available options to implement the government policies or company's strategies into the simulation model (Azhaginiyal & Umadevi, 2014). Steps of the SD model development are as shown in Figure 2.4.

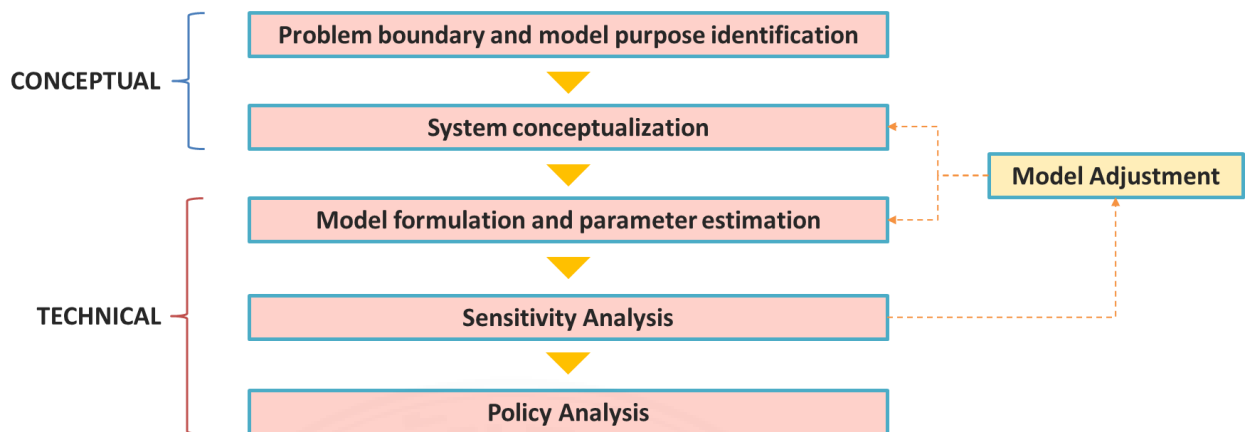


Figure 2.4 Steps of SD Model Development

SD modeling was initially applied in corporate and managerial problems, then it has been applied to other areas, such as government policy, socioeconomic, healthcare, industrial production, energy, and urban studies (Armenia et al., 2010). It is increasingly used in a number of research because it allows systems and policies to interact over time (Shepherd, 2014). Moreover, it can help explore the real drivers of future demand as well as explain how to change user perception and behavior of the system. Currently, there are a number of studies with an application of the SD modeling in transportation research area. However, there are few studies specifically applying SD modeling in multimodal transportation system, especially in Thailand. So, this study aims to develop a dynamic model to analyze the feasibility of the government plan projecting to the next 20 years, and to demonstrate the relevant evidence to the block rubber companies that multimodal transportation has higher efficiency and effectiveness than road transportation in terms of costs reduction. The study results then urge government to fully develop multimodal transportation infrastructure which will lead to encourage block rubber companies to fully utilize multimodal transportation. Moreover, greater market competitiveness of companies can, then, give rise to greater national industrial competitiveness on a global scale.

2.2.6 Application of SEM Results in System Dynamics Model Development

SEM concept is the establishments of causal relationships among latent variables (Roy & Mohapatra, 2000), whereas SD concept is to understand the dynamic

behavior of complex systems (Azizan, 2012). SD modeling method allows interrelationships among variables to help explore the real drivers of future result, as well as explain how to change policy to receive the satisfactory result in a specific time (Shepherd, 2014). Thus, SEM is applied to SD modeling to include interrelationships among latent variables into dynamic models (Houghton et al., 2014). Moreover, SEM results help include qualitative data into SD model which requires quantitative input, for example, Medina-Borja & Pasupathy (2007) applied SEM and SD to construct the evaluation of the “happiness” in a different way. SEM is needed to uncover the equation that relates a quantifiable variable to an abstract variable. The SEM results were developed as equations for SD modeling (as shown in Figure 2.5). These mean that an increase in the happiness of respondent by one unit is shown by an increase in the voice tone, joyful demeanour and smiley face by 0.35, 0.75 and 0.48, respectively. The structural correlation coefficients are the cause-and-effect sizes calculated by SEM and used to formulate the structural equations in SD model.



Figure 2.5 Example of Combining SEM results with SD modeling
(Medina-Borja & Pasupathy, 2007)

In this study, the SD model development focuses on reducing logistics and transportation costs from the use of multimodal transportation of block rubber in Thailand, which is encouraged by the road transportation issues and limitations. Thus, the product of SEM correlation coefficients will be used as a reduction proportion in logistics cost of multimodal transportation.

CHAPTER 3

LITERATURE REVIEW

This chapter identifies research gaps in the existing literature. It is divided into five topics. It begins with the background of block rubber production and export to indicate the economic significance of block rubber to Thai economy. Then, the transportation of block rubber in Thailand is presented to summarize the background and current situation of block rubber transportation from manufacturers to export point, as well as issues and potential of successful multimodal transportation. Items influencing multimodal transportation are then summarized from previous studies, in both developed and developing countries, to be used in the questionnaire survey development. The statistical analysis methods used in multimodal transportation studies are then reviewed to decide the most appropriate analysis method for the collected data. Lastly, previous studies on multimodal transportation model development are considered to find the method that is suitable for simulating and quantifying the behavior of key multimodal influencing factors over a period of time, which is considered essential in understanding problems and implications for long-term success of multimodal transportation implementation.

3.1 Block Rubber Industry in Thailand

For decades, the southern region of Thailand is the major area of rubber plantation and production because of the favorable climate and soil fertility for the rubber plantation (Mongkolsawat & Putklang, 2010). Current southern planting area is 23 billion square meters with production capacity of 3.1 million tons per year, representing 72% of total production capacity in Thailand (Office of Agricultural Economics, 2019). However, due to the growing demand of natural rubber, rubber plantation and production area have expanded to the northeastern region of Thailand following the government's new planting area project (Kritchanchai & Chanpuypetch, 2009). The northeastern planting area is successfully expanded with the increasing rate of 10% per year. The current planting area is four billion square meters with production capacity of 670,000 tons per year, representing 15% of total production capacity in

Thailand (Office of Agricultural Economics, 2019). Thus, southern and northeastern planting areas take the majority of production capacity of the country with 87% of total production capacity in Thailand.

Nowadays, total rubber plantation area in Thailand then covers 36 billion square meters with a total production of five million tons per year (Office of Agricultural Economics, 2019). This makes Thailand the world largest producer of natural rubber, representing 33.4% of the global natural rubber production. Countries with high rubber production include Indonesia, Vietnam, China and Malaysia, accounting for 24.7%, 8.5%, 6.4%, and 3.8% of the global natural rubber production, respectively (Office of Agricultural Economics, 2019).

Rubber can be harvested as fresh latex using tree tapping. The fresh latex is then processed into primary rubbers, including field latex, unsmoked sheet, and cup-lumps (Chanchaichujit, 2014). These primary rubbers are considered as an upstream industry. They are consequently processed into semi-finished products or natural rubbers, which are considered as a midstream industry (Doner & Abonyi, 2013). Three main types of natural rubbers include concentrated latex, ripped-smoked sheet, and block rubber, and that they are used as raw materials in various rubber products in the downstream industry (see Figure 3.1) (Doner & Abonyi, 2013). Concentrated latex, for example, is used for dipped products, such as surgical glove, condom, elastic thread, and adhesive. Ripped-smoked sheet, on the other hand, is used in shoe sole and automobile parts production. Block rubber is mainly used in automobile tire production (Chanchaichujit, 2014).

Figure 3.1 shows that most of Thai natural rubber is exported as semi-finished products (concentrated latex, ripped-smoked sheet, and block rubber) due to limited investment in rubber products manufacturing (Krungsri Research, 2020). The export amount covers almost 80% of total production, accounting for 70.3% of the gross domestic product (GDP) in the country (Workman, 2020).

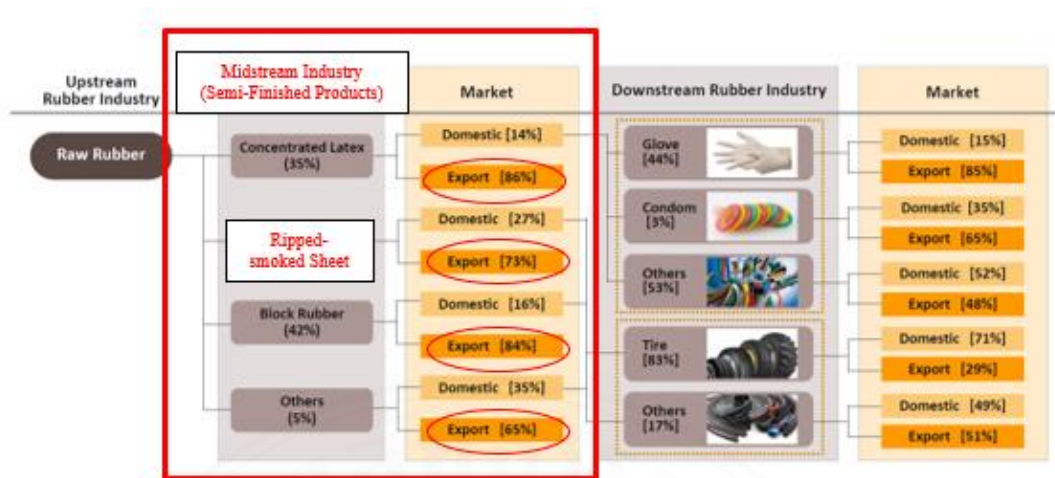


Figure 3.1 Thailand's Rubber Market (Krungsri Research, 2020)

Major partners of Thai natural rubber include China, Malaysia, Japan, USA, and South Korea, respectively (The Thai Rubber Association, 2022). Demand of Thai natural rubber from China increase from 920,000 tons in 2013 to 1.7 million tons in 2021 with increasing rate of 9.2% per year (see figure 3.2). China, especially, has high increasing trend of natural rubber requirement to be used in its automotive industry that has been developing and growing steadily in the past decades (Chanchaichujit, 2014; Doner & Abonyi, 2013; Krungsri Research, 2020). While global automotive industry grew at annual rate of 2.4% during 2006 to 2018, China experienced average growth of 11.2% per year (Krungsri Research, 2020).

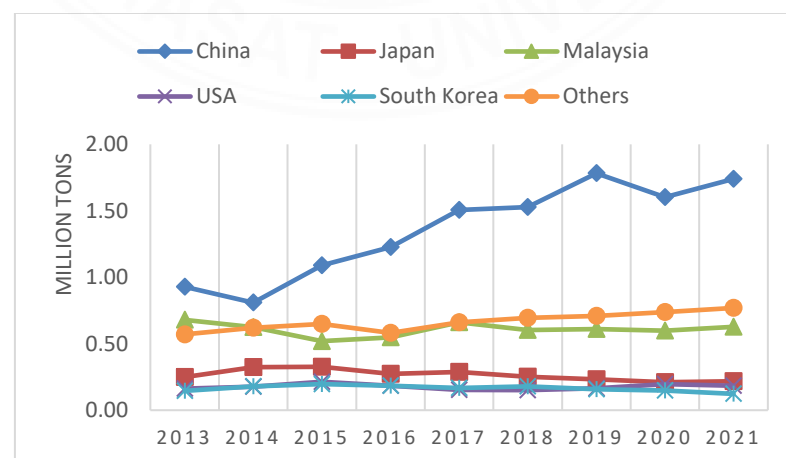


Figure 3.2 Major Importers of Thai Natural Rubber from 2013 to 2021
(The Thai Rubber Association, 2022)

As block rubber is mainly used in tire production in the automotive industry (Chanpuypetch, 2010), the export amount of block rubber leads that of ripped-smoked sheet and concentrated latex, respectively (see figure 3.3). It is expected that the export amount of block rubber will grow by 4% in 2022 (Krungsri Research, 2020). However, Thai block rubber industry will experience a strong competition on global market due to China tends to increase block rubber import from CLMV countries as they offer lower prices (The Thai Rubber Association, 2022).

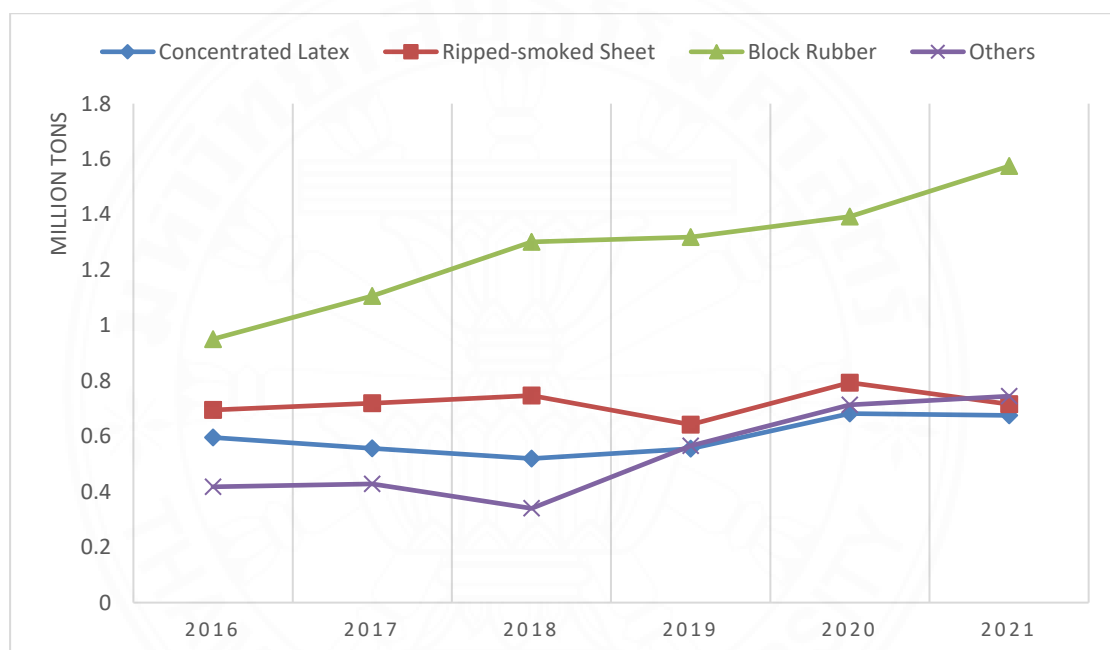


Figure 3.3 Exported Natural Rubbers from 2016 to 2021
(The Thai Rubber Association, 2022)

It is a challenge for Thai government to stay competitive and be the world largest exporter of block rubber in the long-term. The government comes up with a number of supporting strategies from upstream to downstream to achieve sustainable block rubber production and export. Such programs vary from new planting area, yield enhancement, effective production, and block rubber transportation. As block rubber has low level of product differentiation, in order to be competitive in prices, a major focus is given to the development of the transportation infrastructure which can help reduce logistics costs.

According to Kar & Sinha (2020), in case of international trade, logistics costs play an important role in pricing of goods. However, Thai government has been struggling to reduce logistics costs due to the increase in fuel price, congestion, insufficient transportation network capacity, and lack of competitiveness in rail and water transportation. In recent years, there are a number of initiatives of modal shifts proposed by the government. The government realizes the importance of inland transportation connecting with the export gateways. Thus, the government proposes the “Thailand’s Transport Infrastructure Development Strategy 2015-2022” to develop the efficient transportation network for being a regional hub (Ministry of Transport, 2015). This plan aims to enhance the efficiency of multimodal transportation and reduce logistics cost. The plan includes two main parts; the double-track railway project for improving the transportation network and the development of ports to support the increasing amount of export products. Therefore, a multimodal transportation will be a major challenge for government and block rubber companies.

3.2 Multimodal Transportation of Block Rubber in Thailand

Block rubber supply chain in Thailand consists of four main contributors, including rubber farmer, middleman and cooperative, rubber production company, and inland logistics for domestic stock, domestic consumption, and export (Chanchaichujit, 2014) (see Figure 3.4).

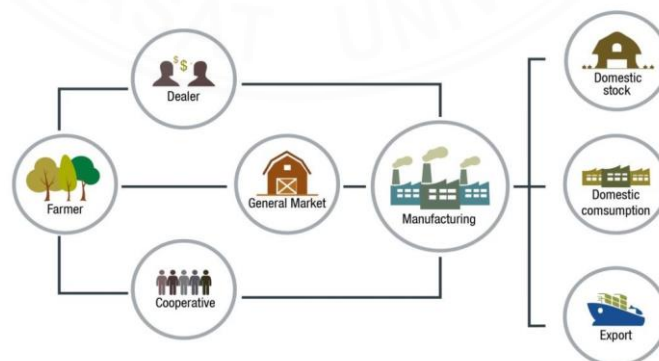


Figure 3.4 Block Rubber Supply Chain

Domestic stock of block rubber is managed by the government as a regular intervention program to manage supplies and stabilize block rubber prices. Domestic stock generally plays as a price-supporter, with average stock level at 11% of total annual production (Chanchaichujit, 2014). Domestic consumption of block rubber is approximately 18% of total annual production (Krungsri Research, 2020). It is processed by block rubber production company to produce automobile tire, glove, condom, rubber band, and rubber elastic for domestic consumption (Chanchaichujit, 2014). However, as mentioned in previous topic, due to limited investment in rubber products manufacturing, most of block rubber is exported, with China as a major importer of Thai block rubber. Block rubber export, therefore, turns out to be the largest proportion of Thai block rubber production.

According to Klaewphun and Suthiwartnarueput (2016), most of Thai block rubber is exported through the Laem Chabang port at Chonburi province, which is considered as the largest port in Thailand. Transportation from rubber farmer to middleman and cooperative, as well as from middleman and cooperative to block rubber production company is mainly undertaken by road because the travel-distance is relatively short at the provincial level (Chanchaichujit & Saavedra-Rosas, 2018). On the other hand, inland transportation from block rubber production company to Laem Chabang port can be transported by different combinations of transportation modes including road, rail and water, which all transportation activities from company to export point are responsible by block rubber production company (Chanchaichujit & Saavedra-Rosas, 2018). However, most of block rubber transportation from block rubber production company to Laem Chabang port is currently transported by truck because of the convenience and extensive network of roads (SCB Economic Intelligence Center, 2021).

Generally, road transportation at provincial level generates cheap freight costs but road transportation from block rubber production company to Laem Chabang port contributes high logistics costs because of long distance. From this reason, the government realizes the challenge of reducing logistics costs in order to be competitive in the world market. According to Office of Transport and Traffic Policy and Planning (2021), the government gives attention to concept of multimodal transportation in supporting inland transportation development for integration, convenience, and

efficiency of transportation services, which then lead to logistics costs reduction. Thus, as mentioned in previous topic, the government proposes the “Thailand’s Transport Infrastructure Development Strategy 2015-2022” to enhance the efficiency of multimodal transportation and reduce logistics cost (Ministry of Transport, 2015). Multimodal transportation in Thailand is commonly described by the transportation of products by at least two different modes among existing three modes; road, rail, and water modes (Timaboot & Suthikarnnarunai, 2017). However, road transportation plays as a support mode for door-to-door services (SCB Economic Intelligence Center, 2021). Thus, major focus is to promote the usage of rail and water transportation due to cost and energy savings by improving existing infrastructure and network and promoting multimodal transportation activities.

The government, then, attempts to improve rail infrastructure by investing more than 10,000 million baht to expand double-track railways to develop railways system and link transportation from all areas, especially northeastern and southern regions, to Laem Chabang port (Office of Transport and Traffic Policy and Planning, 2021). Moreover, with limited capacity of Laem Chabang port, government also attempts to increase capacity of the port and modernize port facilities and equipment due to the increasing amount of export products (Office of Transport and Traffic Policy and Planning, 2021).

Block rubber transportation from the southern region can be exported via two export point. If the company is located in the upper southern region (provinces that are located above Nakhon Si Thammarat province), block rubber can be transported by three ways.

- By road from company to Laem Chabang port
- By combination of road and rail transportation starting from road transportation from company to Surat Thani province at Ban Thung Pho Junction Railway Station then block rubber will be transported by rail transportation from Ban Thung Pho Junction Railway Station to Lat Krabang Inland Container Depot (ICD) which is connected to Laem Chabang Port.

- By combination of road and water transportation starting from road transportation from company to NP Marine and Panja ports at Surat Thani province, then block rubber will be transported by ship to Laem Chabang Port.

For the lower southern region, there is no rail transportation to Laem Chabang port. However, there are international rail transport service from Thailand to Penang Port at Malaysia (Office of Transport and Traffic Policy and Planning, 2021).

Surat Thani province, which is located in the upper southern region, is the province that produces majority of block rubber in Thailand and there are high potential and capacity train station and port that will be able to support the multimodal transportation of block rubber from upper southern region to Laem Chabang port. Thus, this study considers the transportation routes from companies in Surat Thani province to Laem Chabang port.

According to The Thai Rubber Association (2022), the rubber plantation has been plentifully cultivated in the southern region where climatic and geographic conditions are favorable. Moreover, the rubber plantation has been successfully grown in northeastern region since the past decades with an attractive selling price, resulting in a rapid expansion of the rubber planting area. According to Office of Agricultural Economics (2019), Bueng Kan and Udon Thani provinces are the major rubber planting and block rubber production area, which is consistent with the study of Office of Transport and Traffic Policy and Planning (2021), which stated that companies with largest block rubber production capacity in northeastern region are located in Bueng Kan and Udon Thani provinces.

However, Bungkan Provincial Governor's Office (2018) stated that the block rubber produced in Bueng Kan province are exported to China through Laos and Vietnam by using ferries across the Mekong River to Paksan, Laos then transported by truck to China, respectively. According to Kaew-ngarm et al. (2016), block rubber produced in Udon Thani province are exported to China through Laem Chabang port. Thus, this study considers the transportation routes from companies in Udon Thani province to Laem Chabang port.

Nowadays, block rubber transportation in Thailand have changed from bulk loaded to container loaded cargo (Klaewphun & Suthiwartnarueput, 2016). It is found that most block rubber are currently and mainly transported to Laem Chabang port by road because the rail transportation issues, including delays, unreliability, lack of CY and vehicle capacity, and poor roads condition connecting between companies and container yard (CY) of train station. However, Office of Transport and Traffic Policy and Planning (2021) has launched a project to improve road condition and boost road safety of roads that are connected to CY of Nong Takai Railway Station in Udon Thani province to facilitate block rubber transportation in northeastern region. Along with the double-track railways development and expansion project, these projects will substantially influence block rubber transportation in northeastern region to shift transportation mode from road-only to multimodal transportation through road and rail transportation.

Thus, this study considers transportation routes of block rubber from companies in Surat Thani and Udon Thani provinces to Laem Chabang port. There are two multimodal transportation routes in southern region and one multimodal transportation route in northeastern region, including:

1. Company → Ban Thung Pho Junction Railway Station (CY) → Laem Chabang port (Truck + Train)
2. Company → Ports in Surat Thani → Laem Chabang port (Truck + Ship)
3. Company → Nong Takai Railway Station (CY) → Laem Chabang port (Truck + Train)

3.3 Items Influencing Multimodal Transportation

Recently, multimodal transportation is preferred mode of transportation because of its energy efficiency, reduction in road traffic congestion, environmental impacts, and overall transportation (Macharis et al., 2011; Macharis & Pekin, 2009). Researchers and engineering managers realize that the traditional mode of transportation, which is truck mode, does not meet the needs of modern cities (Fang et al., 2020; Jiang et al., 2019). They recognize that the successful multimodal transportation can fully utilize the existing transportation network and infrastructure, integrate transportation capacity,

support the transportation demand, and achieve the company targets in time, costs, and profit aspects (Marufuzzaman & Ekşioğlu, 2017; Zhang et al., 2015).

According to these benefits, it is clear that multimodal transportation has the potential in providing numerous advantages for all partnerships involved in the supply chain. In order to encourage the use of multimodal transportation in Thailand, this study is needed to gain additional insights of multimodal transportation potential in Thailand. A literature review of multimodal transportation related studies and the data analysis methods used in their studies is needed to identify the gap of previous studies, as well as summarize the items influencing multimodal transportation and the most suitable analysis method.

A number of research studies have been conducted to enhance the effectiveness and efficiency of multimodal transportation. Examination of key factors influencing multimodal transportation is one of the major interests. Hanssen and Mathisen (2011), for example, mentioned that pollution, accident rate, and congestion on the road network raise concerns of modal shift from road to rail and water modes. Ezanee et al. (2013), on the other hand, stated that utilizing multimodal transportation increases the company's image, resulting in cost reduction and competitive advantages. Rantasila and Ojala (2012) stated that the use of multimodal transportation that lower logistics costs help encourage sales, increase trade, thus, opening new markets and increase company's competitiveness. Transshipment processes are, however, required in multimodal transportation (Bontekoning et al., 2004). Stokland et al. (2010) added that effective modal shift requires cooperation and interaction between company and transport service providers.

In this study, a total of 20 items influencing multimodal transportation are extracted according to the citation frequency analysis of the multimodal transportation related previous studies (see Table 3.1 and Table 3.2). The citation frequency analysis is used for counting the number of item citation in each selected journal paper. In general, 80% of items that are most cited will be selected and used for further study (Fang et al., 2020; Masso & McCarthy, 2009).

Table 3.1 Items Influencing Multimodal Transportation

Item	Description
Capacity (CAP)	Capacity of container yard (CY) of train station or port to support big bulk transportation (Kritchanchai & Chanpuypetch, 2009).
Accessibility (ACY)	Ability to access to CY of train station or port by inland transportation (Kritchanchai & Chanpuypetch, 2009).
Delivery Speed (SPD)	Time taken for the transportation from seller to buyer (Danielis & Marcucci, 2005; Heljedal, 2013).
Punctuality (PUN)	On-time arrival or departure of the service (Bektas & Crainic, 2007; Islam et al., 2016).
Transshipment Equipment (EQP)	Handling equipment, such as swap bodies and semi-trailers, available for modal shift processes (Choi et al., 2014).
Vehicle Design (DSN)	Design of locomotives, carriages, or barges to accommodate multimodal transportation (Heljedal, 2013; Islam et al., 2016).
Government Policy (GOV)	Multimodal transportation-related government policies (Choi et al., 2014; Corman et al., 2017).
Volume Flexibility (VOL)	Variations in volumes to respond to changes in transportation demand (Arnold et al., 2004; Heljedal, 2013).
Logistics Costs (LOG)	Logistics costs of multimodal transportation (Kritchanchai & Chanpuypetch, 2009).
Green Image (IMG)	Green image of company from using multimodal transportation (Heljedal, 2013; Kreutzberger et al., 2003).
Market Competitiveness (MKT)	Market competitiveness due to new competitors and customers (SteadieSeifi et al., 2014).
Transshipment Costs (TSC)	Transshipment costs related to modal shift processes (SteadieSeifi et al., 2014).

Item	Description
Documentation (DOC)	Documentation processes required in modal shift process (Butta & Abegaz, 2016; Kritchanchai & Chanpuypetch, 2009).
Skilled Employee (EMP)	Skilled employees to perform modal shift processes (Butta & Abegaz, 2016).
Tracking System (TRK)	Tracking system in multimodal transportation (Butta & Abegaz, 2016; Islam et al., 2016).
Service Providers (SER)	Adequacy of multimodal transport service providers (Bektas & Crainic, 2007; Roberts, 2012).
Relationships (REL)	Relationships between companies and multimodal transport service providers (Butta & Abegaz, 2016; Casaca & Marlow, 2009).
Road Law Enforcement (LAW)	Limited driving hours per driver in road transportation (Heljedal, 2013; Kritchanchai & Chanpuypetch, 2009).
Road Traffic (TRF)	Road traffic volume (Choi et al., 2014; SteadieSeifi et al., 2014).
Road Accident (ACD)	Road-related accidents (Heljedal, 2013; Kreutzberger et al., 2003).

Table 3.2 Citation Frequency Analysis

NO.	Reference	Country	Year	1. Punctuality	2. Accessibility	3. Capacity	4. Delivery Speed	5. Volume Flexibility	6. Transshipment Costs	7. Logistics Costs	8. Government Policy	9. Transshipment Equipment	10. Vehicle Design	11. Service Providers	12. Relationships	13. Skilled Employee	14. Documentation	15. Green Image	16. Road Accident	17. Road Traffic	18. Tracking System	19. Road Law Enforcement	20. Market Competitiveness	21. Competitor	22. Truck Loading	23. Customer Cooperation	24. Sustainability	25. Distance*	26. Product Characteristics*	27. Product Safety*	28. Product Damage*	
1	Bektas and Crainic	Canada	2007	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
2	Janic	Netherlands	2007	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
3	Valente de Oliveira	EU	2008	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
4	Kritchanchai and Chanpuyetch	Thailand	2009	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
5	Samimi et al.	USA	2011	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
6	Heljedal	Sweden	2013	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
7	Choi et al.	Korea	2014	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
8	Butta and Abegaz	Ethiopia	2016	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
9	Islam et al.	EU	2016	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
10	Corman et al.	Netherlands	2017	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
11	Mutlu et al.	Turkey	2017	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
12	Marufuzzaman and Eksioğlu	USA	2017	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
13	Ngamvichaikit	Thailand	2017	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
14	Timaboot and Suthikarnarunai,	Thailand	2017	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
15	Chen et al.	China	2019	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
16	Dua and Sinha	India	2019	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
17	Jiang et al.	China	2019	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
18	Fang et al.	China	2020	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Count				18	16	16	16	15	14	13	13	12	11	10	10	9	9	9	8	8	8	7	7	5	4	4	4	13	13	8	8	8
Accounted Percentage (%)				6.25	5.56	5.56	5.56	5.21	4.86	4.51	4.51	4.17	3.82	3.47	3.47	3.13	3.13	3.13	2.78	2.78	2.78	2.43	2.43	1.74	1.39	1.39	1.39	4.51	4.51	2.78	2.78	2.78
Cumulative Percentage (%)				79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51	79.51

*Excluded Items

*Excluded Items Proof:

1. Minimum Distance between Origin and Destination

- Flodén (2007) concludes that combined transportation can be competitive mostly on distances above 500 kilometers.
- The distance from study areas to Laem Chabang port is completely more than 500 kilometers.

2. Product Characteristics

- The physical characteristic of a product is the primary factor taken into consideration (Roberts, 2012).
- Multimodal transportation is suited with a heavy bulk, low value, low selling price per unit, and not perishable products (Athikomrattanakul, 2008).
- In general, agricultural products have low price and low value. The most effective transportation mode is the mode that can carry them in large volume (Timaboot and Suthikarnnarunai, 2017).

3. Product Safety and Product Damage

- Nowadays, the natural rubber transportation in Thailand have changed from bulk loaded to container loaded cargo (Klaewphun and Suthiwartnarueput, 2016).
- The utilization of container enables cargo handling processes to gain a high level of standardization and helped overcome many of the technical difficulties concerning the transshipment of products.
- Multimodal transportation is transportation of products from one place to others using different modes of transportation (Kindred and Brook, 1997). It was greatly encouraged by the prevalence of the use of containers. It lessens the occurrence of pilferage during cargo transfer and reduce loading and discharging time (Hoeks, 2009).
- The use of container protects products and greatly reduces the risks of loss and damage during carriage. Most multimodal transportation contracts use container as the physical unit in which products are transported (Besong, 2007)

These items are used in the questionnaire survey development to investigate opinions of respondents on each item according to the context of multimodal transportation in Thailand. The EFA is applied to analyze how items are interrelated (Hon et al., 2013). Moreover, it is performed to reduce the number of variables into a smaller number of factors (Hair et al., 2010). The SEM is then applied to confirm key factors influencing multimodal transportation efficiency of agricultural products in Thailand, as well as examines their interrelationships. The SEM results then simplify the idea of constructing a simulation model of a feasibility model and policy analyses of multimodal transportation in Thailand.

It is expected that the study results provide better understanding and implication to the government and business sectors to reach successful implementation of multimodal transportation in the long-term.

3.4 Multimodal Transportation Related Studies

Freight transportation is a key component to supply chain for ensuring the efficient movement and timely availability of products (SteadieSeifi et al., 2014). Demand of freight transportation arises from producers and consumers who are geographically apart from each other (SteadieSeifi et al., 2014). With the trade globalization, the traditional road-only transportation, however, does not meet the needs of modern cities (Fang et al., 2020; Jiang et al., 2019). The researchers recognize that the multimodal transportation can fully utilize the existing transportation network and infrastructure, integrate transportation capacity, support the transportation demand, and achieve the company targets in time, costs, and profit aspects (Marufuzzaman & Ekşioğlu, 2017; Zhang et al., 2017). Multimodal transportation can be defined as the transportation of products by the combination of at least two modes of transportation with the responsibility of a single operator (UNEC, 2009). It is effective in allowing an increasing in the number of products transported in one time through the use of alternative modes that can carry more products per vehicle (Transportation Research Board, 2011). The benefits of multimodal transportation that make it an attractive opportunity for both government and business sectors (Goh et al., 2008) include:

- Better capacity utilization based on the optimum usage of each mode of transportation, resulting in cost and time savings.
- Greater returns on private and public infrastructure investments.
- Reduced energy consumption.
- Decreased environmental impacts.

3.4.1 Factors Influencing Multimodal Transportation Analysis Method

Recently, multimodal transportation is preferred mode of transportation because of its energy efficiency, reduction in road traffic congestion, environmental impacts, and overall transportation (Macharis et al., 2011; Macharis & Pekin, 2009). It can fully utilize the existing transportation network and infrastructure, integrate transportation capacity, support the transportation demand, and achieve the company targets in time, costs, and profit aspects (Marufuzzaman & Ekşioğlu, 2017; Zhang et al., 2015).

This is shown in a number of research studies on multimodal transportation in various aspects. Beresford et al. (2011), for example, examined factors affecting modal choice selection by conducting an in-depth discussion using primary data collected through observation and field interviews. The study discovered five key factors, including transport distance, transit time, transport costs, schedule reliability, and cargo volume, weight, and value. However, the study recommended the further study with more specific sources of data and application of statistical analysis method. Zhang et al. (2017) investigated the effects of the logistics service time windows and CO₂ emission taxes on multimodal transportation by constructing the optimization model using stochastic algorithm. The study results showed that different service time windows significantly affect transportation mode selections. Besides, the CO₂ emission taxes encourage logistics users to switch to multimodal transportation to serve as green logistics service. Kritchanhai and Chanpuypetch (2009) proposed a gateway selection model for Thai natural rubber transportation using the fuzzy analytic hierarchy process. The study considered four main factors influencing gateway selection, including transportation, economic, port or custom, and environmental factors. Weight of each criterion was calculated using pairwise comparison to identify the most appropriate gateway for rubber transportation. Yücekaya (2013) developed the multi-objective

model using an analytic hierarchy process method to select suppliers, transportation routes, and orders for multimodal transportation of coal. The study summarized AHP scores of each factor to obtain an overall score for each alternative. Then, the scores of each alternative are ranked to select the best alternative with the highest overall score. Kengpol and Tuammee (2014) developed a framework for route selection in multimodal transportation. The AHP method was also used in this study to prioritize factors influencing the route selection process by obtaining the scores for each factor from the pairwise comparisons.

Choi et al. (2014) applied SEM method to study the impact of policy measures on promoting the modal shift from road to rail. The study considered four perspectives of policy measures, including road pricing, multimodal transportation services, transportation planning, and multimodal infrastructure. The results showed both direct and indirect effects of four factors on multimodal transportation development, as well as direct and indirect effects among them. The study suggested that the road pricing and multimodal transportation services can encourage the strategic planning and operation, which, then, positively affects the improvement in infrastructure, and eventually results in the multimodal transportation development. Papaioannou and Martinez (2015) applied SEM method to study the effects of accessibility and connectivity in mode choice decisions. The results indicated that a good accessibility and connectivity are necessary in mode choice decisions as they significantly affect the travel time. Jiang et al. (2017) examined the relationships between multimodal transportation investment and economic development using SEM method. The results indicated that investment in transportation infrastructure influences economic development by promoting connectivity, and thus encourages the travel demand. Dua and Sinha (2019) identified factors affecting performance of multimodal transport service providers using SEM method. Four key factors were identified, including communication, collaboration, process and documentation, and variation in quantity, time, cost and form. The study concluded that variation in time, cost, and quantity does not significantly affect the quality of multimodal transport service in the study area when such phenomena occurred frequently. However, this factor needs to be included when the geography is different from this study.

The above research studies pinpoint various perspectives of multimodal transportation in achieving the transport effectiveness. They are based on different analyses method. Some methods can only measure the direct relationship between two factors and does not allow the simultaneous evaluation of all relationships. The evaluation has to be performed in sequential steps to analyze all relationships among influencing factors (Tabachnick & Fidell, 2013). SEM method, however, gains a superior benefit in simultaneously explaining both direct and indirect relationships among key factors (Dastgeer et al., 2012; Jiao et al., 2016), which are found important to the transportation planning in local, regional, and national scales (Choi et al., 2014; Dua & Sinha, 2019; Jiang et al., 2017; Papaioannou & Martinez, 2015). The understanding of both direct and indirect effects among key multimodal factors will help the government and business sectors to limit possible negative impacts that might interrupt the implementation of plans and policies in the long-term (European Environment Agency, 2016).

The use of SEM method in this study is expected to help clarify direct and indirect relationships among key multimodal factors simultaneously, so that an effective plans and policies can be established.

3.4.2 Multimodal Transportation Model Development

In recent years, multimodal transportation has become more popular with the support from the development of technology and government policy, leading to competition among companies to offer multimodal transportation service to gain comparative benefit. The ultimate goal is to “deliver greater value to customers or create compatible value at a lower cost, or do both” (Al-Muhaisen, 2005).

However, to select transportation route that offers lower cost, decision making in combination of mode choices is crucial. According to Bui (2011), there are three main steps in decision making. The first step is to study the factors influencing multimodal transportation decision because each country has different infrastructure and conditions to develop and use multimodal transportation. Thus, questionnaire survey is a good tool to reflect multimodal transportation condition and situation of the country. The second step is to develop a model, based on influencing factors, to help in

decision-making process. The last step is to choose a route, with combination of different modes, that can deliver all products according to demand at the lowest cost.

In order to develop a multimodal transportation model, there are many methods, in both static framework and dynamic framework, to help in multimodal transportation decision. The static model development ignores the time-dependent variations, such as variations in fuel price, demand, and traffic volume (Bajwa et al., 2005). Bui (2011), for example, applied the “zero-one goal program modeling” to find the best modes combination to transport cargoes within the ASEAN region. The study considered three main factors, including transit cost, transit time, and transit time variability (service’s reliability and punctuality). The results showed that transportation route from Bangkok to Ho Chi Minh City by road and sea was the best choice because of time and costs savings compared to other routes. Timaboot and Suthikarnnarunai (2017) presented a concept of designing the new transportation network in Thailand using rail as a major mode of transportation. The study applied linear programming to develop models represent the current transportation model and the new transportation model. The current transportation model represented road transportation and the new transportation model represented the multimodal transportation by road and rail. The study considered two main factors, including transportation cost and vehicle capacity. The result reveals that the new distribution network can lower the total cost up to 51.63% compared to the current distribution network. However, these studies assume that the values of these factors are constant over the given time period, all quantities are computed as single figures specific to a time period. Thus, the results can only suggest the best route for shippers and multimodal transport operators at the specific time.

The dynamic model development, however, considers the variations in factors which changes over time, such as interest rate, increasing or decreasing rate of demand, government policy, and traffic volume (Armenia et al., 2010). These factors are highly interrelated and influenced by each other. System dynamics (SD) modeling, which is a combination of qualitative (the structure of the model) and quantitative (the parameters of the model) analytical methods based on feedback control theory, is designed to handle this kind of complexity in an understandable way (Pfaffenbichler et al., 2010; Yu et al., 2014).

According to Randers and Göluke (2007), SD modeling has been used in a number of multimodal transportation studies to understand the behavior of shipping freight rates. Schade and Schade (2005), for example, integrated five models; transportation, macroeconomic, regional economic, policy, and environmental models into one model, named ESCOT, using holistic SD modeling. The study considered all transportation modes including water, rail, road, and air that aims to reach a sustainable transportation system and analyzed impacts of the transportation system to the economy. Fiorello et al. (2010) continually built their SD model based on the ESCOT model (Schade and Schade, 2005). The study analyzed investment, capacity, and their respective economic outcomes of each transportation mode. Videira et al. (2012) also constructed the SD model for road and maritime transportation policy development. The study indicated that cooperation between government, policymakers, and transportation managers is crucial for the best policy decision. Okyere et al., (2018) assessed the effect of dynamic multimodal transportation system on logistics responsiveness and modal choices using SD modeling. The study concluded that the dynamic multimodal transportation system significantly affected logistics responsiveness and has great impact on modal choices. The study also recommended that policymakers should improve the expansion and integration of rail transportation system to achieve cost-efficient and logistics responsive goals.

These SD models were built to simulate the interactive relationship between the multimodal transportation system and the economy. The proposed SD models analyze the direct and indirect effects of economy, society, and environment had on transportation policy development. These studies indicate that the SD modeling is practical to deal with complex relationships among time-dependent factors. SD modeling also considers causal relationships, allows what-if scenario analysis, and can be adapted to study fundamental changes in the system. Moreover, sensitivity analysis can be constructed within the model, which can help policymakers and transportation managers to better analyze the changes in multimodal transportation policies (Dikos et al., 2006). Thus, SD modeling is a useful tool for an alternative transportation modes selection and multimodal transport policies analysis.

CHAPTER 4

DATA COLLECTION AND DATA SCREENING FOR EFA AND SEM ANALYSES

In this chapter, a set of questions in questionnaire survey is developed from items influencing multimodal transportation summarized from previous studies. This study collects data mainly by mailed questionnaire survey to obtain sufficient responses required for further analyses. However, the interview is also applied to support in examining more detailed answers in an open-ended question asking for suggestions and opinions regarding the possible use of multimodal transportation in Thailand. The collected data is then screened to confirm its level of confidence which will allow more accurate EFA and SEM results.

4.1 Data Collection

With theoretical references from the literature, summarized items influencing multimodal transportation form a set of questions in questionnaire survey development to be used for data collection process. Target respondents are reasonably determined to provide effective identification of current multimodal transportation system in Thailand, as well as implications for future development, needs and priorities. Pilot test is then performed on a smaller scale of target respondents to identify weaknesses in the questionnaire survey and readjust the questions in questionnaire survey to minimize the likelihood of respondents having problems in answering the questions. Sample size is calculated and justified to ensure that it will draw valid conclusions from the results. The data is then collected through interview and mailed questionnaire survey with follow-up to be completed within a time frame. The collected data is then interpreted and analyzed to summarize and prepare the data for further analyses (see Figure 4.1).

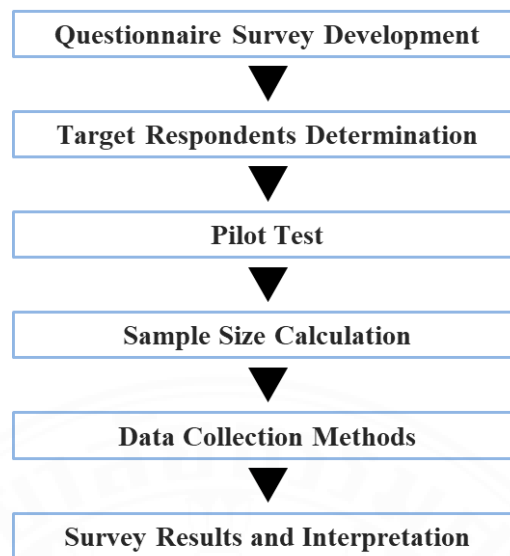


Figure 4.1 Data Collection Steps

4.1.1 Questionnaire Survey Development

According to Pinsonneault and Kraemer (1993) a questionnaire survey is defined as a mean for gathering information about characteristics, actions, or opinions from large samples of the population. OECD (2012) provided a checklist for drafting good questions in questionnaire survey development, including:

- Do the answers to the questions help meet the objectives of the survey?
- Is the language simple and technical jargon avoided?
- Are key terms clearly defined?
- Do all questions only ask one question at a time? (Avoid asking two questions in one.)
- Does the target population have the capacity and knowledge to answer all questions?
- Are questions clear and precise enough that they will be consistently understood in the same way by all respondents?
- Is the formulation of questions as neutral as possible? (Avoid suggesting answers?)
- Are the scales clearly defined and consistently understood across respondents?

- Is the questionnaire short enough to ensure that respondents will concentrate until the end?

With this checklist, a questionnaire is carefully constructed. Scale rating method is selected based on supported references and clearly explained to ensure consistent understandings of all respondents. The pilot test is conducted to ensure that questions clear, precise, and neutral. Target respondents are carefully considered to ensure their abilities and experiences to effectively reflect current and potential of multimodal transportation of block rubber in Thailand.

In this study, questionnaire survey consists of three parts (see Appendix A):

- 1) The first part collects demographical information of respondents and their respective organizations, for examples are respondent's position, type of company, years of experience, and current transportation modes used in the company.
- 2) The second part covers 20 statements reflecting 20 items (or observed variables) affecting the multimodal transportation efficiency of block rubber in Thailand. The statements are designed to extract perceptions and opinions of respondents on different items in the context of multimodal transportation enhancement using Likert scale. According to Likert (1932), Wu (2007), and Joshi et al. (2015), Likert scale is a popular instrument to measure constructs such as attitudes, images and opinions. 5-, 7- and 10-point scales are the most common used in survey studies. They are all comparable for analytical tools, such as factor analysis and structural equation modeling, as there are no significant differences in mean score, variance, skewedness, and kurtosis within the data (Dawes, 2007). However, 5-point Likert scale is easier for the researcher to construct and administer, and it is easier for the respondents to understand and read out the complete list of scale descriptors. Therefore, it is suitable for mail, telephone, personal, and online interviews. This study then applies the 5-point Likert scale to discover respondents' level of agreement on each multimodal transportation influencing items based on their experiences, opinions, and perceptions.

Point 1 represents ‘strongly disagree’ and point 5 represents ‘strongly agree’ opinions.

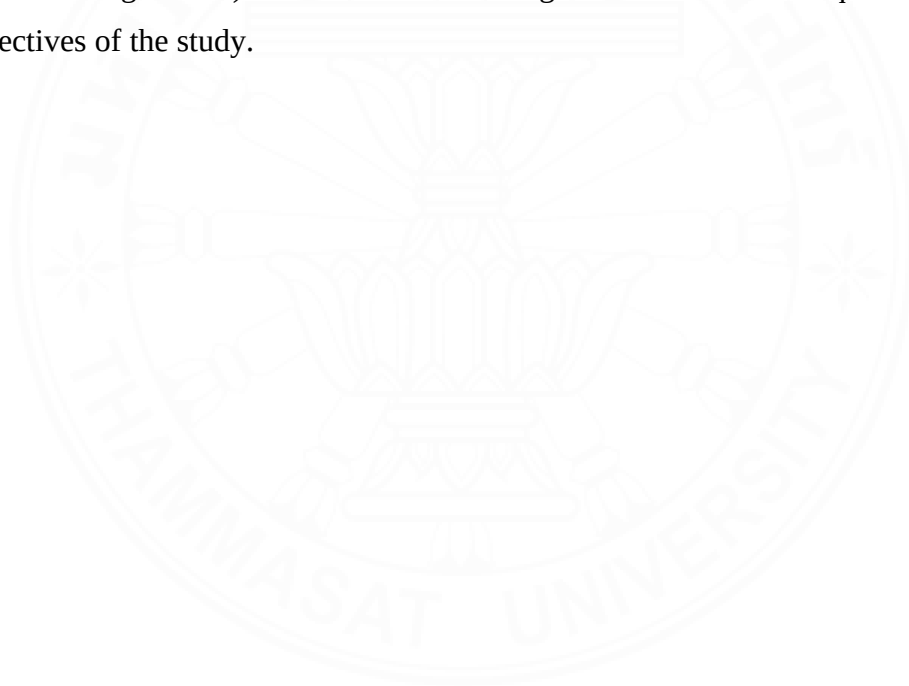
- 3) The last part is an open-ended question asking for suggestions and opinions regarding the possible use of multimodal transportation in Thailand. This part is used in the discussion of SEM analysis results to reflect the respondents’ perceptions of multimodal transportation in Thailand.

4.1.2 Target Respondents Determination

This study focuses on the northeastern and the southern regions of Thailand as they are the new growing area of government plan and the heart of rubber growing area and rubber production, respectively. Block rubber production and exporting companies, transport service providers, policy-related government sectors, and associations are selected as target respondents. Block rubber companies are medium to large companies in the northeastern and the southern regions of Thailand, with more than 50 employees and 50 million Baht of fixed assets, to confirm their ability to export to huge markets (Thailand Board of Investment, 2019). Transport service providers are companies that offer transport services from the northeastern and the southern regions of Thailand to Laem Chabang port. Transportation and rubber policy-related government sectors are organizations that deal with transportation and rubber regulations and policies in the northeastern and the southern regions of Thailand, for example Department of Highways, Department of Rural Roads, The Office of Transport and Traffic Policy and Planning, State Railway of Thailand, Port Authority of Thailand, and Rubber Authority of Thailand. Associations are groups of transport service providers and rubber companies organized for a connection or cooperative link between companies or organizations. With this respect, a list of 287 block rubber companies, government organizations, and associations is used as target respondents (as shown in Appendix B).

4.1.3 Pilot Test

According to Saunders et al. (2019), a pilot test is a small-scale study to test a questionnaire to minimize the likelihood of respondents having problems in answering the questions and of data recording problems as well as to allow some assessment of the questions' validity of the data that will be collected. Harrison (1983) stated that a test's validity measures what it is intended to measure. Rovinelli and Hambleton, (1977) developed the Index of the Item – Objective Congruence (IOC) to measure content validity. This index is used as a basis for screening item quality (Laksana, 2016). Thus, the IOC index is used to test a content validity of each question in questionnaire survey, which reflects its multimodal transportation influencing item (as shown in Figure 4.2) and evaluate the congruence between the questions and the objectives of the study.



Part II: Items influencing multimodal transportation efficiency of agricultural products in Thailand.

Statements below reflect 20 items influencing multimodal transportation efficiency of agricultural products in Thailand. **Please indicate level of your agreement** on each statement based on your experience.

1 = Strongly Disagree

2 = Disagree

3 = Neither agree nor disagree

4 = Agree

5 = Strongly Agree

NO.	Statement	Level				
		1	2	3	4	5
1.	Government policy supporting the multimodal transportation (GOV)					
2.	Road traffic congestion (TRF)					
3.	Law enforcement on truck driving hours (LAW)					
4.	Accident occurrence during road transportation (ACD)					
5.	Adequacy of multimodal transportation service providers (SER)					
6.	Good relationship between company and transport service providers (REL)					
7.	Punctuality of multimodal transportation (PUN)					
8.	Delivery speed of multimodal transportation from company to the export point (i.e. Laem Chabang Port) (SPD)					
9.	Easy access to Container Yard (CY) or port (ACY)					
10.	Sufficient Capacity of Container Yard (CY) or port (CAP)					
11.	Effective transshipment equipment for the multimodal transportation (EQP)					
12.	Low transshipment cost (TSC)					
13.	Information sharing on tracking system (TRK)					
14.	Volume flexibility in multimodal transportation (VOL)					
15.	Efficient locomotive and carriage or barge (DSN)					
16.	Low logistic cost using the multimodal transportation (LOG)					
17.	Company's green image using the multimodal transportation (IMG)					
18.	Ability to compete in multimodal transportation market (MKT)					
19.	Skilled employees in modal shift processes (EMP)					
20.	Less documentation procedure (DOC)					

Figure 4.2 Questions in Questionnaire Survey Representing Multimodal Transportation Influencing Item

In each item, the experts are asked to determine the content validity score, which can be -1, 0, and 1:

- Score = 1 indicates that the expert agree that the item is clearly measuring the objective and is clearly not measuring any other objective.

- Score = 0 indicates that the expert is not sure that the item does measure or does not measure the objective.
- Score = -1 indicates that the experts believe that the item is not measuring the objective and may measure another objective that is not defined to measure in this study (Rovinelli & Hambleton, 1977).
- If the mean of experts' IOC indices is less than 0.5, the question needs to be revised (Chamroonsawasdi et al., 2017) accordingly to expert's suggestions and comments.

In this study, a pilot test using IOC index is carried out through the interview of:

- Two owners of block rubber production and exporting companies as they have experience more than 20 years in block rubber production and logistics perspectives. Moreover, they experienced rubber situations through a number of government eras.
- Two executive directors of transportation service provider companies who have a considerable amount of transportation and logistics experience in planning, designing and managing transportation service projects.

The study topic, objectives, and process of a pilot test are explained to these respondents before performing the interview. The IOC index form representing 20 items judged by four experts and their IOC indices are shown in Table 4.1.

Table 4.1 IOC Indices Form and Results

No.	Item	IOC Index				Mean of IOC Indices
		Expert 1	Expert 2	Expert 3	Expert 4	
1	GOV	1	1	1	1	1
2	TRF	1	1	1	1	1
3	LAW	0	1	1	0	0.50
4	ACD	1	1	0	1	0.75
5	SER	1	1	1	1	1

No.	Item	IOC Index				Mean of IOC Indices
		Expert 1	Expert 2	Expert 3	Expert 4	
6	REL	1	1	1	1	1
7	PUN	1	1	1	0	0.75
8	SPD	1	1	1	0	0.75
9	ACY	1	1	1	1	1
10	CAP	1	1	1	1	1
11	EQP	1	1	1	1	1
12	TSC	1	0	1	1	0.75
13	TRK	1	1	0	1	0.75
14	VOL	1	1	1	1	1
15	DSN	1	1	1	1	1
16	LOG	1	0	1	1	0.75
17	IMG	1	1	1	1	1
18	MKT	1	1	1	1	1
19	EMP	1	1	0	0	0.50
20	DOC	1	1	1	0	0.75

According to Table 4.1, the average scores of IOC indices for each item are summarized for further assessment of experts' perceptions on the clarity of each item. The test items obtain average scores of IOC indices between 0.50 – 1.00, which are considered acceptable. The results indicate that the experts agree that 20 items clearly measure the objective of the questionnaire survey. Thus, this questionnaire survey is used in data collection for further analyses.

4.1.4 Sample Size Calculation

Sample size is an important criterion in EFA and SEM methods because it determines the precision of the generated results due to the asymptotic property of maximum likelihood estimation which helps in reproducing the population values and obtaining statistically significant parameter estimates (Hair et al., 2010; Wolf et al., 2013). However, there is no absolute principle for the minimum requirement of sample size (Chao, 2011).

In this study, Taro Yamane formula is used to calculate a sample size (Yamane, 1967). It is a random sampling technique to estimate sample size with a specified margin of error (e) (Israel, 2013), as a following equation:

$$n = \frac{N}{1+Ne^2} \quad (4.1)$$

Where: n = Size of the sample

N = Size of the population

e = Level of precision

Various guidelines are available for determining an acceptable sampling error precision level (e), ranging from 3% to 10% (Salant & Dillman, 1994). With a population of 287 companies (N), a sample size between 75 and 229 data sets are acceptable for further analyses.

According to Deng et al. (2018), a small or large sample size in the EFA and SEM analyses is relative to the number of items considered in the model. According to Gorsuch (1983), Hatcher (1994), and Pallant (2005), a minimum ratio of 5:1, representing five responses for each item, is required to perform the statistical analysis. Some researchers suggest that uncomplicated EFA and SEM models could be significantly constructed even if sample size is quite small (Hoyle & Kenny, 1999; Marsh & Hau, 1999; Wang & Wang, 2019). A sample size of 100 to 150 respondents with expertise in the area of the study is considered acceptable for conducting EFA and SEM analyses (Coakes & Steed, 2003; Ding et al., 1995; Tabachnick & Fidell, 2013). Wolf et al. (2013) studied sample size requirements for SEM method, the results

revealed that sample sizes of 30 to 460 data sets are required to perform SEM analysis that is varied by type of model, number of factors, number of items, strength of the factor loadings and correlations, and the amount of missing data per item.

4.1.5 Data Collection Methods

Once the questionnaire has been validated through the previous pilot test and sample size of the target population is calculated, the next step is to distribute them to prospective respondents. This study collects data mainly by mailed questionnaire survey to obtain sufficient responses required for further analyses. Moreover, it is usually more cost effective, can be completed within a time frame that is convenient for the respondent, the respondent can stay anonymous, and the interviewer bias is avoided (Forza, 2002). However, the interview is also applied to support in examining more detailed answers in an open-ended question asking for suggestions and opinions regarding the possible use of multimodal transportation in Thailand.

A set of mailed questionnaire survey consists of two copies of the survey and cover letter, as well as two business envelopes and two stamps for each respondent for sending the survey to the respondent and for it to be returned. The return envelope is pre-stamped and pre-addressed for the convenience of the respondent. An interview also provides two copies of the survey per one company or organization.

Only two sets of questionnaire survey are distributed to each company or organization to prevent bias in the collected data. Thus, a total of 574 questionnaire surveys are expected from 287 companies and organizations (as shown in Appendix B) through the mailed questionnaire survey and interview. The data collection is conducted over a period of 3 months. A total of 161 responses are returned with 28% response rate.

4.1.6 Survey Results and Interpretation

A total of 574 questionnaire surveys are distributed, with 161 responses representing 28% response rate. According to Taro Yamane formular, a sample size between 75 and 229 data sets are needed to generate precise and effective results. According to Gorsuch (1983), Hatcher (1994), and Pallant (2005), a minimum ratio of

5:1, representing five responses for each item, is required to perform the statistical analysis. Coakes and Steed (2003), Ding et al. (1995), Tabachnick and Fidell (2013) added that a sample size of 100 to 150 respondents with expertise in the area of the study is considered acceptable for conducting EFA and SEM analyses. Demirkesen and Ozorhon (2017), for example, applied the SEM method in engineering management field to measure project management performance in the construction industry using 63 variables with 121 responses from experts, representing the response rate of 24%. Consequently, with a total of 20 items influencing multimodal transportation efficiency of agricultural products in Thailand, the returned 161 responses (28% response rate) are considered appropriate.

According to the returned responses, two responses are subsequently removed due to the job positions of the respondents are not in the related function serve for multimodal transportation and block rubber fields i.e., security staffs. As a result, 159 responses are used for further analyses.

As shown in Figure 4.3, respondents work in block rubber companies, transport service provider companies, and government sectors and associations to provide a solid result in the understanding of both direct and indirect effects among key multimodal transportation efficiency factors in both government and business perspectives. These can help limit possible negative impacts that might interrupt the implementation of plans and policies in the long-term (European Environment Agency, 2016).

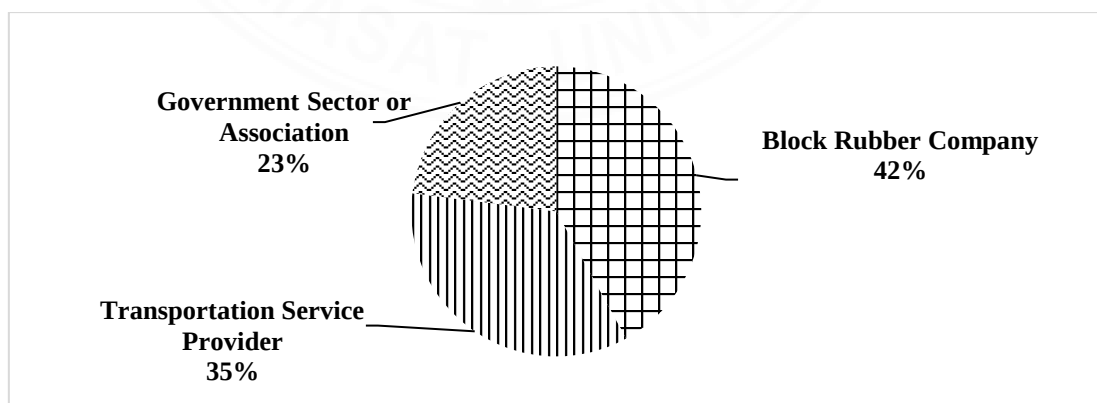


Figure 4.3 Type of Company or Organization

Figures 4.4, 4.5, and 4.6 show that most of respondents work in high level (owner, executive, and managerial levels) with at least five-year working experiences, which indicate reasonably high working experience rate of the respondents. These reflect reliable opinions of the respondents to summarize key multimodal transportation influencing factors and effectively plan for future development of multimodal transportation in Thailand.

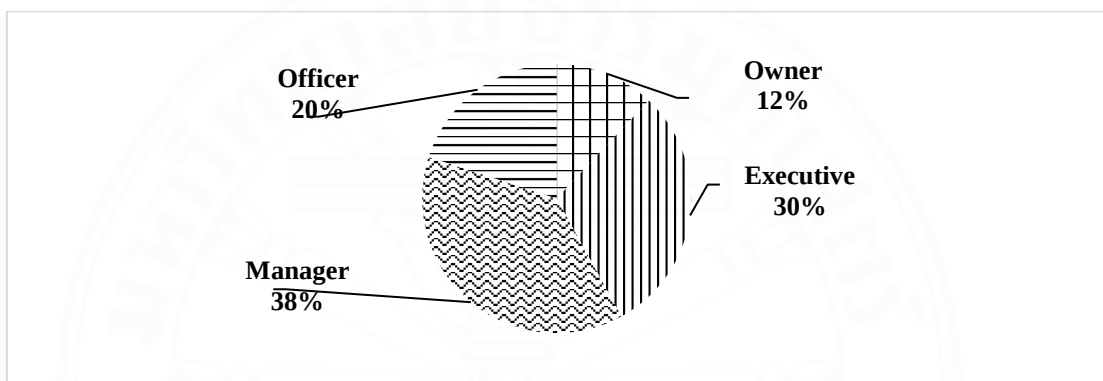


Figure 4.4 Job Position in Company

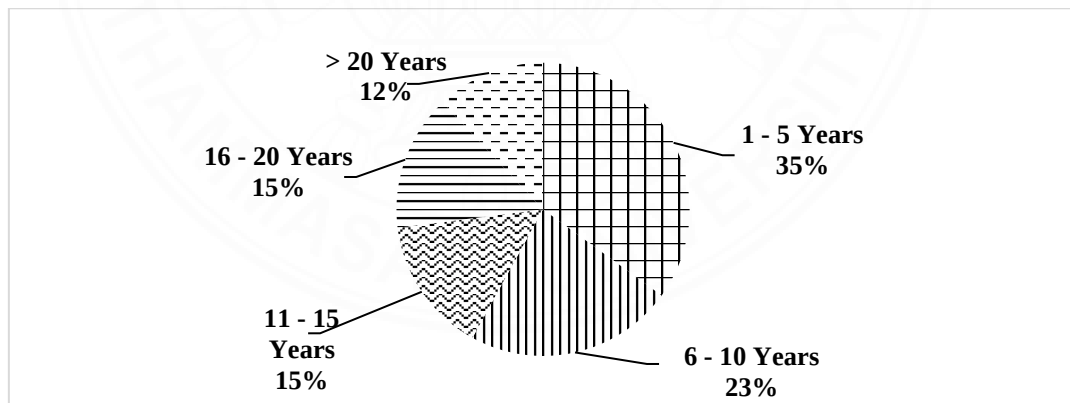


Figure 4.5 Working Experience in Current Company

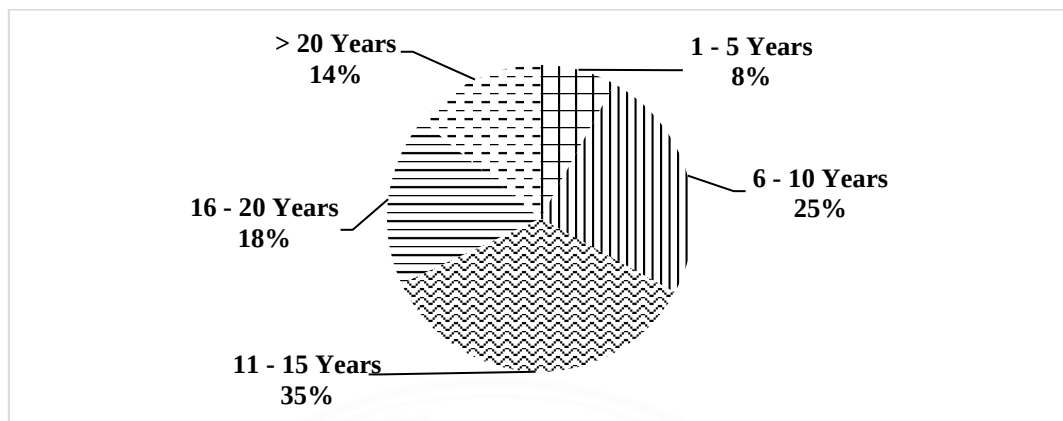


Figure 4.6 Working Experience in Rubber and Transportation Industries

Figure 4.7 shows that most of companies export their products or offer transportation services through Laem Chabang port, Bangkok, which is the major export point of Thailand and the target destination in the SD model development of this study.

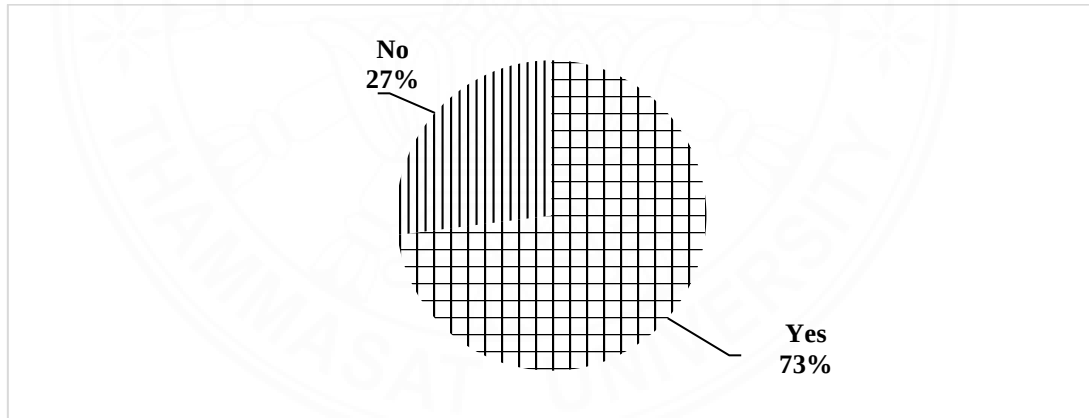


Figure 4.7 Does Company Export Block Rubber or Provide Transport Services Through Laem Chabang Port?

Figure 4.8 shows that almost half of block rubber and transport service provider companies currently use and provide multimodal transportation services, respectively. However, most of companies still confront with high transportation and logistics cost, with more than 2.00 Baht/ton – km, due to the insufficient development of rail and water transportations (Krungsri Research, 2020) (as shown in Figure 4.9).

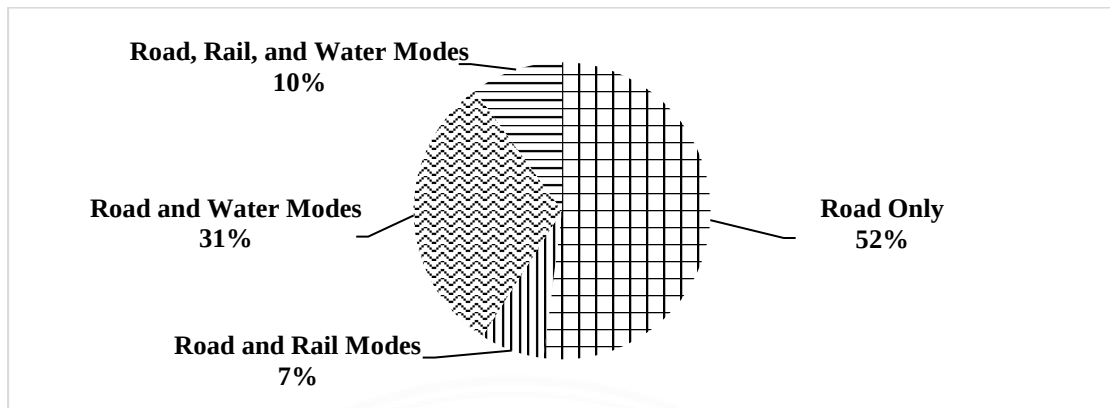


Figure 4.8 Current Transportation Modes Used in Company

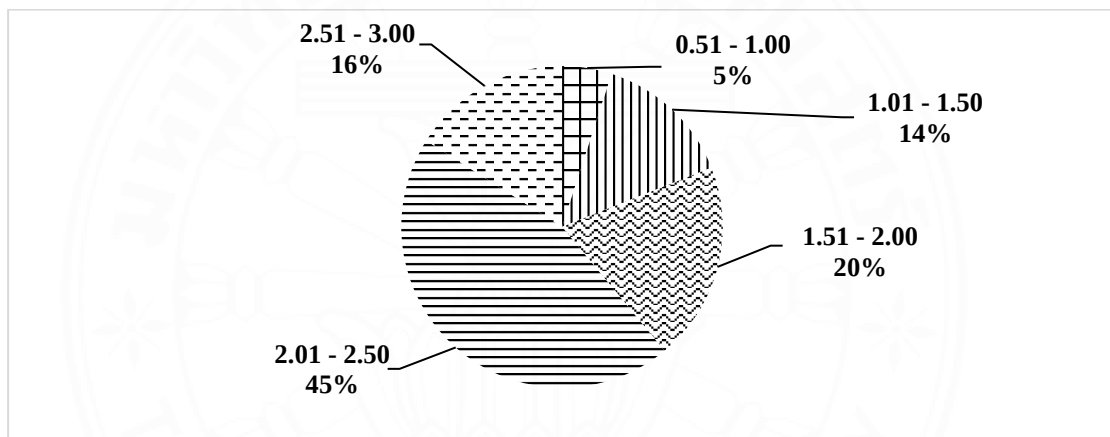


Figure 4.9 Current Logistics and Transportation Cost (Baht/ton - km)

The respondents also provide comments and suggestions of multimodal transportation in Thailand in the last part of questionnaire survey. Most of them agree with multimodal transportation usage for block rubber. However, they state that the current facilities and infrastructure of multimodal transportation do not fully support the demand of block rubber export and transportation. This is the main reason that the majority of current transportation still relies on road mode. The major problems stated by the respondents include:

- Inadequate transportation supported facilities, such as transshipment equipment, locomotives, carriages, and barges.
- Undeveloped transportation infrastructure, such as CY and port capacity.
- Lack of intermodal connection and accessibility.

- Delay in the delivery from rail and ship modes due to poor facilities and management.

In conclusion, the respondents have solid backgrounds and experiences in block rubber and transportation industries to provide reliable opinions to reflect multimodal transportation key influencing factors and effectively plan for future development of multimodal transportation in Thailand. Moreover, many companies agree with multimodal transportation usage for block rubber. However, the current major transportation mode still relies on road as the current facilities and infrastructure of multimodal transportation are insufficient. Thus, this study aims to apply the collected data in studying factors influencing multimodal transportation of block rubber in Thailand and constructing the dynamic model to simulate the interaction of their causal relationships over a period of time.

The collected data is then screened to confirm its level of confidence through a number of data screening methods.

4.2 Data Screening and Preliminary Analyses

Data screening is essential and serves as a foundation in all multivariate analyses to receive meaningful outcomes from quantitative research (Abdulwahab et al., 2011). Specifically, the quality of the statistical analysis results is subject to the quality of the screened data. A single outlier can potentially misrepresent correlation estimates (Stevens, 1984), normality of the data (Gao et al., 2008), measures of item-factor congruence such as Cronbach's alpha (Christmann & Aeist, 2006), EFA model factor loadings (Mavridis & Moustaki, 2008), as well as SEM model parameters and its goodness-of-fit indices (Yuan & Zhong, 2016). Outliers may eventually lead to incorrect models being specified (Pison et al., 2003). Accordingly, the assessment of missing data, straight-lining, outliers, and normality are carried out.

In this study, 159 collected data are found having no missing data. However, there are three responses with straight-lining that give the same answers for all statements in questionnaire survey, representing 1.89% of respondents, which are considered as very low rates of straight-lining (under 2% of respondents) (Cole et al., 2012). Moreover, straight-lining does not always indicate a loss in data quality.

Respondents, who have high working experience and work in high position, may have carefully considered each statement which caused the identical responses (Schonlau & Toepoel, 2015). Thus, 159 collected data are used in data screening and preliminary analyses.

The collected data are then screened with two major data screening tests, including outlier and normality tests to confirm its level of confidence (Garson, 2012). The 5% trimmed mean and standardized scores (z – scores) are used to detect outliers of the 20 items associated with multimodal transportation, while skewedness and kurtosis are common measures for normality test.

4.2.1 Outlier Test

Gao and Mokhtarian (2008) suggested that researchers should identify and remove significant outliers that most impact on normality of the data. According to Bollen and Arminger (1991), outliers in the collected data may create extravagant factors in EFA results. There are a number of methods of detecting outliers within the collected data. This study applies the 5% trimmed mean and standardized scores (z – scores) methods as they detect items that are significantly influenced by extreme values and identify responses that appear to be inconsistent with other responses in the data set, respectively.

1) 5% Trimmed Mean

The 5% trimmed mean is a mean calculated by discarding a 5% of the lowest and the highest scores and then computing the mean of the remaining scores of each item (Walfish, 2006). If a difference between mean and 5% trimmed mean is not beyond the criteria of 0.20, it demonstrates an insignificant influence of any possible outliers on that item (Pallant, 2005). Table 4.2 illustrates the means, the 5% trimmed means, and the mean differences (Δ mean) of all influencing items. The results show that the mean differences of all influencing items are relatively small (less than 0.20) which means that the population mean is relatively insensitive to the outliers, thus providing support for the absence of outliers (Walfish, 2006).

Table 4.2 5% Trimmed Mean Results

NO.	Item	Mean	5% Trimmed Mean	Δ Mean
1	GOV	3.80	3.85	0.05
2	TRF	3.62	3.64	0.02
3	LAW	3.43	3.43	0
4	ACD	3.58	3.62	0.04
5	SER	3.91	3.95	0.04
6	REL	3.80	3.83	0.03
7	PUN	4.16	4.21	0.05
8	SPD	4.09	4.12	0.03
9	ACY	3.82	3.85	0.03
10	CAP	3.86	3.90	0.04
11	EQP	4.06	4.08	0.02
12	TSC	3.96	3.99	0.03
13	TRK	3.75	3.78	0.03
14	VOL	3.75	3.79	0.04
15	DSN	3.64	3.65	0.01
16	LOG	3.85	3.89	0.04
17	IMG	3.76	3.80	0.04
18	MKT	3.78	3.81	0.03
19	EMP	3.67	3.71	0.04
20	DOC	3.76	3.80	0.04

2) Standardized Scores (z – scores)

The 5% trimmed mean helps detect outliers in the items, the standardized scores, on the other hand, is used to identify the influence and presence of outliers on each response. A response is considered to be a potential outlier if its absolute standardized residual is greater than 3.29 at $p < 0.01$, two – tailed test (± 3.29) (Tabachnick & Fidell, 2013). In this study, the results show that the standardized scores are between -3.11 to 1.74 which are not exceed ± 3.29 (as shown in Appendix C). Thus, a total of 159 responses remained for further analyses.

4.2.2 Normality Test

In any multivariate analysis, normality test is the most important (Coakes et al., 2010, Hair et al., 2010). A non-normally distributed data could distort the relationships among variables and the significance of the analysis results (Hulland, 1999). The normality test helps increase confidence in collected data which will allow more accurate EFA results (Arifin, 2017). Before conducting EFA, the normality in data distribution must be tested through skewedness and kurtosis indicators (Yu & Richardson, 2015). Assessment of normality using skewedness and kurtosis indicators is relatively correct in both small and large sample sizes (Kim, 2013).

Skewedness measures asymmetry of the data distribution (Watkins, 2018). The skewedness value of a normal distribution is zero, which representing symmetric distribution. The skewed data is the data that its mean is not in the center of the distribution. A positive skewedness value indicates that the tail on the right side of the distribution is longer than the left side, which means that the bulk of the data lie to the left of the mean. In contrast, a negative skewedness value indicates that the tail on the left side of the distribution is longer than the right side, which means that the bulk of the data lie to the right of the mean (Kim, 2013).

Kurtosis, on the other hand, measures a peak or height of the data distribution (Watkins, 2018). The kurtosis value of a normal distribution is also zero (Field, 2009). The higher kurtosis values indicate a higher and sharper peak, which mean that the bulk of the data are a few extreme differences from the mean. The lower kurtosis values indicate a lower and less distinct peak, which mean that the bulk of the data are modest differences from the mean (Brown, 2011).

According to Curran et al. (1996) and Garson (2012), serious problems in EFA results may occur when absolute value of skewedness is ≥ 2 and kurtosis is ≥ 7 . In this respect, absolute values of skewedness < 2 and kurtosis < 7 are acceptable (Kim, 2013). Table 4.3 shows the skewedness and kurtosis values of 20 items. The results show that all 20 items have normal distribution, thus increasing the confidence in data.

Table 4.3 Skewedness and Kurtosis Results

NO.	Item	Skewness		Kurtosis	
		Stat.	S.E.	Stat.	S.E.
1	GOV	-0.60	0.19	0.79	0.38
2	TRF	-0.41	0.19	-0.31	0.38
3	LAW	-0.17	0.19	-0.36	0.38
4	ACD	-0.39	0.19	-0.13	0.38
5	SER	-0.32	0.19	-0.51	0.38
6	REL	-0.34	0.19	0.09	0.38
7	PUN	-0.61	0.19	-0.30	0.38
8	SPD	-0.43	0.19	-0.24	0.38
9	ACY	-0.34	0.19	-0.62	0.38
10	CAP	-0.35	0.19	-0.77	0.38
11	EQP	-0.31	0.19	-0.16	0.38
12	TSC	-0.32	0.19	-0.50	0.38
13	TRK	-0.30	0.19	-0.31	0.38
14	VOL	-0.36	0.19	0.44	0.38
15	DSN	-0.14	0.19	-0.65	0.38
16	LOG	-0.34	0.19	-0.37	0.38
17	IMG	-0.33	0.19	-0.15	0.38
18	MKT	-0.28	0.19	-0.47	0.38
19	EMP	-0.40	0.19	0.47	0.38
20	DOC	-0.44	0.19	0.06	0.38

Note: Stat. = Statistics Value, S.E. = Standard Error Value

The screened data will be further used in EFA and SEM model development to identify key influencing factors and their interrelationships.

CHAPTER 5

EXPLORATORY FACTOR ANALYSIS

As Thai block rubber export is growing and multimodal transportation in Thailand is developing continuously according to the government policies aim at reducing road transportation issues and costs, a study of factors influencing multimodal transportation of block rubber in Thailand is crucial for block rubber production industry, multimodal transportation service providers, and government to be competitive in the world market. This study then summarizes items influencing multimodal transportation from previous studies in various fields, countries, and markets. Thus, EFA method is needed to explore the possible underlying factors of a set of measured variables or items in accordance with Thailand multimodal transportation conditions and situation.

Since the normality of the data distribution is confirmed, the EFA is conducted using Statistical Package for the Social Sciences (SPSS, version 21). The EFA enables the understanding of how variables are interrelated (Hon et al., 2013). It is performed to reduce the number of items into a smaller number of factors (Hair et al. 2010). According to Seo et al., the EFA is an important precursor of the SEM model development (Cudeck & MacCallum, 2007). To conduct EFA, there are six main steps to follow in this study, including 1) the assessment of data suitability to conduct EFA, 2) the selection of factor extraction method, 3) the selection of factor rotation method, 4) the EFA performing, 5) the measurement of internal consistency reliability of the EFA results, 6) the EFA results discussion and conclusion (as shown in Figure 5.1).

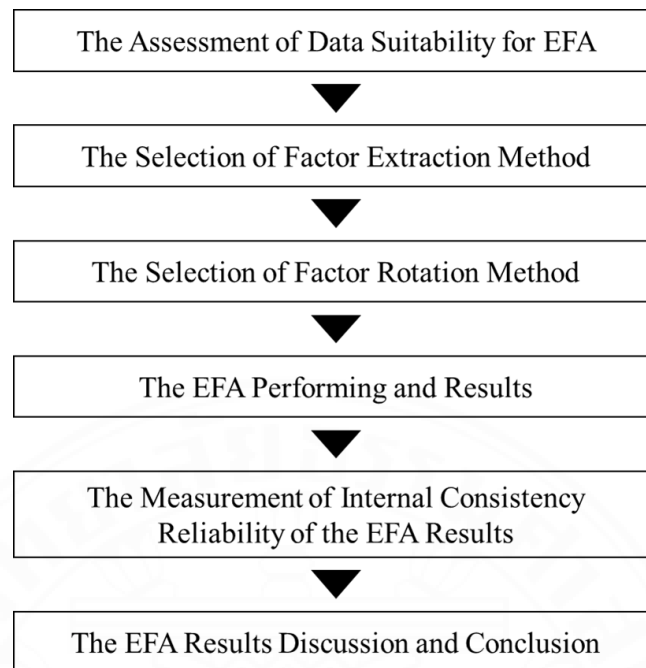


Figure 5.1 EFA Steps

5.1 The Assessment of Data Suitability for EFA

The EFA processes begin with an initial analysis, the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity, to determine construct validity and to confirm that the collected data are appropriate for the EFA. The KMO test is used to confirm the sampling adequacy for the analysis, and the Bartlett's Test of Sphericity is used to determine if correlations between items are sufficiently large for EFA (Yu & Richardson, 2015). The KMO index ranges from 0 to 1, with at least 0.60 considered suitable for the EFA (Tabachnick & Fidell, 2007). The Bartlett's Test of Sphericity should be significant ($p < 0.05$) for the collected data to be further analyzed by the EFA (Tabachnick & Fidell, 2007). In this study, KMO index is 0.84, and the collected data is significant at $p < 0.05$ (as shown in Table 5.1). Thus, the results confirmed that the collected data is suitable for the EFA method.

Table 5.1 Kaiser-Meyer-Olkin Measure of Sampling Adequacy and Bartlett's Test of Sphericity Results

Test	Recommended Value	Calculated Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO)	0.60	0.84
Bartlett's Test of Sphericity	< 0.05	0.00

5.2 The Selection of Factor Extraction Method

Factor extraction is a process for determining the smallest number of factors that best represent the interrelationships among set of items (Watson, 2017). The aim of factor extraction is to simplify the factor structure of a group of items (Costello & Osborne, 2005). It helps discover which items form coherent subsets, but largely independent of other subsets, are to be combined into factors (Tabachnick & Fidell, 2007).

There are numerous ways to extract factors, generally including, Principal Components Analysis (PCA), Principal Axis Factoring (PAF), unweighted least squares, generalized least squares, image factoring, maximum likelihood, and alpha factoring. However, PCA is commonly used in the published literatures as it is the default method in many statistical programs (Tabachnick & Fidell, 2007). Moreover, PCA is recommended when there is no priori theory or model (Gorsuch, 1983). According to Coughlin (2013), when the researcher's aim is data reduction, the researcher should apply PCA as the factor extraction method. PCA is appropriate when the goal is to reduce a large number of measured variables into groups of a small set of variables (Maskey et al., 2018).

There are several studies dealing with multimodal transportation factors using PCA in factor extraction process. Maskey et al. (2018), for example, gathered maritime influencing factors from a number of maritime transportation studies and applied EFA to summarize the final factor structure of influencing factors in shipping-related issues, port service quality, quality management in the shipping industry, and container development strategies. The PCA was applied in this study to reduce a large number of

measured variables into a small set of composite variables. The study stated that in PCA extraction method, all variances of variables are analyzed. Thus, it is considered perfect, reliable, and without error. Fang et al. (2020) identified factors influencing container multimodal transport service quality using EFA and SEM. The study also applied PCA extraction method in EFA analysis. The EFA results demonstrated high item loadings on one factor and smaller item loadings on the other factors, which is convenient to summarize the factors and their associated items. This study then applies the PCA extraction method to summarize 20 influencing items into a smaller number of key influencing factors.

5.3 The Selection of Factor Rotation Method

While factor extraction helps reduce the data dimension, the factor rotation helps in interpretability of factor loadings. In factor rotation, factors are rotated in ‘n’ (number of factors) dimensions to produce simple structure of factors (Park, 2002). There are two ways to rotate factors, oblique and orthogonal rotation methods. An orthogonal rotation method constrains factors to be independent of each other, while an oblique rotation method allows factors to be correlated (Park, 2002, Osborne, 2014). Orthogonal and oblique rotations produce virtually identical results in the case where factors are perfectly uncorrelated (Osborne, 2014). However, oblique rotation is much less popular than orthogonal rotation as an orthogonal rotation generally produces a simpler and more easily interpretable structure of factors (Park, 2002, Osborne, 2014).

This study applies orthogonal rotation in factor rotation process because the factor analysis generally deals with independent variables (Ertel, 2013). It attempts to identify factors that are responsible for the covariation among group of independent variables (Walker & Maddan, 2008). The most popular orthogonal rotation technique is Varimax rotation (Weide & Beauducel, 2018). It helps maximize the variance of factor loadings by making an explicit difference value between high loadings and low loadings for each factor (Tabachnick, 2013). Thus, the Varimax rotation method is used in this study.

5.4 The EFA Performing and Results

Following the assessment of data suitability, and selections of factor extraction and rotation methods, EFA is performed to explore relationships among items and reduce the number of items into key factors (latent variables). In order to proceed EFA, SPSS version 21 is used as the statistical analysis software. According to Hair et al. (2010), to access significance of factor loadings, variables with factor loadings below 0.40 should be eliminated, while variables with factor loadings greater than 0.7 are considered as practically significant (Maskey et al., 2018). Thus, items with factor loadings below 0.40 will be eliminated in this study.

In this study, 20 items are categorized into three groups based on their functional contents and theoretical references before conducting EFA (as shown in Table 5.2).

Table 5.2 Groups of 20 Items

Group	Item	References
Operation	1) Capacity (CAP)	Kritchanchai and Chanpuypetch (2009), Heljedal (2013), Choi et al. (2014), Islam et al. (2016), Corman et al. (2017)
	2) Accessibility (ACY)	
	3) Delivery Speed (SPD)	
	4) Punctuality (PUN)	
	5) Transshipment Equipment (EQP)	
	6) Government Policy (GOV)	
	7) Vehicle Design (DSN)	
	8) Documentation (DOC)	
	9) Skilled Employee (EMP)	
	10) Tracking System (TRK)	
	11) Volume Flexibility (VOL)	
Market	1) Service Providers (SER)	Kreutzberger et al. (2003), Casaca and Marlow (2009), Heljedal (2013), Choi et al. (2014), SteadieSeifi et al. (2014), Butta and Abegaz (2016)
	2) Relationships (REL)	
	3) Green Image (IMG)	
	4) Logistics Costs (LOG)	
	5) Market Competitiveness (MKT)	
	6) Transshipment Costs (TSC)	

Road Constraints	1) Road Law Enforcement (LAW)	Kreutzberger et al. (2003), Casaca and Marlow (2009), Choi et al. (2014), Butta and Abegaz (2016)
	2) Road Traffic (TRF)	
	3) Road Accident (ACD)	

Each group is then analyzed with the EFA method to determine how items are interrelated and to reduce the number of items into a smaller number of factors (Hair et al. 2010, Hon et al., 2013). They are subjected to EFA with the PCA extraction and Varimax rotation methods. The factor loading cutoff is fixed at 0.40. The EFA results show that Operation group is extracted into two factors with 55.75% of the total variance explained, Market group is extracted into two factors with 70.84% of the total variance explained, and Road Constraints items are suggested to be combined as one factor which account for 72.55% of the total variance (as shown in Table 5.3). According to Hair et al. (2010), in the natural science, once the factors are summarized, they can explain at least 95% of the variance. However, in other study areas, the total variance explained more than 50% is considered acceptable (Thilakarathne & Jayaratne, 2019).

Table 5.3 EFA Results

Item	Operation		Market		Road Constraints
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
CAP	.822				
ACY	.815				
SPD	.794				
PUN	.749				
EQP	.738				
DSN	.490				
GOV	.462				
VOL	.416				
DOC		.852			

Item	Operation		Market		Road Constraints
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
EMP		.808			
TRK		.753			
REL			.867		
LOG				.841	
IMG				.830	
MKT				.814	
TSC				.630	
LAW					.872
TRF					.854
ACD					.829

In this study, five factors associated with 20 items are extracted from the EFA (as summarized in Table 5.3). The EFA results will be confirmed with the reliability test (as described in Section 5.5) and the Confirmatory Factor Analysis which is a part of SEM model development (as described in Chapter 6).

5.5 The Measurement of Internal Consistency (Reliability) of the EFA Results

Reliability analysis is established by testing whether the items grouped under a factor are internally consistent and stable. Cronbach's alpha is utilized to analyze the internal consistency and reliability of each factor (Hon et al., 2013). According to Tavakol and Dennick (2011), Cronbach's alpha is expressed as a number between 0 and 1. The value of 0.70 is the minimum acceptable values of Cronbach's alpha. In this study, the results show that all factors had alpha values ranging from 0.751 to 0.839, thus confirming the reliability of all factors resulted from EFA (see Table 5.4).

Table 5.4 Reliability Test Results

Factor	Cronbach's Alpha
Factor 1: Multimodal Transportation Infrastructure Factor (8 items: CAP, ACY, SPD, PUN, EQP, DSN, GOV, VOL)	0.839
Factor 2: Operation Factor (3 items: DOC, EMP, TRK)	0.763
Factor 3: Multimodal Service Provider Factor (2 items: SER, REL)	0.751
Factor 4: Market Factor (4 items: LOG, IMG, MKT, TSC)	0.821
Factor 5: Road Constraints Factor (3 items: LAW, TRF, ACD)	0.810

Once the reliability and validity of the collected data are measured, the key influencing factors and their associated items are summarized from the EFA results. Factors derived from EFA results will be then validated by SEM method to confirm key factors and their associated items, as well as to explore the complex relationships among them.

5.6 The EFA Results Discussion and Conclusion

The Multimodal Transportation Infrastructure factor focuses mainly on the multimodal transportation infrastructure to achieve a successful multimodal transportation operation (Crainic & Laporte, 1997). It consists of eight associated items, including capacity of container yard (CAP), accessibility to container yard (ACY), delivery speed (SPD), punctuality (PUN), transshipment equipment (EQP), vehicle design (DSN), government policies (GOV), and volume flexibility (VOL). Bontekoning et al. (2004), for example, stated that effective multimodal transportation facilities and infrastructure are required in successful multimodal transportation.

The Operation factor pinpoints key operations necessary to achieve multimodal transportation effectiveness, including documentation (DOC), skilled employee (EMP), and tracking system (TRK). Butta and Abegaz (2016), for instance, stated that

key challenges in multimodal transportation operations are documentation processes, shortage of skilled employees, and lack of effective tracking system.

The Multimodal Service Provider factor identifies the transport service provider as a key stakeholder to achieve the multimodal transportation effectiveness. The focuses should be on having adequate number of transportation service providers (SER) and maintaining relationships with the companies to gain transport benefits in the long term (REL) (Chao, 2011). Stokland et al. (2010) added that effective modal shift requires cooperation and interaction between company and transport service providers.

The Market factor is associated with four items, namely logistics costs (LOG), green image (IMG), market competitiveness (MKT), and transshipment costs (TSC). It mainly considers multimodal transportation market and its related costs. Rantasila and Ojala (2012), for example, stated that the use of multimodal transportation helps encourage sales, increase trade, open the new markets, and increase company's competitiveness. Ezanee et al. (2013) added that utilizing multimodal transportation increases the company's image, resulting in cost reduction and competitive advantages.

The Road Constraints factor is associated with three items, namely road law enforcement (LAW), road traffic (TRF), and road accident (ACD). It is the key problems of road transportation caused by its limited infrastructure network and truck restriction rule (Uabharadorn, 2009). Hanssen and Mathisen (2011) mentioned that road issues raise concerns of modal shift from road to rail and water modes.

The five key factors influencing multimodal transportation efficiency of block rubber transportation in Thailand form the baseline model which leads to the conceptual framework in this study to further examine causal relationships, as well as directions of relationships, among them utilizing the SEM approach (see Figure 5.2). According to Ockey (2014), SEM method is often used to determine the extent to which an already established theory, generally based on previous research or model, about relationships among variables is supported by the observed data.

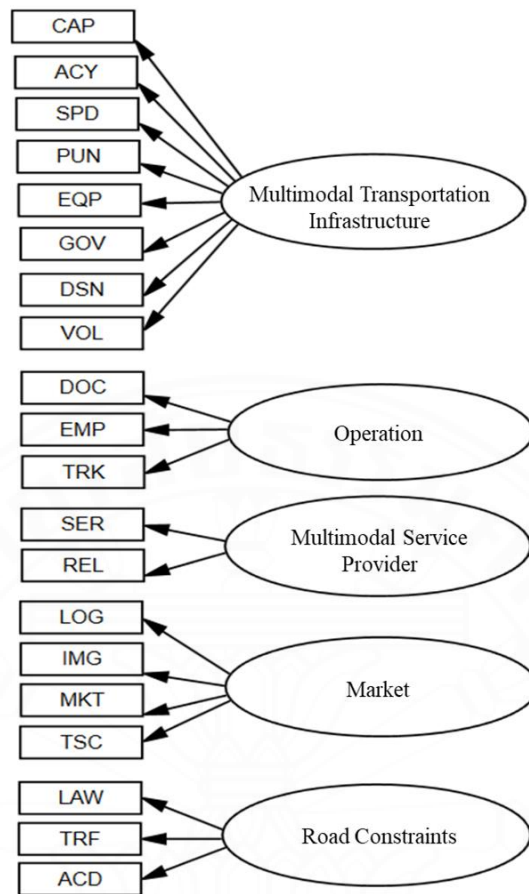


Figure 5.2 Baseline Model of Key Factors Influencing Multimodal Transportation Efficiency

CHAPTER 6

STRUCTURAL EQUATION MODELING

The interrelationships among key multimodal transportation efficiency factors achieved from Chapter 5 should be examined to better understand the causes and effects of multimodal transportation implementation. Thus, the effective plans and policies of multimodal transportation development could be established. This study, therefore, confirms key factors influencing multimodal transportation efficiency of agricultural products in Thailand, as well as examines their interrelationships by using the structural equation modeling (SEM) method. The study results could also be used as a foundation for further analysis, such as benefit-cost and policy analyses to help policymakers and engineering managers in multimodal transportation planning.

6.1 Research Design

In this study, the conceptual framework of multimodal transportation efficiency is constructed to develop a baseline model of key factors influencing multimodal transportation efficiency of agricultural products in Thailand. Questionnaire survey is, then, developed to collect data based on key influencing factors and their associated items. Preliminary analyses are performed to screen the collected data. SEM is, then, utilized to examine interrelationships among key factors influencing multimodal transportation efficiency. Guideline for multimodal transportation implementation is developed based on the SEM results. Thus, the agricultural production companies, transport service providers, and government sector can effectively plan for multimodal transportation enhancement in the long-term.

6.2 Conceptual Framework

Recently, multimodal transportation is widely used because of its benefits, including energy efficiency, road traffic congestion alleviation, environmental impacts reduction, and less logistics costs (Macharis et al., 2011; Macharis & Pekin, 2009). Researchers and engineering managers realize that the traditional transportation or road-only transportation, does not meet the needs of modern cities (Fang et al., 2020;

Jiang et al., 2019). They recognize that the successful multimodal transportation can fully utilize the existing transportation network and infrastructure, integrate transportation capacity, support the transportation demand, and achieve the company targets in time, costs, and profit aspects (Marufuzzaman & Ekşioğlu, 2017; Zhang et al., 2015).

In this study, the summarized five key factors extracted from EFA method with their 20 associated items are further studied with SEM method to identify interrelationships among them, see Table 6.1.

Table 6.1 Factors Influencing Multimodal Transportation Efficiency in Thailand

Factor	Item	Description
Multimodal Transportation Infrastructure	Capacity (CAP)	Capacity of container yard (CY) of train station or port to support big bulk transportation (Kritchanchai & Chanpuypetch, 2009).
	Accessibility (ACY)	Ability to access to CY of train station or port by inland transportation (Kritchanchai & Chanpuypetch, 2009).
	Delivery Speed (SPD)	Time taken for the transportation from seller to buyer (Danielis & Marcucci, 2005; Heljedal, 2013).
	Punctuality (PUN)	On-time arrival or departure of the service (Bektas & Crainic, 2007; Islam et al., 2016).
	Transshipment Equipment (EQP)	Handling equipment, such as swap bodies and semi-trailers, available for modal shift processes (Choi et al., 2014).
	Vehicle Design (DSN)	Design of locomotives, carriages, or barges to accommodate multimodal transportation (Heljedal, 2013; Islam et al., 2016).

Factor	Item	Description
	Government Policy (GOV)	Multimodal transportation-related government policies (Choi et al., 2014; Corman et al., 2017).
	Volume Flexibility (VOL)	Variations in volumes to respond to changes in transportation demand (Arnold et al., 2004; Heljedal, 2013).
	Logistics Costs (LOG)	Logistics costs of multimodal transportation (Kritchanchai & Chanpuypetch, 2009).
	Green Image (IMG)	Green image of company from using multimodal transportation (Heljedal, 2013; Kreutzberger et al., 2003).
	Market Competitiveness (MKT)	Market competitiveness due to new competitors and customers (SteadieSeifi et al., 2014).
Market	Transshipment Costs (TSC)	Transshipment costs related to modal shift processes (SteadieSeifi et al., 2014).
	Documentation (DOC)	Documentation processes required in modal shift process (Butta & Abegaz, 2016; Kritchanchai & Chanpuypetch, 2009).
	Skilled Employee (EMP)	Skilled employees to perform modal shift processes (Butta & Abegaz, 2016).
	Tracking System (TRK)	Tracking system in multimodal transportation (Butta & Abegaz, 2016; Islam et al., 2016).
Multimodal Service Provider	Service Providers (SER)	Adequacy of multimodal transport service providers (Bektas & Crainic, 2007; Roberts, 2012).
	Relationships (REL)	Relationships between companies and multimodal transport service providers (Butta & Abegaz, 2016; Casaca & Marlow, 2009).

Factor	Item	Description
Road Constraints	Road Law Enforcement (LAW)	Limited driving hours per driver in road transportation (Heljedal, 2013; Kritchanchai & Chanpuypetch, 2009).
	Road Traffic (TRF)	Road traffic volume (Choi et al., 2014; SteadieSeifi et al., 2014).
	Road Accident (ACD)	Road-related accidents (Heljedal, 2013; Kreutzberger et al., 2003).

The Multimodal Transportation Infrastructure factor consists of eight associated items, including capacity of container yard (CAP), accessibility to container yard (ACY), delivery speed (SPD), punctuality (PUN), transshipment equipment (EQP), vehicle design (DSN), government policies (GOV), and volume flexibility (VOL). It provides an effective multimodal transportation operation (Crainic & Laporte, 1997). Bontekoning et al. (2004) stated that effective multimodal transportation facilities and infrastructure are required in successful multimodal transportation.

The Market factor is associated with four items, including logistics costs (LOG), green image (IMG), market competitiveness (MKT), and transshipment costs (TSC). Rantasila and Ojala (2012), for example, stated that the use of multimodal transportation helps encourage sales, increase trade, open the new markets, and increase company's competitiveness. Ezanee et al. (2013) added that utilizing multimodal transportation increases the company's image, resulting in cost reduction and competitive advantages.

The Operation factor pinpoints key operations that are necessary to achieve multimodal transportation effectiveness, including documentation (DOC), skilled employee (EMP), and tracking system (TRK). Butta and Abegaz (2016), for instance, stated that key challenges in multimodal transportation operations are documentation processes, shortage of skilled employees, and lack of effective tracking system.

The Multimodal Service Provider factor consists of two items, including transport service providers (SER) and relationships between agricultural production companies and transport service providers (REL). Stokland et al. (2010) stated that

effective modal shift requires cooperation and interaction between companies and transport service providers. The adequate transport service providers and relationships maintaining between agricultural production companies and transport service providers will lead to multimodal transportation effectiveness and benefits in the long-term (Chao, 2011).

The Road Constraints factor is associated with three items, including road law enforcement (LAW), road traffic (TRF), and road accident (ACD). It is the key problems of road transportation caused by its limited infrastructure network and truck restriction rule (Uabharadorn, 2009). Hanssen and Mathisen (2011) mentioned that road issues raise concerns of modal shift from road to rail and water modes.

The five key factors influencing multimodal transportation efficiency form a baseline model to further examine causal relationships and directions among them utilizing the SEM approach (see Figure 6.1). According to Ockey (2014), SEM method is often used as an extension of the established theory based on previous research. It deals with relationships among variables that are supported by the observed data. Table 6.2 shows the differences between using EFA and SEM in this Study.

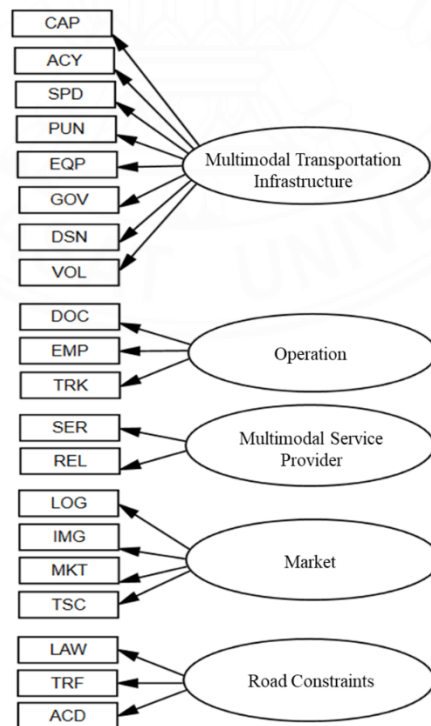


Figure 6.1 Baseline Model from EFA Results

Table 6.2 Differences between using EFA and SEM in this Study

	EFA	SEM
Aim	To examine key factors influencing multimodal transportation efficiency.	To confirm key factors influencing multimodal transportation efficiency, as well as examine their interrelationships.
Analysis Method	Exploratory Factor Analysis (EFA) method. EFA method helps identify the appropriate group of factors and their associated items for the subsequent application of SEM method (Chao, 2011).	Structural Equation Modeling (SEM) method. SEM method helps confirm group of factors and their associated items based on empirical research (including EFA results) (Byrne, 2001). This method can identify multiple and interrelated relationships, as well as direct and indirect relationships among the factors (Hair et al., 2010).
Findings	The EFA results identified the most important item of each factor that should be focused. However, the results did not provide the implications of the sequence of causes and effects occurrence.	The SEM results provide complex interactions among factors and their associated items in both direct and indirect causes and effects.

In this study, the causal relationships among key factors are hypothesized based on a number of multimodal transportation-related literature. The hypothesized relationships are, then, confirmed by the SEM analysis. The results of this study provide a better understanding of key multimodal transportation efficiency factors, and implications to the government and business sectors through theoretical justifications

with practical recommendations in order to reach successful implementation of multimodal transportation in the long-term.

Thailand aims to become the center of agricultural products manufacturing, as well as logistics and transportation hub in Southeast Asia because of its geographical advantage and variety of high-quality agricultural products, such as rice, block rubber, and cassava (Krungsri Research, 2020). The country, for example, is the world's major exporter of block rubber to automotive manufacturing companies around the world, such as China, Germany, and USA. Being the center of agricultural products production and the logistics hub can lead to an increasing of the export volume which causes more traffic and environmental issues. Thailand, therefore, needs to consider all aspects of multimodal transportation, not only the infrastructure readiness, but also resources and capacity utilization to ensure the multimodal transportation efficiency to deal with upcoming issues. A better understanding of key factors affecting multimodal transportation efficiency and their interrelationships helps achieve potential practices for positive changes, for example new government policies, new modes combination, and new transportation routes. This, in turn, reduces the logistics and transportation costs, and increase the country's transportation network efficiency.

The confirmed five key factors and their 20 associated items under the 159 datasets are next performed with the SEM analysis to examine their causal relationships to better plan for multimodal transportation policies in Thailand.

The respondents also provide comments and suggestions of multimodal transportation in Thailand in the last part of questionnaire survey. Most of them agree with multimodal transportation usage for agricultural products. However, they state that the current facilities and infrastructure of multimodal transportation do not fully support the demand of agricultural products transportation. This is the main reason that the majority of current transportation still relies on road mode. The major problems stated by the respondents include:

- Inadequate transportation supported facilities, such as transshipment equipment, locomotives, carriages, and barges.
- Undeveloped transportation infrastructure, such as CY and port capacity.
- Lack of intermodal connection and accessibility.

- Delay in the delivery from rail and water modes due to poor facilities and management.

6.3 Structural Equation Modeling Studies on Multimodal Transportation

In this study, the SEM analysis method is utilized to examine causal relationships among five key factors influencing multimodal transportation efficiency of agricultural products in Thailand. This method is an appropriate multivariate statistical analysis method that allows simultaneous analysis of multiple and interrelated dependences, as well as direct and indirect relationships among the variables (Hair et al., 2010). It also allows hypothesis testing of a theoretical model in a quantitative approach. It helps distinguish direct, indirect, and total effects then it interprets the interaction effects in the context of a simultaneous equation model (Batista-Foguet et al., 2004).

Werner and Schermelleh-Engel (2009) summarized practical advantages of using SEM for data analysis, including:

- **Validity:** SEM allows a utilization of several indicator variables per construct simultaneously, which leads to more valid conclusions on the construct level.
- **Reliability/measurement error:** SEM can take measurement error into account by explicitly including measurement error variables that correspond to the measurement error portions of observed variables. Therefore, conclusions about relationships between constructs are not biased by measurement error, and are equivalent to relationships between variables of perfect reliability.
- **Complex models:** SEM allows a modeling and a test of complex relationships, including a multitude of hypotheses simultaneously as a whole (including mean structures and group comparisons). Using other analysis methods would frequently require several separated analyses.
- **Confirmatory approach:** For hypotheses testing, simple statistical methods usually provide tests on the basis of explained variance in single criterion variables. This is inappropriate for evaluating complex models containing a

multitude of variables and relationships. In contrast, SEM allows a test of complex models to analyze their compatibility with the data, and allows a test of specific assumptions about parameters for their compatibility with the data. As a result, the variances and covariances of all observed variables are systematically factored.

The complexity of SEM, however, comes with statistical and interpretational challenges in terms of parameter identification and interpretation of results (Werner & Schermelleh-Engel, 2009).

A number of multimodal transportation-related studies have been conducted utilizing the SEM analysis. Choi et al. (2014), for example, utilized the SEM analysis to examine impacts of policy measures on promoting modal shift in South Korea. The study considered four perspectives of policy measures, including road pricing, multimodal transportation services, transportation planning, and multimodal transportation infrastructure. The study results showed both direct and indirect effects of four factors on each other and on multimodal transportation development. The study suggested that the road pricing and multimodal transportation services can encourage the strategic planning and operation, which positively affects the transportation infrastructure development policies, and eventually results in the multimodal transportation development. Papaioannou and Martinez (2015) applied the SEM method to study the effects of accessibility and connectivity in mode choice decisions. The study addressed effects of public transportation network layout and service provision on transportation mode choices. It was found that good accessibility and connectivity are the most significant criteria when considering mode choices because they significantly affect the travel time. Jiang et al. (2017) examined the relationships between multimodal transportation investment and economic development using the SEM method. The results indicated that investment in transportation infrastructure influences economic development by promoting connectivity and encouraging the travel demand. Dua and Sinha (2019) identified factors affecting performance of multimodal transport service providers using the SEM method. Four key factors were identified, including communication, collaboration, process and documentation, and variation in time, cost, and quantity. The study concluded that variation in time, cost, and quantity

does not significantly affect the quality of multimodal transport service in the study area where such phenomena occurred frequently. However, this factor needs to be included when the geography is different from the study.

The above research pinpoint various perspectives of multimodal transportation in achieving the multimodal transport efficiency. With application of the SEM method, these studies gain superior benefits in simultaneously explaining both direct and indirect relationships among key factors (Dastgeer et al., 2012; Jiao et al., 2016), which are found important to the transportation planning in local, regional, and national scales (Choi et al., 2014; Dua & Sinha, 2019; Jiang et al., 2017; Papaioannou & Martinez, 2015). However, these studies partially focused on benefits of multimodal transportation on either government or business sectors. The understanding of both direct and indirect effects among key multimodal transportation efficiency factors in both government and business perspectives can help limit possible negative impacts that might interrupt the implementation of plans and policies in the long-term (European Environment Agency, 2016). Thus, the use of SEM method in this study is expected to help clarify direct and indirect relationships among key multimodal transportation efficiency factors simultaneously. Thus, effective plans and policies can be established for both government and business-related sectors.

6.4 Structural Equation Model Development for Multimodal Transportation of Block Rubber in Thailand

Various software can be used to perform the SEM analysis, such as LISREL and AMOS (Arbuckle & SPSS Inc., 1997; Jöreskog et al., 1988). This study applies AMOS version 21.0 software in constructing the multimodal transportation model to explain impacts of five key factors on multimodal transportation efficiency in Thailand. The model is schematically drawn as path diagrams through the collaboration of four geometric symbols: a circle or oval representing latent variable, a square or rectangle representing observed variable, a single-headed arrow ($\rightarrow$) representing the impact of one variable on another, and a double-headed arrow ($\leftrightarrow$) representing the covariance between pairs of variables (Byrne, 2001; Khine, 2013).

To perform SEM analysis, two main parts, namely measurement and structural models are considered (Kline, 2011). The measurement model, so-called the

confirmatory factor analysis, is performed to confirm key factors, their associated items, and their relationships. The structural model, on the other hand, identifies directions of relationships among key constructs, as well as levels of influences (Blunch, 2008). The structural model can only be performed after the best fit measurement model is achieved, by using the same dataset (Abdullah & Rosli, 2015). Steps of the SEM analysis are as shown in Figure 6.2.

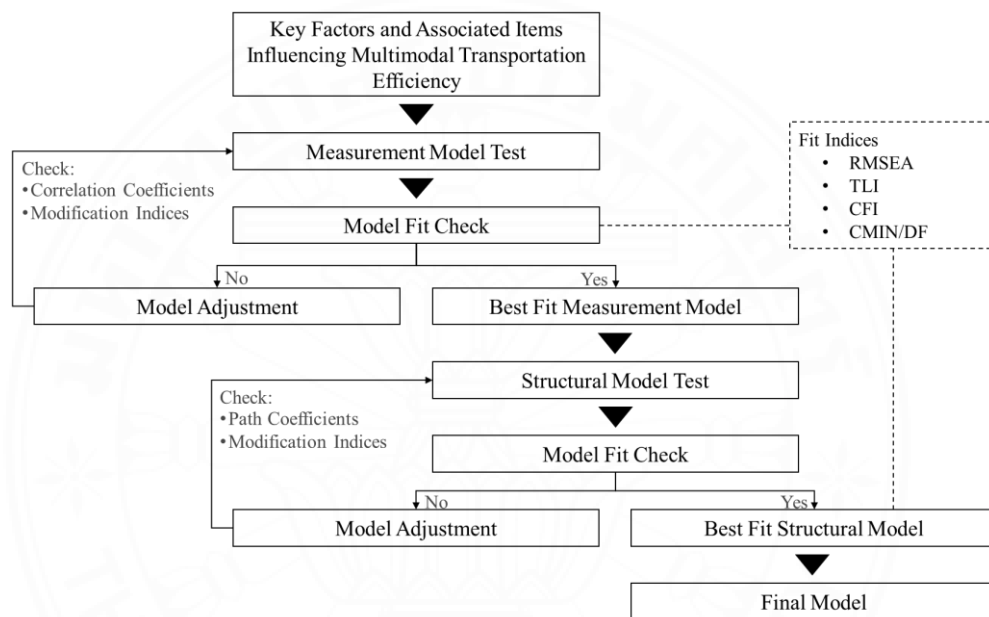


Figure 6.2 Steps of SEM Analysis

Key factors and their associated items influencing multimodal transportation efficiency are performed with the measurement model test to confirm their constructs and relationships. A number of fit indices are used to assess fitness of the developed model (Maydeu-Olivares & Garcí'a-Forero, 2010). Four common indices, including root mean square error of approximation (RMSEA), Tucker–Lewis index (TLI), comparative fit index (CFI), and relative chi-square (CMIN/DF), are used in logistics and transportation studies as well as in this study, as they are not excessively sensitive to sample size (Bentler, 1990; Chao, 2011; Golob, 2001; Noudoostbeni et al., 2018). These indices offer tests of model fit in favour of minimizing potential bias due to sample size (Peugh & Feldon, 2020). RMSEA is a badness-of-fit measure which lower values indicate a better fit (Shi et al., 2018). A value of $RMSEA < 0.10$ is considered

acceptable (Mehmetoglu & Jakobsen, 2016). TLI measures a relative reduction in misfit per degree of freedom (Tucker & Lewis, 1973). A value of $TLI \geq 0.90$ is considered acceptable (West et al., 2012). According to Tabachnick and Fidell (2013), CFI is formally bounded between 0 and 1, which performs well even when sample size is small. A value of $CFI > 0.90$ indicates good-fitting model (Kline, 2011). CMIN/DF is the chi-square fit index divided by degrees of freedom. This index attempts to make model's chi-square less dependent on sample size (Shadfar & Malekmohammadi, 2013). A value of $CMIN/DF < 2.00$ is considered acceptable (Byrne, 2001).

Model adjustment may be performed if the fit indices are not in the acceptable ranges. Correlation coefficients, path coefficients, and modification indices (MI) are used to adjust the model fit (Hox & Bechger, 1999; Kline, 2011). According to Venturini and Mehmetoglu (2019), paths between latent variables of less than 0.30 should be removed as they possess low correlation coefficients. On the other hand, paths with high MI values should be added into the model to improve model fit (Hox & Bechger, 1999; Karakaya-Ozyer & Aksu-Dunya, 2018).

The best fit measurement model is, then, performed with the structural model test to examine directions of relationships among key multimodal transportation efficiency factors. Model adjustment can also be performed, if needed, to increase the model fit, and accept the best fit structural model. The final model of key factors influencing multimodal transportation efficiency of agricultural products in Thailand is achieved after the best fit structural model is confirmed.

6.4.1 Measurement Model Test

Five key factors and their 20 associated items form a conceptual measurement model of key factors influencing multimodal transportation efficiency of agricultural products in Thailand. Five key factors are initially hypothesized to be correlated with each other using double-headed arrows to represent correlations among them. As a result, a total of 10 correlations are hypothesized (see Figure 6.3).

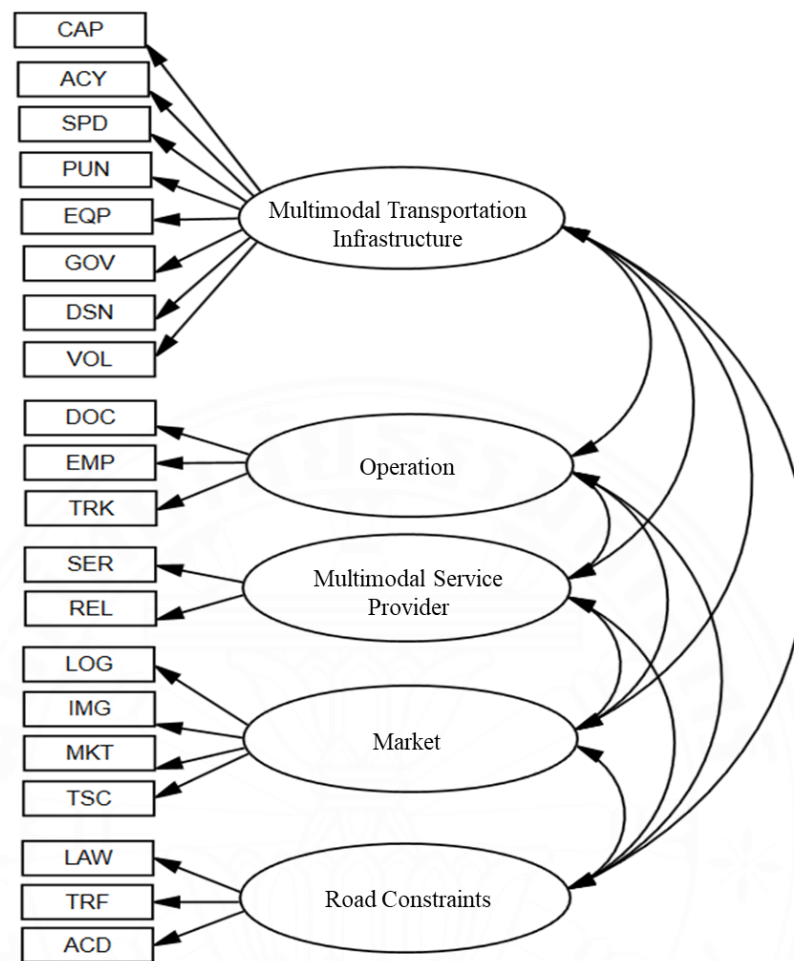


Figure 6.3 Conceptual Measurement Model

The conceptual measurement model is run, and the fit indices reveal a need to adjust the model to improve the model fit (see Table 6.3). The MI values, ranging from 9.83 to 27.26, suggest seven paths to be correlated to improve the model fit (see Table 6.4). On the other hand, the correlation coefficient between the Road Constraints and Multimodal Transportation Infrastructure factors of 0.07 should be removed as it is lower than the minimum acceptable level (see Figure 6.4).

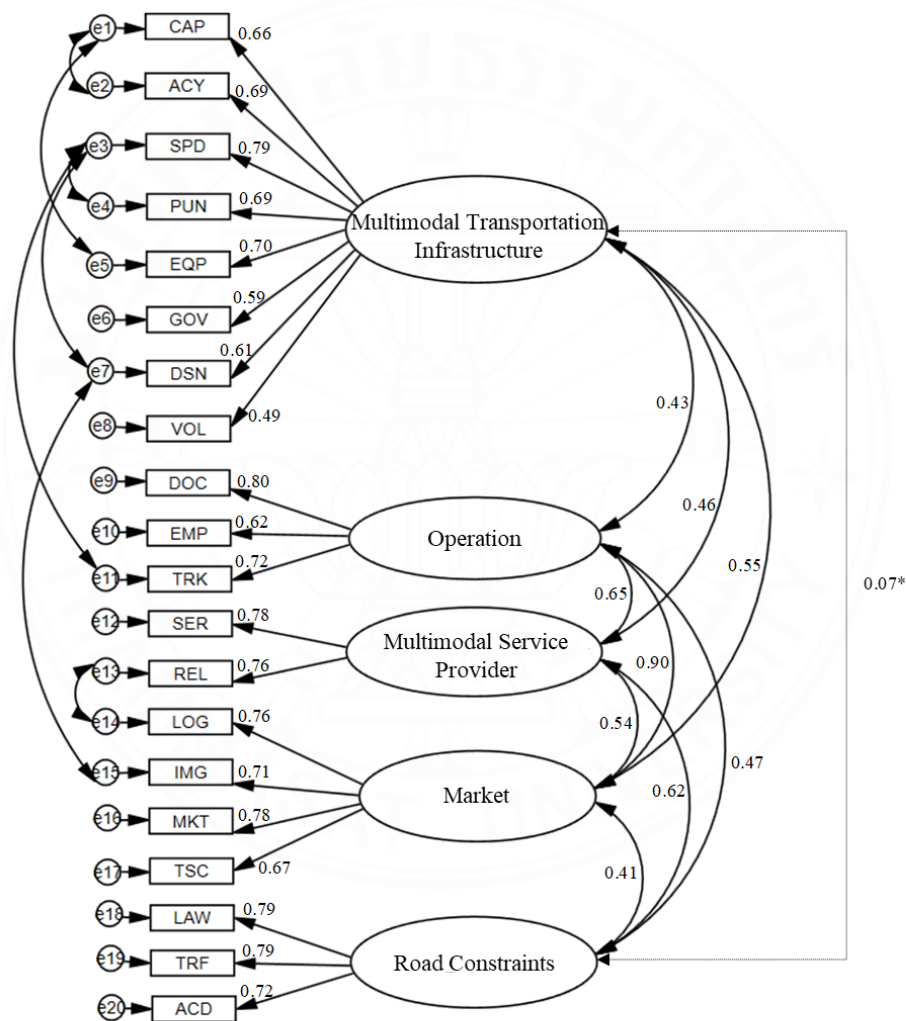
Table 6.3 Fit Indices Results

Fit Indices	Recommended Level	Conceptual Measurement Model	Best Fit Measurement Model	Conceptual Structural Model	Best Fit Structural Model
	< 0.10				
RMSEA	(Mehmetoglu & Jakobsen 2016)	0.11	0.08	0.08	0.07
	≥ 0.90				
TLI	(West et al., 2012)	0.76	0.90	0.90	0.90
	> 0.90				
CFI	(Kline, 2011)	0.80	0.91	0.91	0.91
	< 2.00				
CMIN/DF	(Byrne, 2001)	2.88	1.96	1.96	1.86

Table 6.4 Items Suggested to be Correlated by MI Values.

Relationship	MI Value	Reference
CAP ↔ ACY	27.26	The accessibility of container yard is defined by the handling capacity of a container terminal (Kemme, 2013).
CAP ↔ EQP	20.69	Layout and capacity of CY or port is designed to accommodate the handling equipment for modal shift processes (Cobo, 2016).
SPD ↔ PUN	18.27	Speed of vehicles affects delivery time of the products (Sanchez-Diaz et al., 2020).
SPD ↔ DSN	18.16	Improvements in vehicle design help reduce energy consumption and increase maximum speed (The Watt Committee on Energy, 2007).
SPD ↔ TRK	12.49	Tracking system assists in tracking vehicle location and speed (Ahmed et al., 2015).

Relationship	MI Value	Reference
DSN ↔ IMG	10.13	Environmentally designed vehicles enhance green image of the company (Hagman & Selvig, 2007).
REL ↔ LOG	9.83	Good relationship between logistics service provider and customer leads to lower logistics cost (Wallenburg & Lukassen, 2011).



*Relationship between Multimodal Transportation Infrastructure and Road Constraints is insignificant.

Figure 6.4 Best Fit Measurement Model

After the adjustments, the model is run, and the best fit measurement model is achieved with all fit indices fall in acceptable ranges (see Table 6.3 and Figure 6.4). The best fit measurement model confirms key factors and their associated items

extracted from EFA analysis. It reveals nine relationships among five key factors influencing multimodal transportation efficiency of agricultural products in Thailand. According to Kozak et al. (2012), the correlation coefficients are classified into three categories, where an absolute value lower than 0.30 indicates a very weak or non-existent relationship, an absolute value between 0.30 and 0.70 indicates a significant relationship, and an absolute value higher than 0.70 indicates a strong relationship between factors. The best fit measurement model reveals one strong relationship between the Operation and Market factors with correlation coefficient of 0.90 (see Figure 6.4). This strong relationship is confirmed by Mutlu et al. (2017) that the operation of multimodal transportation should be flexible to gain competitiveness in transportation market. The optimal operational plans increase cost efficiency, ensure convenient transportation, and enhance environmental sustainability. These, in turn, lead to competitive advantages in the market.

The best fit measurement model also reveals eight significant correlation coefficients between the Multimodal Transportation Infrastructure and Operation factors, the Multimodal Transportation Infrastructure and Multimodal Service Provider factors, the Multimodal Transportation Infrastructure and Market factors, the Operation and Multimodal Service Provider factors, the Operation and Road Constraints factors, the Multimodal Service Provider and Market factors, the Multimodal Service Provider and Road Constraints factors, and the Market and Road Constraints factors. These significant relationships are consistent with, for example, Woodburn (2003) stated that the increases in road congestion and accidents deviate the transport service providers from using truck mode to multi-modes of transportation. Goh et al. (2008), added that an effective documentation system is needed for an effective modal shift operation.

The best fit measurement model is further performed with the structural model test to examine directions of total nine relationships found in the best fit measurement model.

6.4.2 Structural Model Test

In the structural model, directions of nine relationships among five key factors are tested. The direction of relationship is represented by one-headed arrow, signifying direct causal effect from one factor to another factor. In this study, directions of nine

relationships are hypothesized based on a number of transportation-related literatures (see Table 6.5). Butta and Abegaz (2016), for example, stated that skilled employees (an item in the Operation factor) are needed in multimodal transportation to gain competitiveness in the market (an item in the Market factor). This shows the direction of relationship from the Operation factor to Market factor. Moreover, market competitiveness from cost reduction and emerging competitors and customers (items in the Market factor) urges improvements in multimodal transportation system and infrastructures, such as CY capacity and advanced design of multimodal transportation vehicles and equipments (items in the Multimodal Transportation Infrastructure factor) (Islam et al., 2016). This represents the direction of relationship from the Market factor to Multimodal Transportation Infrastructure factor.

Table 6.5 Hypothesized Directions of Nine Relationships among Five Key Multimodal Transportation Efficiency Factors

Hypothesized Direction		Description	Reference
From	To		
Multimodal Transportation	Multimodal Service Provider	Improvement in CY or port capacity may attract more multimodal service providers in the market.	(Butta & Abegaz, 2016; Goh et al., 2008; Roberts, 2012)
Operation	Multimodal Transportation	Applications of information technology and employee's quality management are needed to ensure the efficiency and effectiveness of multimodal transportation.	(Bui, 2011; Goh et al., 2008; Mutlu et al., 2017)
Operation	Market	Skilled employees and updated information technology usage are crucial in enhancing market competitiveness.	(Butta & Abegaz, 2016; Wallenburg & Lukassen, 2011)

Hypothesized Direction		Description	Reference
From	To		
Multimodal Service Provider	Operation	When the transport service providers initiate the use of multimodal transportation, the development in documentation process is needed to harmonize the modal shift operations.	(Goh et al., 2008; Mutlu et al., 2017)
Multimodal Service Provider	Market	Long-term relationship with transport service providers helps company in reducing logistics costs, thus, increasing companies' competitiveness.	(Butta & Abegaz, 2016; Stojanovića & Aas, 2015)
Market	Multimodal Transportation	An increase in market competitiveness attracts more investment on multimodal transportation infrastructure development.	(APEC Policy Support Unit, 2010; Islam et al., 2016)
Road Constraints	Operation	Road accident statistics lead to the use of tracking system to improve safety of operations.	(Al-Baimani & Al-Din, 2015; Marell & Westin, 1999; Tiwari et al., 2015)
Road Constraints	Multimodal Service Provider	Partners in the supply chain switch to multimodal transportation when changes, such as increase in road haulage tax, road congestion, and road accident statistics occur.	(Chen et al., 2019; Goh et al., 2008; Timaboot & Suthikarnnaruna i, 2017;

Hypothesized Direction		Description	Reference
From	To		
			Woodburn, 2003)
Road Constraints	Market	Less use of road transportation enhances company's green image.	(Chen et al., 2019; UNCTAD, 2003)

The conceptual structural model with nine hypothesized directions of relationships is analysed, and the fit indices results are as shown in Table 6.3. It is found that four path coefficients, from the Operation to Multimodal Transportation Infrastructure, from the Multimodal Service Provider to Market, from the Road Constraints to Operation, and from the Road Constraints to Market factors should be removed, as they have insignificant relationships (path coefficients ranging from 0.07 to 0.20).

After the adjustment, the structural model is re-analysed and the best fit structural model is achieved (see Figure 6.5). The best fit structural model shows five and four significant direct and indirect relationships among five key factors influencing multimodal transportation efficiency of agricultural products in Thailand, respectively (see Table 6.6).

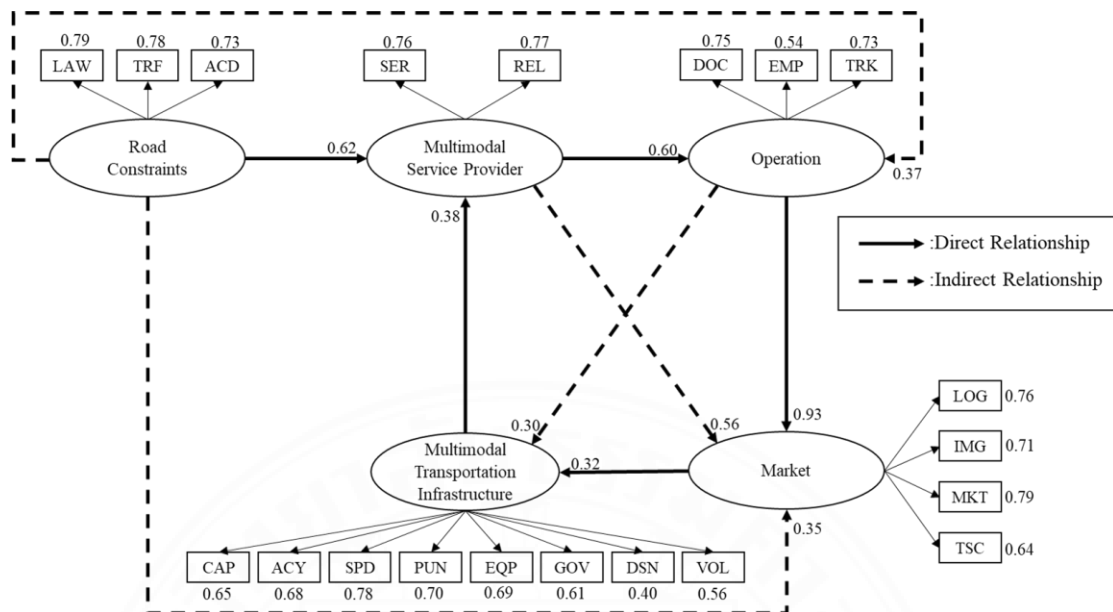


Figure 6.5 Best Fit Structural Model

Table 6.6 Path Coefficients of Direct and Indirect Relationships among Key Multimodal Transportation Efficiency Factors

Relationship	Direct Relationship	Indirect Relationship
Operation → Market	0.93	-
Road Constraints → Multimodal Service Provider	0.62	-
Multimodal Service Provider → Operation	0.60	-
Multimodal Service Provider → Market	-	$0.60 \times 0.93 = 0.56$
Multimodal Transportation Infrastructure → Multimodal Service Provider	0.38	-
Road Constraints → Operation	-	$0.62 \times 0.60 = 0.37$
Road Constraints → Market	-	$0.62 \times 0.60 \times 0.93 = 0.35$
Market → Multimodal Transportation Infrastructure	0.32	-
Operation → Multimodal Transportation Infrastructure	-	$0.93 \times 0.32 = 0.30$

The best fit structural model shows that the Operation factor has a strong direct influence on the Market factor with the path coefficient of 0.93, whereas direct relationships between the Road Constraints and Multimodal Service Provider factors, the Multimodal Service Provider and Operation factors, the Multimodal Transportation Infrastructure and Multimodal Service Provider factors, and the Market and Multimodal Transportation Infrastructure factors are found significant, with path coefficients ranging from 0.32 to 0.62.

Despite their insignificant direct relationships, the indirect relationships from the Operation to Multimodal Transportation Infrastructure factors, from the Multimodal Service Provider to Market factors, from the Road Constraints to Operation factors, and from the Road Constraints to Market factors are found significant. The Operation factor, for example, influences the Multimodal Transportation Infrastructure factor through the Market factor. An effective tracking system used in multimodal transportation (an item in the Operation factor), for example, helps reduce logistics cost (an item in the Market factor), resulting in more supporting policies from the government and related sectors (an item in the Multimodal Transportation Infrastructure factor) (Kritchanchai & Chanpuypetch, 2009; Choi et al., 2014; Butta & Abegaz, 2016).

6.5 SEM Results Discussion

The results reveal a strong direct relationship between the Operation and Market factors. This is confirmed by Woodburn (2003) that an increase in road transportation issues, such as air pollution, traffic congestion, and energy consumption grow preferences of transport service providers on multimodal transportation. Direct relationships between the Road Constraints and Multimodal Service Provider factors, the Multimodal Service Provider and Operation factors, the Multimodal Transportation Infrastructure and Multimodal Service Provider factors, and the Market and Multimodal Transportation Infrastructure factors are also found significant. These are consistent with Chao (2011) that the transportation facilitation enhancement, by reducing documentation processes, helps reduce documentation cost and promote the companies' competitiveness. Ngamvichaikit (2017) added that apart from transportation facilitation enhancement, company must support the competency

development to ensure the adequacy of knowledge, skill, and attitude of employees to enhance job performance and reduce logistics and transshipment costs. Government may also support the multimodal transportation by improving multimodal transportation infrastructures, such as vehicle capacity and capability, transshipment facilities, and multimodal accessibility to minimize resources and modal shift processes. This is consistent with the comments of the respondents requiring government to improve multimodal infrastructure to support the practical use of multimodal transportation. The government policies supporting multimodal transportation will, in turn, stimulate the transport service providers in using multimodal transportation in the long-term through continuous improvement processes.

Interestingly, the Multimodal Service Provider factor is found having no direct relationship with the Market factor. However, the significant indirect relationship between the Multimodal Service Provider factor and the Market factor is found with path coefficients of 0.56, through the implementation of the Operation factor. When the transport service providers take their interests in multimodal transportation, the operations in multimodal transportation service are improved to fully utilize company resources and maximize efficiency. These lead to reduction in logistics costs and enhancement of company's green image, thus, increasing companies' ability to compete in global market (Wallenburg & Lukassen, 2011). Road constraints are found a major cause of modal shift, as it directly and indirectly affects the operations and market of multimodal transportation. The improvement of multimodal transportation infrastructure, in terms of capacity, delivery time, and transshipment equipment will also indirectly stimulate the multimodal transportation market through the competitiveness among transport service providers that try to improve their operations to reduce logistics and transportation costs. These represent indirect relationships among the Road Constraints, Operation, Market, and Multimodal Transportation Infrastructure factors.

6.6 Managerial Implications

In the engineering management perspectives, the selection of combination of transportation modes can be performed systematically utilizing the study results. Each combination of transportation modes, for example, truck-train, truck-ship, and truck-

train-ship can be assessed and evaluated based on weights (or factor loadings) achieved from the best fit structural model (see Table 6.7). This will provide the numerical results that are easy to understand and interpret. This assessment helps engineering managers in deciding on transportation modes and routes selection in order to design optimal transportation strategies for a highly volatile market to reduce logistics costs and enhance the market competitiveness. Agricultural production companies in Thailand, regardless of size, may apply the study results in making decisions regarding the multimodal transportation.

Table 6.7 Transportation Mode Combination Selection based on the Study Results

Factor and Item	Weight (x)	Level (y)					Score (x*y)
		1	2	3	4	5	
Road Constraints Factor							
Truck Law enforcement	0.79						
Road traffic	0.78						
Road Safety (Accident Occurrence)	0.73						
Total Score of Road Constraints Factor							
Multimodal Service Provider Factor							
Relationship between Company and Transport Service Provider	0.77						
Adequacy of Multimodal Transportation Service Provider	0.76						
Total Score of Multimodal Service Provider Factor							
Operation Factor							
Documentation Processes	0.75						
Tracking System	0.73						
Skilled Employees	0.54						
Total Score of Operation Factor							
Market Factor							
Company's Market Competitiveness	0.79						

Factor and Item	Weight (x)	Level (y)					Score (x*y)
		1	2	3	4	5	
Logistic Costs	0.76						
Company's Green Image	0.71						
Transshipment Costs	0.64						
Total Score of Market Factor							
Multimodal Transportation Infrastructure Factor							
Delivery Speed	0.78						
Transportation Punctuality	0.70						
Transshipment Equipment	0.69						
CY or Port Accessibility	0.68						
CY or Port Capacity	0.65						
Government Supporting Policy	0.61						
Volume Flexibility	0.56						
Vehicle Design	0.40						
Total Score of Multimodal Transportation Infrastructure Factor							
Influence	Weight (x)	Equation					Score
Road Constraints → Multimodal Service Provider	0.62	Score = (x)*(Total Score of Road Constraints Factor)					
Road Constraints → Operation	0.37	Score = (x)*(Total Score of Road Constraints Factor)					
Road Constraints → Market	0.35	Score = (x)*(Total Score of Road Constraints Factor)					
Multimodal Service Provider → Operation	0.60	Score = (x)*(Total Score of Multimodal Service Provider Factor)					

Factor and Item	Weight (x)	Level (y)					Score (x*y)
		1	2	3	4	5	
Multimodal Service Provider → Market	0.56	Score = (x)*(Total Score of Multimodal Service Provider Factor)					
Operation → Market	0.93	Score = (x)*(Total Score of Operation Factor)					
Operation → Multimodal Transportation Infrastructure	0.30	Score = (x)*(Total Score of Operation Factor)					
Market → Multimodal Transportation Infrastructure	0.32	Score = (x)*(Total Score of Market Factor)					
Multimodal Transportation Infrastructure → Multimodal Service Provider	0.38	Score = (x)*(Total Score of Multimodal Transportation Infrastructure Factor)					
Total Influence Score							
Final Score (Total Score of Factors + Total Influence Score)							

CHAPTER 7

SYSTEM DYNAMICS MODEL DEVELOPMENT OF BLOCK RUBBER TRANSPORTATION IN THAILAND

The SEM analysis results reveal complex direct and indirect relationships among key multimodal transportation factors. These relationships reinforce each other, creating dynamic relationships that are changed through time. To examine complex and dynamic relationships among key multimodal transportation factors, the SD model is developed in this chapter. Complex relationships among key multimodal transportation factors are examined through equations and developed in the SD model. The analysis results are achieved through simulation results in the end of this chapter.

7.1 SD Model Development Concept

SD modeling is invented during the mid-1950s at the Massachusetts Institute of Technology (MIT) by Professor Jay W. Forrester (Forester, 1958). SD modeling method is a policy modeling based on the foundations of decision-making, feedback mechanism, and simulation. Decision-making focuses on how actions are to be executed by decision-makers. Feedback deals with the way information generated affects decision-making in current and future. Simulation provides decision-makers with a tool to work in a virtual environment where they can view and analyze the effects of their decisions in the future (Monga, 2001).

This study focuses on the design of an SD model of block rubber transportation in Thailand from production areas in the south and northeast regions to the export point i.e., Laem Chabang port in the east of Thailand. The transportation problems generally involve a number of factors, decision variables, and constraints which are generally large scale and complex. Therefore, an appropriate mathematical model simulation method is essential to contribute the effective model design and formulation, which will address the current issues and provide the future recommendations for both government and business sectors.

The simulation model may be performed with various methods, such as optimization model and SD modeling to establish appropriate strategies for long-term

multimodal transportation development. However, SD modeling is increasingly applied in a number of studies, as it helps explore the real drivers of future demand and explain how to change user perceptions and behavior of the systems. This study applies the SD modeling method to simulate the model by incorporating the government policies, demand, supply, economic factors, and transportation – related factors of block rubber in current and potential modes to analyze the total transportation costs and introduce the alternative routes with various modes of transportation for the next 20 years. Moreover, SEM results are applied in the SD model to convert qualitative data into quantitative input, such as the use of the correlations among the Road Constraints factor to other factors as important weights of using multimodal transportation instead of road-only transportation. The correlations of key multimodal transportation factors are also used as input in the SD model to reflect the influences the factors have on each other.

The objectives of SD model development are summarized into two perspectives:

- 1) Business Sector Perspective: SD model helps transportation managers in decision-making of transportation modes and routes selection in order to design optimal transportation strategies for a highly volatile market to reduce logistics costs and enhance the market competitiveness. Agricultural production companies and transport service providers in Thailand, regardless of size, may apply the study results in making decisions regarding the multimodal transportation. Thus, companies can enhance their market competitiveness by reducing their logistics costs, thus lowering the total costs of goods and services.
- 2) Government Sector Perspective: SD model can lead to the development of effective policies to achieve sustainable transportation.

Greater market competitiveness of companies gives rise to national's industrial competitiveness on a global scale, through effective logistics and transportation in Thailand.

7.2 Steps of SD Model Development

According to Azhaginiyal and Umadevi (2014), SD modeling consists of four basic elements, as shown in Figure 7.1.

- Stocks: They are used to represent anything that accumulates.
- Flows: They represent activities that increase and decrease stocks.
- Connectors: They are used to establish the relationships among variables in the model.
- Converters: They transform input to output. They can be the variables that affect the system behavior.

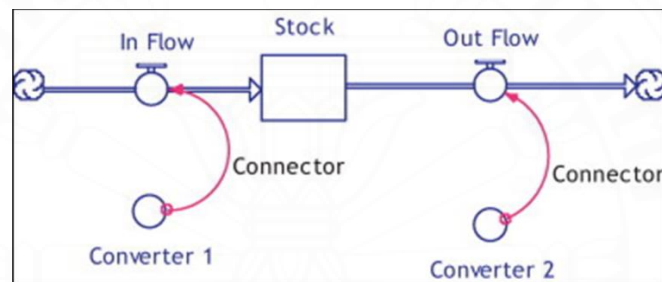


Figure 7.1 SD Modeling Basic Elements

Figure 7.2 shows an example of SD model of cashflow in savings account. Withdrawal, which is affected by amount of debt, drains money from the account. The increasing amount of salary, on the other hand, defines the deposit amount, filling up the amount of cash in the savings account again.

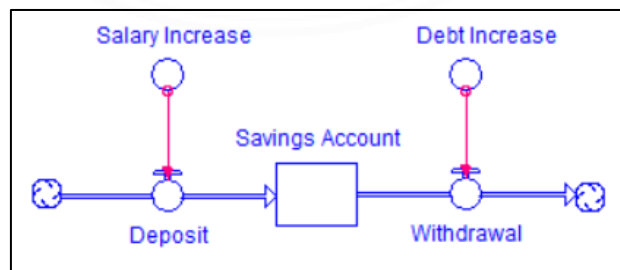


Figure 7.2 SD Modeling Example

In SD model development, the first phase is to recognize and define problems that lead to identification of problem boundary and model purpose. The system

conceptualization is then conducted to identify key factors that affect the system. Next, SD model is constructed to describe behaviors of key factors. When the SD model development is completed, the sensitivity analysis is performed to ensure that the uncertainties will not significantly affect the overall behavior of the model. If the sensitivity analysis shows that the SD model is significantly affected by the uncertainties, model adjustment must be performed until the model replicates system behaviour. Finally, the policy analysis is performed by examining the available options that the government or company may implement to achieve the best solutions (Azhaginiyal & Umadevi, 2014). Steps of the SD model development are summarized in Figure 7.3.

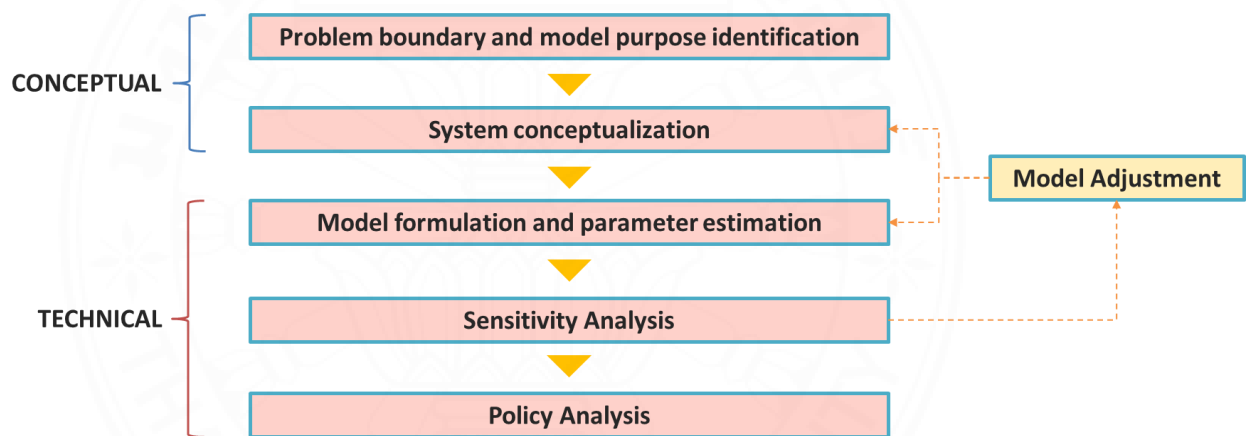


Figure 7.3 Steps of SD Model Development
(Adjusted from Azhaginiyal & Umadevi, 2014)

7.3 Multimodal Transportation Routes in SD Model of Block Rubber Transportation in Thailand

This study considers multimodal transportation routes of block rubber from companies in Surat Thani and Udon Thani provinces to Laem Chabang port. There are two multimodal transportation routes in southern region and one multimodal transportation route in northeastern region (see Figures 7.4 and 7.5). In southern region, Surat Thani is considered as a hub of block rubber transportation, as it is the biggest area of block rubber production. Multimodal transportation from Surat Thani to Laem Chabang port could be performed through either Ban Thung Pho Junction Railway

Station and Panja and N P Marine ports. In northeastern region, on the other hand, Udon Thani is considered as a hub of block rubber transportation as the government has developed the double-track_railway project that covers the area of Udonthani province at Nong Ta Kai Railway Station that connects to Laem Chabang port.

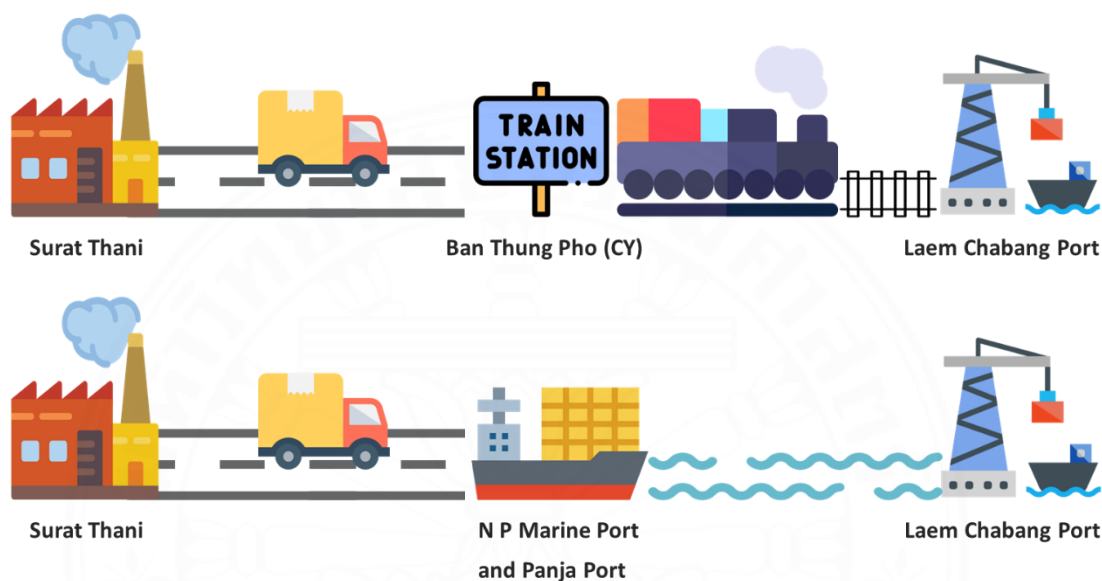


Figure 7.4 Multimodal Transportation Routes in Southern Region



Figure 7.5 Multimodal Transportation Routes in Northeastern Region

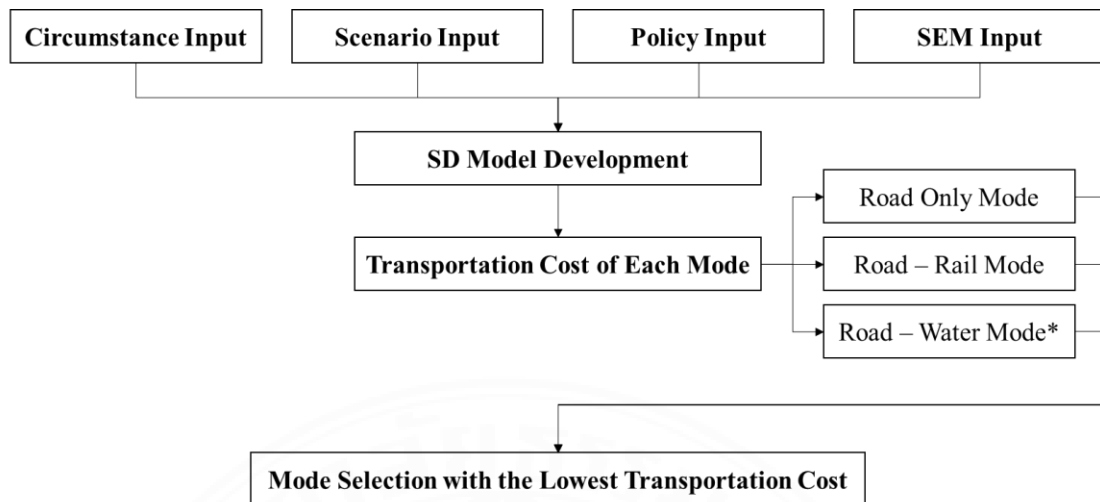
7.4 Data Input for SD Model Development

SD modeling is capable of analyzing policies and assessing their impacts over time (Pfaffenbichler et al., 2010). In this study, government policies supporting multimodal transportation in Thailand will be put in the SD model together with demand and supply of block rubber, block rubber production capacity, and transportation costs and capacity of each transportation mode. The model includes four

main types of data input, including circumstance input, scenario input, policy input, and SEM input.

- The circumstance inputs are the baseline data of block rubber production and transportation in Thailand, for example, current fuel prices, block rubber demand and supply, CYs capacity, and ports capacity. The data provides transportation cost resulting from the current condition and situation which will be a foundation for projecting the analysis results for the next 20 years.
- The scenario inputs are the trends of the circumstance inputs which are defined by the historical data, for example, the increasing rates of fuel prices and block rubber demand and supply.
- The policy inputs are the government policies in supporting multimodal transportation, for example, the double-track railway project that aims to increase efficiency of the rail transportation, which will increase the train capacity and train rounds per day. These will enable the assessment of the impacts of policies over time.
- SEM inputs are the correlation results from SEM model that will be applied in the SD model. The correlations of the Road Constraints factor to other factors will be used as an incentive of using multimodal transportation instead of road-only transportation. The correlations between the Road Constraints and Market factors and between the Multimodal Transportation Infrastructure and Market factors will be used as reductions in transportation costs of multimodal transportation.

The input data are used to simulate the SD model to calculate the transportation cost of each mode for the next 20 years. Transportation mode that provides the lowest transportation cost is selected and summarized for each year (see Figure 7.6). The results provide guidelines to block rubber companies to decide on modes of transportation. Moreover, the results help the government sector to analyze and adjust the government plans and policies of multimodal transportation over the next 20 years to maximize the multimodal transportation efficiency in Thailand in the long-term.



*Road – water mode is only applicable in the southern region of Thailand.

Figure 7.6 Structure of the SD Model Development

7.4.1 The Circumstance Inputs

The circumstance inputs are the baseline data of block rubber production and transportation in Thailand which are used for current logistics and transportation costs calculation and analyzed with other inputs to predict the long-term logistics and transportation costs and select the most suitable transportation modes for the next 20 years. In this study, the circumstance inputs are based on data in year 2019 which is used as a beginning year of the SD model. The circumstance inputs consist of rubber production capacity (supply), amount of block rubber exported at Laem Chabang port (demand), Laem Chabang port capacity, CYs and trains capacity, inland ports and ships capacity, and fuel prices.

- Rubber production capacity (supply): According to Office of Agricultural Economics (2019), Thailand has rubber cultivated areas of 31,281 square kilometers, which contribute 140,000 kilograms per square kilometer. Thus, the initial rubber production capacity is 4,379,340,000 kilograms or 4,379,340 tons in 2019.
- Amount of block rubber exported at Laem Chabang port (demand): Thai rubbers are mainly exported to other countries through Laem Chabang port. The major importer of Thai natural rubber is an automobile tire production

industry in China, which is the world's largest consumer of natural rubbers (Chanchaichujit, 2014; Doner & Abonyi, 2013). Based on 5-year historical data from 2015 to 2019, 81.22% of rubbers produced in Thailand are exported, in which 39.40% of exported rubbers are block rubbers (Krungsri Research, 2020). Laem Chabang port is served as a major export point for block rubber, taking 34% of the exported amount (Thai Marine Department, 2019). According to Ministry of Transport (2019), 73% and 27% of block rubber exported amount are from southern and northeastern regions, respectively.

- **Laem Chabang port capacity:** Laem Chabang port has been constructed since 1986 (Port Authority of Thailand, 2020). Currently, it has two phases: phase I has started the operation in 1991 with the capacity of 4.3 million twenty – foot equivalent units (TEUs), while phase II has started the operation in 2000 with the capacity of 6.8 million TEUs. Thus, the current Laem Chabang port capacity can support total imports and exports for 11.1 million twenty – foot equivalent units (TEUs). It is noted that TEU is a standard container size that can be loaded and sealed onto ships, railroad cars, trucks, and planes with the dimensions of 20 ft long, 8 ft wide, and 9 ft high (Merk, 2018).
- **CYs and trains capacity:** According to Office of Transport and Traffic Policy and Planning (2021), the capacity of Ban Thung Pho Junction railway station in Surat Thani province is 738,000 tons per year in 2019 and will be able to serve 998,900 tons per year when the double-track railway project is completed in 2022. In the northeastern region, the capacity of Nong Takai railway station in Udon Thani province is 1 million tons per year in 2019 and will be able to serve 2.13 million tons per year when the double-track railway project is completed in 2022. Currently, the rail transportation of block rubber from Ban Thung Pho Junction and Nong Takai railway stations to Laem Chabang Port operates two rounds per day, with the capacity of 46 TEUs and 30 TEUs per round, respectively.

- Inland ports and ships capacity: According to Office of Transport and Traffic Policy and Planning (2021), the water transportation of block rubber from local ports in Suratthani province to Laem Chabang port operates three rounds per day, with the capacity of 192 TEUs per round.
- Fuel prices: In this study, the NGV, diesel, and fuel oil are used as fuel sources for road, rail, and water transportations, respectively (Thailand Board of Investment, 2019). The current fuel prices are as shown in Table 7.1 (Office of the National Economic and Social Development Board, 2019).

Table 7.1 Fuel Prices of Road, Rail, and Water Transportation

Transportation Mode	Fuel Type	Current Price (Baht/Litre)
Road	NGV	12.50
Rail	Diesel	28.79
Water	Fuel Oil	22.19

Note: The data are derived in 2019

7.4.2 The Scenario Inputs

The scenario inputs are the trends of the circumstance inputs projecting to the future. These inputs consider the current and historical data to predict average increasing rates of the circumstance inputs, which help predict the effects of future changes in total costs. They are also analyzed with other inputs to predict the long-term logistics and transportation costs and select the most suitable transportation modes for the next 20 years. The scenario inputs consist of the increasing rates of rubber production capacity, amount of block rubber exported at Laem Chabang port, and fuel prices.

- Increasing rate of rubber production capacity: According to Office of Agricultural Economics (2019), the 5-year historical data of rubber production capacity in Thailand shows an average increasing rate of 3.80% per year. However, with the limited rubber growing area of 32,178.17 square

kilometers and the maximum yield of 155,625 kilograms per square kilometer, the maximum bound of rubber production capacity is 5,007,727,706.25 kilograms or approximately 5,007,727 tons.

- Increasing rate of block rubber exported at Laem Chabang port: The most important export market of Thai block rubber is an automotive industry in China. Additionally, China has imposed a policy to stimulate domestic automobile market, leading to the rise in block rubber demand. This leads to an average increasing rate of block rubber export of 3.96% per year, which results in an increasing rate of block rubber exported at Laem Chabang port of 5.70% per year (Port Authority of Thailand, 2020). However, with the limited capacity of the port, the maximum amount of block rubber that can be exported through Laem Chabang port is 2 million TEUs per year.
- Increasing rate of fuel prices: According to Gohari et al. (2018), the most important criteria in transportation mode selection is the transportation operating cost, which is significantly affected by fuel prices. The current fuel prices, increasing rates, and maximum fuel prices are as shown in Table 7.2 (Office of the National Economic and Social Development Board, 2019).

Table 7.2 Increasing Rates of Fuel Prices of Road, Rail, and Water Transportation (Office of the National Economic and Social Development Board, 2019)

Transportation Mode	Fuel Type	Current Price (Baht/litre)	Increasing Rate per Year (%)	Maximum Price (Baht/litre)
Road	NGV	12.50	6.22	19.85
Rail	Diesel	28.79	4.55	30
Water	Fuel Oil	22.19	3.10	23

Note: The data are derived in 2019

7.4.3 The Policy Inputs

The policy inputs consider multimodal transportation development projects from the government. They enable the assessment of impacts of policies over time. They consider future data according to plans and policies, thus helping improve the effectiveness of circumstance inputs. They are also analyzed with other inputs to predict the long-term logistics and transportation costs, and select the most suitable transportation modes for the next 20 years. The policy inputs consist of the expansion of Laem Chabang port and the double-track railway project to increase efficiency of the rail transportation. This will increase the train capacity and train rounds per day.

- The expansion of Laem Chabang port: To serve the increasing throughputs in the future and strengthen the port's role as a gateway port of the Mekong sub-region, Laem Chabang port phase III has been constructed and it will be operated in 2022. It is expected that this new phase supports the capacity of 7 million TEUs, reaching the total capacity of phases I, II, and III of 18.1 TEUs of import and export products. According to Port Authority of Thailand (2020), 11.10% of port capacity is used for agricultural products, thus making the maximum capacity of 2 million TEUs of exported block rubber in this study.
- The double-track railway project: Currently, the rail transportation of block rubber from Ban Thung Pho Junction and Nong Takai railway stations to Laem Chabang Port operates two rounds per day, with the capacity of 46 TEUs and 30 TEUs per round, respectively. When the double-track railway project is fully operated in 2022, it will be able to operate six and four rounds per day, with the capacity of 60 TEUs per round, respectively (Office of Transport and Traffic Policy and Planning, 2021).

7.4.4 The SEM Inputs

The SEM inputs are the correlation results from SEM model used in the SD model development. The correlations of the Road Constraints factor to other factors are used as an incentive of modal shift. The correlations between the Road Constraints and Market factors and between the Multimodal Transportation Infrastructure and Market

factors will be used as reductions in transportation costs of multimodal transportation. The coefficients of Road Constraints and Multimodal Transportation Infrastructure factors (see Figure 7.7) are used as an incentive of using multimodal transportation instead of road-only transportation.

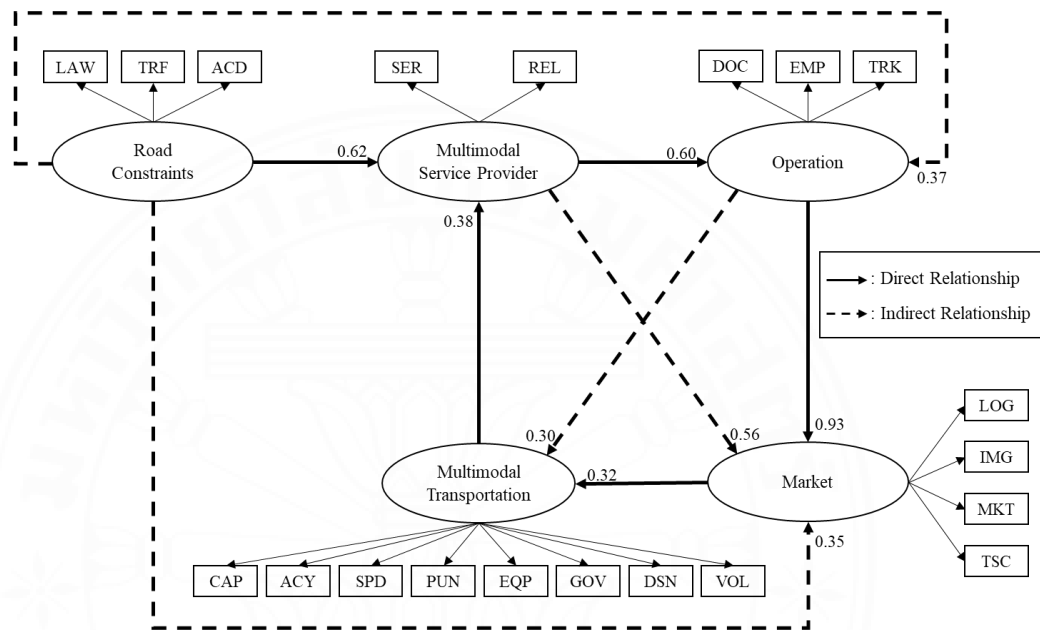


Figure 7.7 SEM Results

- The total coefficients from the Road Constraints to Market factors of $(0.37 \times 0.93) + (0.62 \times 0.60 \times 0.93) + (0.62 \times 0.56) + 0.35 = 1.39$, is applied in multimodal transportation usage, as reflected by road accident statistics, road accident increasing rate, and road-only mode logistics cost.
- The total coefficients from the Multimodal Transportation Infrastructure and Market factors of $(0.38 \times 0.56) + (0.38 \times 0.60 \times 0.93) = 0.42$, is applied in multimodal transportation usage, as reflected by multimodal transportation usage statistics, increasing rate of multimodal transportation usage, and logistics cost of multimodal transportation.

7.5 System Dynamics Model Development of Block Rubber Transportation in Thailand

7.5.1 Key Concepts of the Model Development

Factors in transportation system are highly interrelated and influenced each other. SD modeling is designed to handle this complexity in an intuitively understandable way (Pfaffenbichler et al., 2010). This study examines the feasibility of multimodal transportation of block rubber in the next 20 years. Government and business sectors may use the study results to plan for the improvement of multimodal transportation infrastructure to support multimodal transportation utilization and enhance the country's market competitiveness on a global scale in the long-term.

In this study, block rubber production capacity, number of train rounds, train stations' capacity, number of ship rounds, and ports' capacity are identified as stocks, whereas government plans and transportation conditions represent flows in the SD model. The stocks and flows influence each other, creating feedback and causal loops among them. Both qualitative and quantitative inputs are used in the stocks and flows development. Steps of block rubber transportation from southern and northeastern regions to Laem Chabang port are as shown in Figure 7.8.

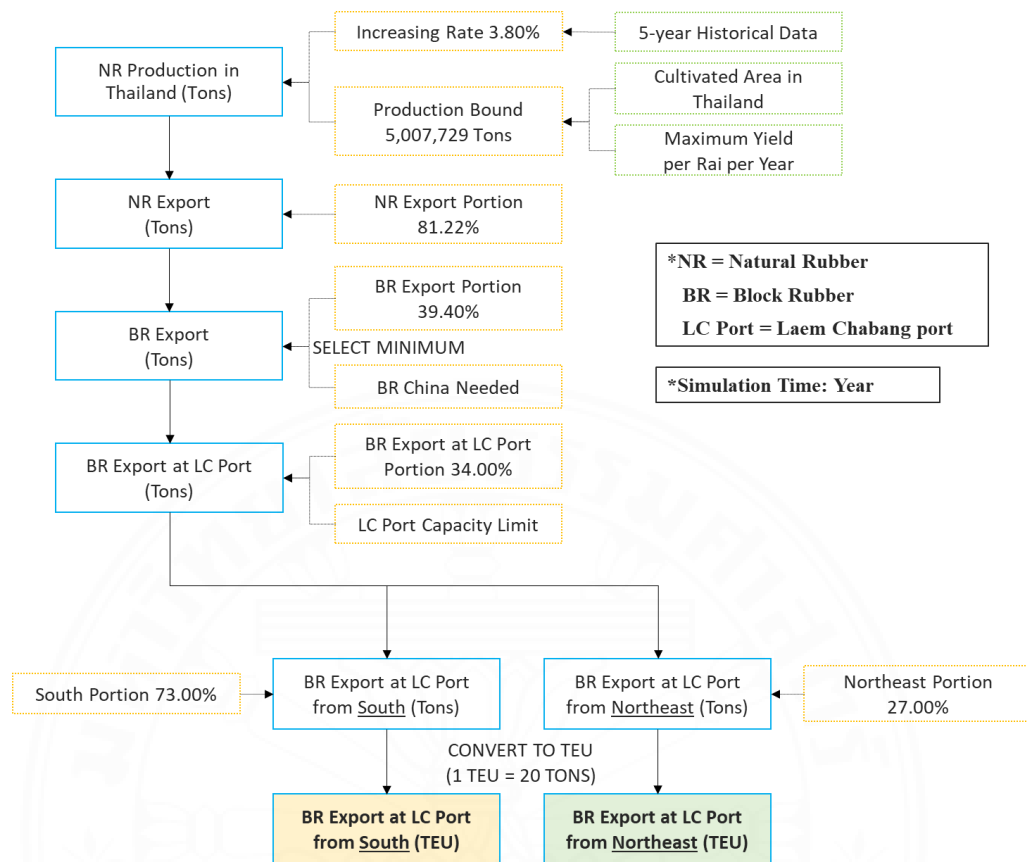


Figure 7.8 Steps of Block Rubber Export from Southern and Northeastern Regions to Laem Chabang Port

Figures 7.9 and 7.10 detail the first multimode of transportation to be used with block rubber transportation from the southern and northeastern regions to Laem Chabang port. To select the multimode of transportation from the southern region to Laem Chabang port, for example, combinations of truck and train, truck and ship, and truck only modes are considered (see Figure 7.9). In each combination, costs related to logistics costs are summed, and the combination with the lowest logistics costs is selected. For instance, truck-train mode includes truck NGV cost from company to train station, and the diesel cost for train transportation to Laem Chabang port. These costs are calculated based on truck-train portion used in this multimode combination which is also adjusted by the weights achieved from the SEM analysis. Apart from that, road accident cost from trucks used in the transportation is added to achieve the total logistics of this multimode combination. Truck-ship mode, on the other hand, considers truck NGV cost from company to the port, and fuel cost for ship transportation to Laem

Chabang port. Truck-ship mode also considers road accident cost in a similar way to truck-train mode.

Two transportation modes, including truck-train and truck-only modes are possible for the transportation from northeastern region to Laem Chabang port as there is no access to the sea (see Figure 7.10).

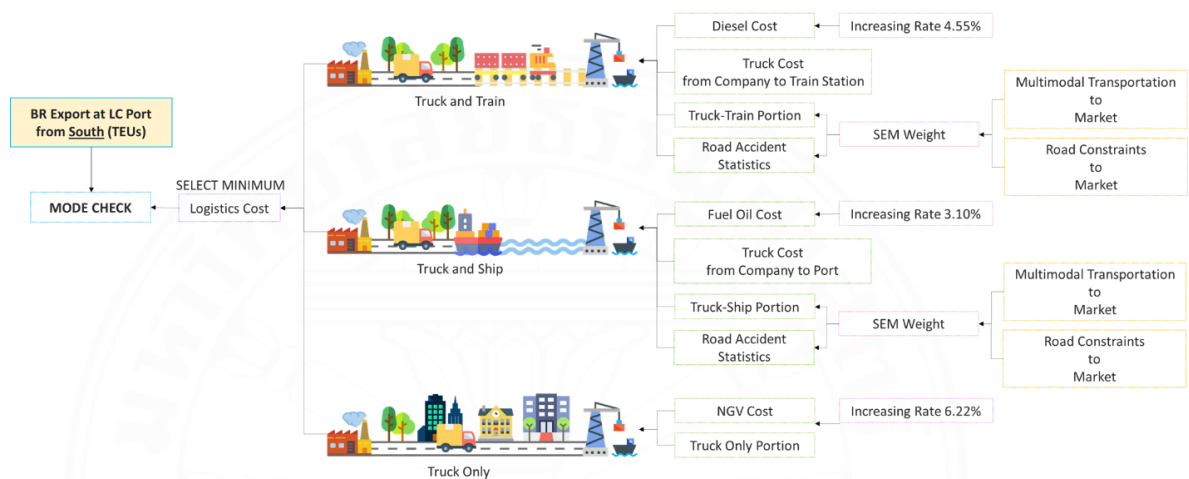


Figure 7.9 First Multimode Selection of Block Rubber Transportation from Southern Region to Laem Chabang Port

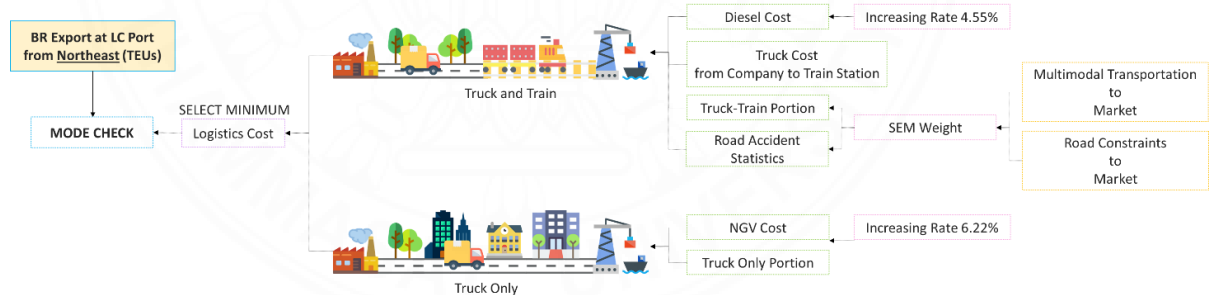


Figure 7.10 First Multimode Selection of Block Rubber Transportation from Northeastern Region to Laem Chabang Port

The first multimode of transportation is selected based on the lowest logistics cost. However, if this first multimode cannot satisfy the transport capacity of block rubber or cannot achieve full capacity in each transportation need (i.e., cannot achieve 100% train or ship load, If used), then the second multimode may be selected to handle the leftover amount of block rubber to Laem Chabang port. Summary of the multimode selection processes is as shown in Figure 7.11.

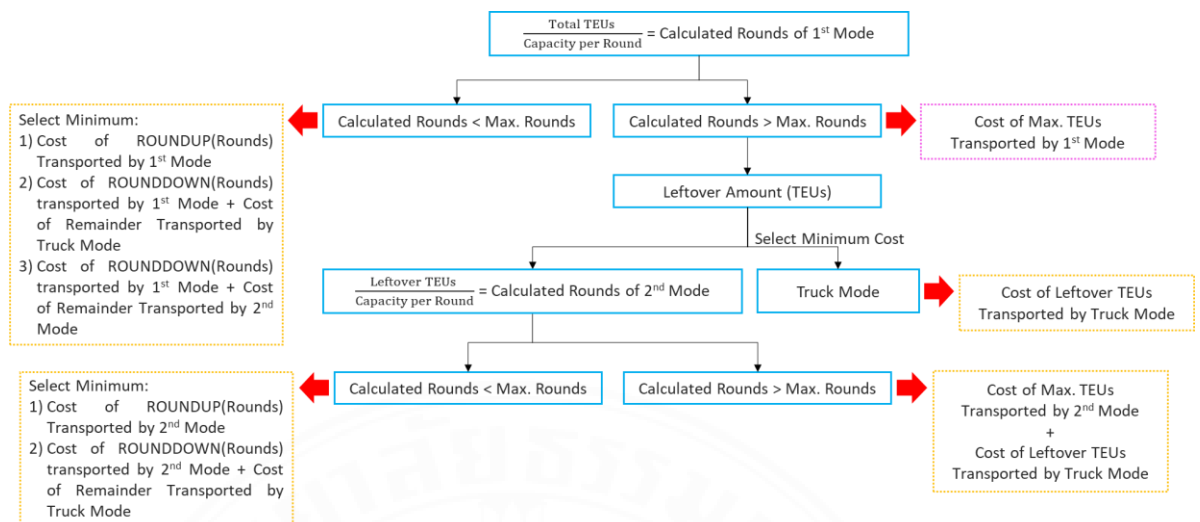


Figure 7.11 Summary of Multimode Selection Processes

Flow of multimode selection and logistics cost calculation, resulting from multimode selection, are explained in detail in Figure 7.12.

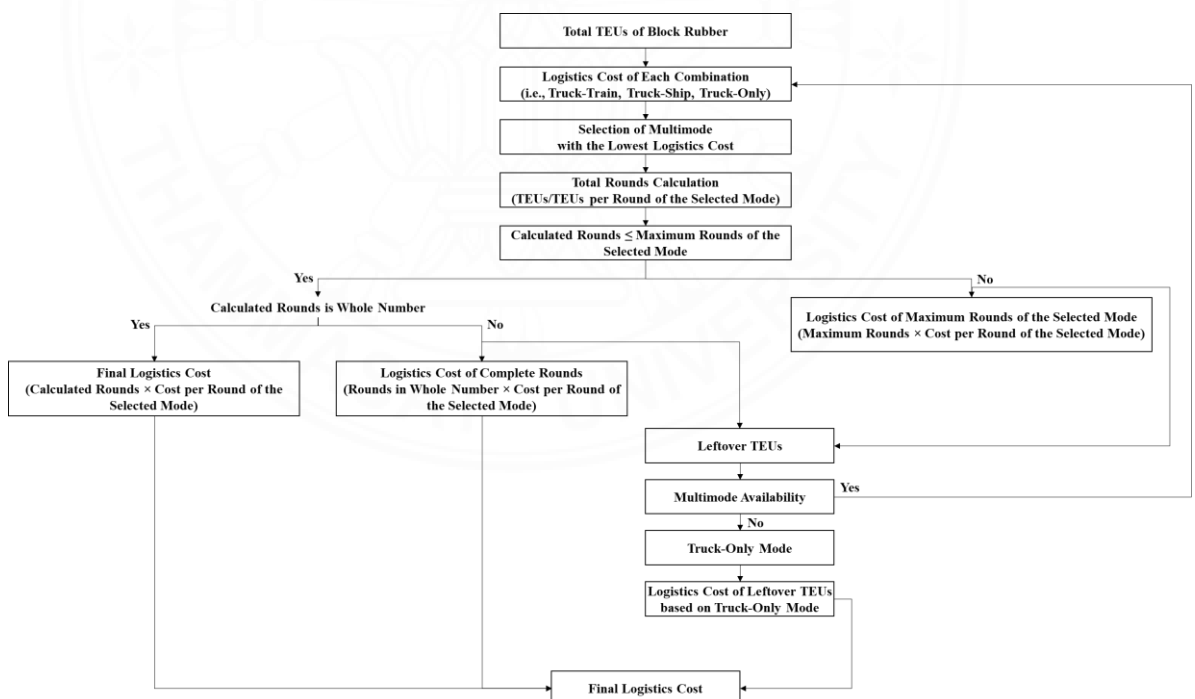


Figure 7.12 Flow of Multimode Selection and Logistics Cost Calculation

Total TEUs of block rubber are first calculated, and logistics costs of mode combinations (i.e., truck-train, truck-ship, and truck-only) are calculated to select the

multimode with the lowest logistics cost as the first selected multimode. Maximum rounds of the first selected multimode are calculated based on mode capacity and are compared with total rounds required for total block rubber transportation. If capacity of the first selected multimode is adequate (i.e., total calculated rounds is less than or equal to maximum rounds of the first selected multimode and the transportation is in complete full-load rounds), then the first selected multimode is utilized for total block rubber transportation and the final logistics cost is calculated. If there is a not-full-load round left in the transportation, then the available mode combinations (i.e., truck-train, truck-ship, and truck-only, if available) must be considered to select the best multimode with the lowest logistics cost to serve for a not-full-load amount. These processes of multimode selection continue until all block rubber is transported, and the final logistics cost is calculated by summing logistics cost incurred in all selected multimode.

In case that the calculated total rounds of block rubber transportation are higher than the maximum capacity of the first selected multimode, the first multimode is fully utilized, and the leftover TEUs are considered with the available mode combinations to select the second and so forth multimode until all block rubber is transported and the final logistics cost is calculated by summing logistics costs incurred in all selected multimode (see Figure 7.12).

7.5.2 The System Dynamics Model Development

According to Figure 7.12, SD model consists of five sections, including 1) amount of block rubber transportation, 2) multimode selection, 3) amount of block rubber served by the first selected multimode, 4) the next available multimode selection for leftover amount, and 5) final logistics cost sections (see Figure 7.13). Full SD model of multimodal transportation of block rubber is displayed in Appendix D.

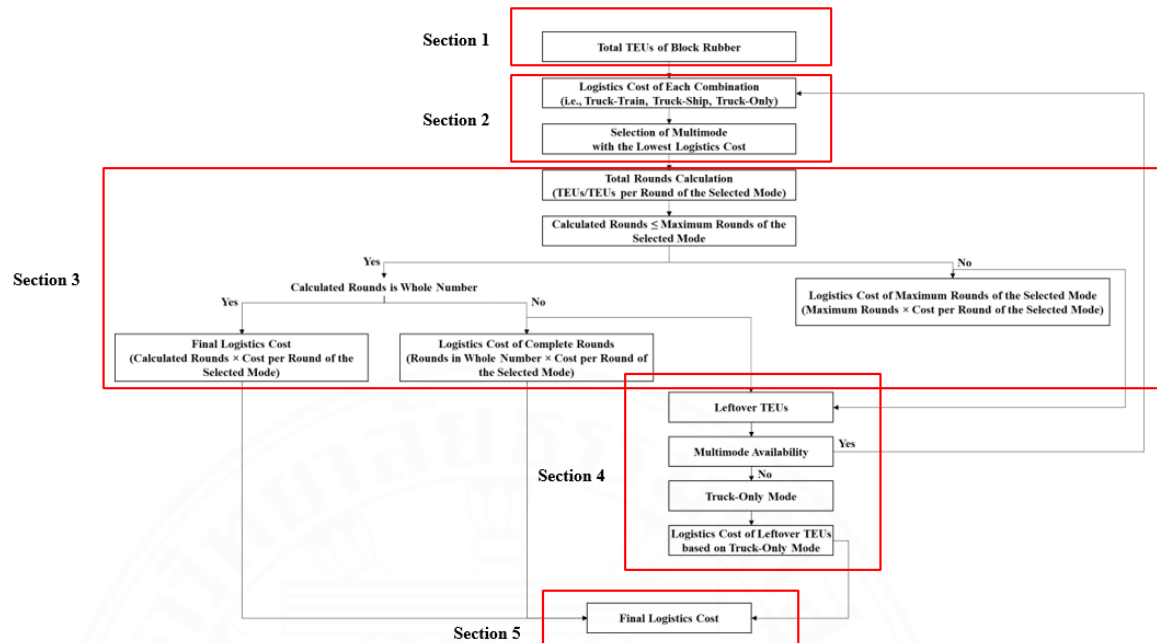


Figure 7.13 Sections of SD model of block rubber's multimodal transportation

7.5.2.1 Section 1: Amount of Block Rubber Transportation

Amount of block rubber exported at Laem Chabang port per year is calculated from natural rubber production capacity, portion of natural rubber exported, portion of block rubber exported, and portion of block rubber exported at Laem Chabang port (see Figure 7.14). Natural rubber production capacity is calculated from an initial amount of natural rubber production capacity in year 2019 of 4.86 million tons with an increasing rate of 3.8% (The Thai Rubber Association, 2022). This production capacity is limited by the rubber growing area in the south and northeastern regions of Thailand which can produce maximum natural rubber amount of five million tons (see Equations 7.1 and 7.2) (The Thai Rubber Association, 2022).

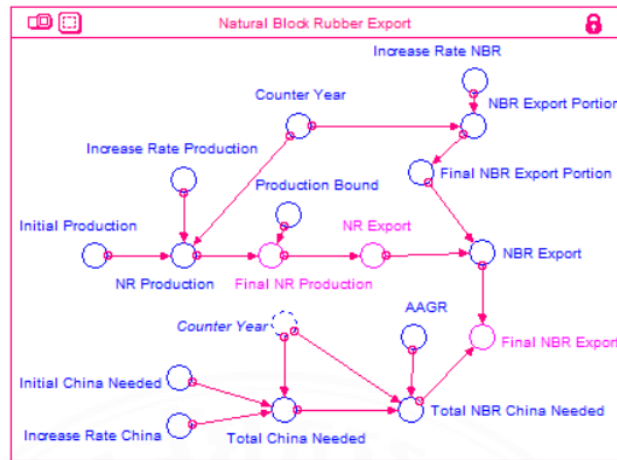


Figure 7.14 Amount of Block Rubber Transportation per Year

NR Production

$$= \text{Initial_Production} * ((1 + \text{Increase_Rate_Production}) ^ (\text{Counter_Year} - 1)) \quad (7.1)$$

Final NR Production

$$= \text{IF } (\text{NR_Production} < \text{Production_Bound}) \text{ THEN NR_Production} \\ \text{ELSE Production_Bound} \quad (7.2)$$

Where NR Production = Annual amount of natural rubber produced.

Initial_Production = Initial amount of natural rubber produced.

Increase_Rate_Production = Increasing rate of amount of natural rubber produced.

Counter_Year = Simulation year.

Final NR Production = Finalized annual amount of natural rubber produced.

Production_Bound = Maximum amount of annual amount of natural rubber produced.

Natural rubber export (NR Export) is calculated by multiplying the amount of natural rubber production capacity with the natural rubber export portion, which is 81.22% (see Equation 7.3) (The Thai Rubber Association, 2022). The amount of block rubber export (NBR Export) is then based on the portion of block rubber transported at Laem Chabang (see Equation 47.4). This “NBR Export” amount also depends on the

demand of block rubber from China, leading to the “Final NBR Export”, as shown in Equations 7.5 and 7.6.

$$\text{NR Export} = \text{Final_NR_Production} * 0.8122 \quad (7.3)$$

$$\text{NBR Export} = \text{NR_Export} * \text{Final_NBR_Export_Portion} \quad (7.4)$$

Total NBR China Needed =

$$\text{IF Total_China_Needed} * ((1+\text{AAGR}) ^ (\text{Counter_Year}-1)) < 5788000 \text{ THEN} \\ \text{Total_China_Needed} * ((1+\text{AAGR}) ^ (\text{Counter_Year}-1)) \text{ ELSE } 5788000 \quad (7.5)$$

$$\text{Final NBR Export} = \text{MIN} (\text{NBR_Export}, \text{Total_NBR_China_Needed}) \quad (7.6)$$

Where NR Export = Annual amount of natural rubber export.

NBR Export = Annual amount of block rubber export.

Final_NBR_Export_Portion = Percentage of block rubber export.

Total NBR China Nee = Annual amount of block rubber export to China.

Total_China_Needed = Annual amount of block rubber needed in China.

AAGR = Increasing rate of amount of annual amount of block rubber needed in China.

Final NBR Export = Finalized annual amount of block rubber export.

7.5.2.2 Section 2: Multimode Selection

Logistics cost of each multimode is calculated based on the “Final NBR Export” and the mode with minimum logistics cost is selected to be the first selected multimode used in the block rubber transportation (see Figure 7.15).

SEM_Reduction_2 is from the use of multimodal transportation to enhance market efficiency.

Logistics cost of truck – train mode per TEU

$$= \text{TruckTrain_Cost_per_TEU} - \text{SEM_Reduction_1} - \text{SEM_Reduction_2} \quad (7.9)$$

$$\text{SEM_Reduction_1} = 1.39 * (\text{Road_Accident_Portion}) * (1 + \text{Increasing_Rate}) ^ {(\text{Counter_Year}-1)} * (\text{Logistics_Cost_of_Truck_Only}) \quad (7.10)$$

$$\text{SEM_Reduction_2} = 0.42 * (\text{Truck-Train_Portion}) * (1 + \text{Increasing_Rate}) ^ {(\text{Counter_Year}-1)} * (\text{Logistics_Cost_of_Truck -Train}) \quad (7.11)$$

“Truck – ship cost per TEU” is, on the other hand, based on the truck cost from company to CYs and the ship cost (in kilograms) of one TEU (see Equations 7.12 and 7.13). The ship cost relies on the oil price and is limited to a maximum of Baht per kilogram based on (Office of Transport and Traffic Policy and Planning, 2021).

TruckShip_Cost_per_TEU

$$= \text{Used_Truck_Cost_from_Company_to_Port} + (\text{Ship_Cost_per_Kg} * \text{Kg_per_1_TEU}) \quad (7.12)$$

$$\text{Ship_Cost_per_Kg} = \text{MIN} (0.54 * ((1 + \text{Fuel_Oil_Increasing_Rate}) ^ {(\text{Counter_Year}-1)}), \text{Max_Ship_Cost_per_Kg}) \quad (7.13)$$

This truck – ship cost per TEU is reduced as a result of multimodal transportation usage that reduces road accidents, thus enhancing the market efficiency. This leads to the “Logistics cost of truck – ship model per TEU”, as shown in Equation 7.14.

Logistics cost of truck – ship mode per TEU

$$= \text{TruckShip_Cost_per_TEU} - \text{SEM_Reduction_1} - \text{SEM_Reduction_2} \quad (7.14)$$

“Logistics cost of truck – only mode per TEU” is based on the truck cost (in kilograms) per one TEU. The truck cost relies on the natural gas for vehicles (NGV) price and is limited to a maximum of Baht per kilogram based on (Office of Transport and Traffic Policy and Planning, 2021) (see Equations 7.15 and 7.16).

$$\text{Logistics cost of truck – only mode per TEU} = \text{Truck_Cost_per_Kg} * \text{Kg_per_1_TEU} \quad (7.15)$$

$$\text{Truck_Cost_per_Kg} = \text{MIN} (0.79 * ((1 + \text{NGV_Increasing_Rate}) ^ (\text{Counter_Year} - 1)), \text{Max_South_Truck_Only_Cost_per_Kg}) \quad (7.16)$$

“Logistics cost of truck – train mode per TEU”, “Logistics cost of truck – ship mode per TEU”, and “Logistics cost of truck – only mode per TEU” are then compared and the multimode with the lowest cost is selected to be the first multimode to be used for block rubber transportation (see Equation 7.17).

$$\begin{aligned} \text{Mode_check} = & \text{IF MIN(Used_South_TruckShip_Cost_per_TEU,} \\ & \text{Used_South_TruckTrain_Cost_per_TEU, Used_South_Truck_Only_Cost_per_TEU)} \\ & = \text{Used_South_TruckTrain_Cost_per_TEU THEN 0 ELSE IF} \\ & \text{MIN(Used_South_TruckShip_Cost_per_TEU,} \\ & \text{Used_South_TruckTrain_Cost_per_TEU, Used_South_Truck_Only_Cost_per_TEU)} \\ & = \text{Used_South_TruckShip_Cost_per_TEU THEN 1 ELSE 2} \end{aligned} \quad (7.17)$$

7.5.2.3 Section 3: Amount of Block Rubber Served by the First Selected

Multimode

After the first multimode is selected, the amount of “Final NBR Export” in TEUs is divided by the TEUs per round of the first selected mode to calculate the total TEU rounds to be transported. The amount of block rubber to be transported by the first selected mode is then calculated based on various conditions. If the calculated rounds (in whole number i.e., full rounds with no decimal round) are less than or equal the maximum rounds that can be supported by the first selected mode (maximum capacity of the first selected multimode), then they are all transported using the first selected

mode and that the logistics cost is calculated based on the calculated rounds (see Figures 7.16 to 7.18).

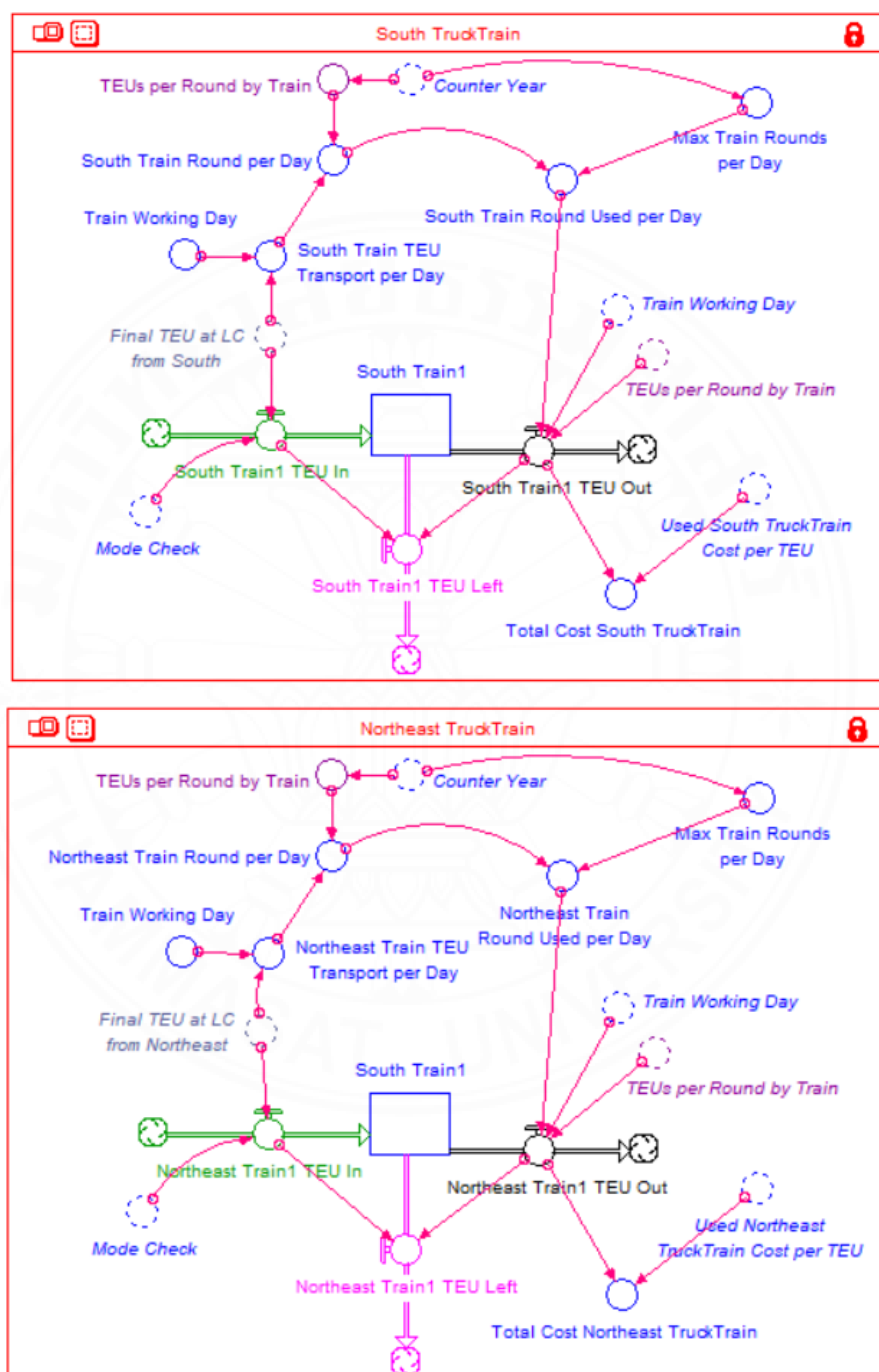


Figure 7.16 Examples of Block Rubber Transported by Truck-Train mode as the First Selected Multimode

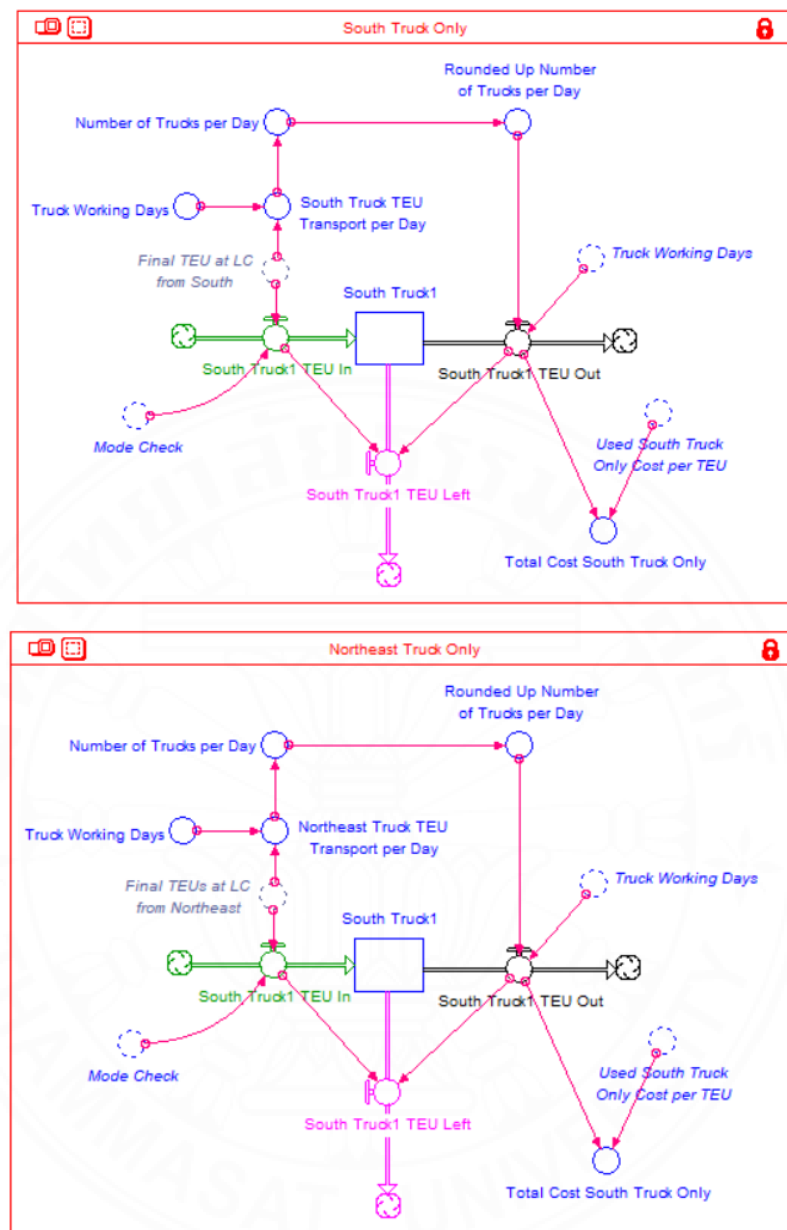


Figure 7.18 Examples of Block Rubber Transported by Truck-Only mode as the First Selected Multimode

If the calculated round is less than the maximum rounds that can be supported by the first selected mode but is not in a whole number (i.e., there is a decimal round in the calculation), then the logistics cost is calculated based on the full calculated rounds (full rounds only). The leftover TEUs are then considered with the next available multimode explained in the next section.

If the calculated round is more than the maximum rounds that can be supported by the first selected mode, then the logistics cost is calculated based on the maximum rounds. The leftover TEUs are then considered with the next available multimode explained in the next section.

In case that the truck-train mode is selected as the first selected multimode (see Equations 7.18 and 7.19), then the calculated rounds per day is achieved (see Equations 7.20-7.23) Please note that the “Mode_Check” in Equations 7.18 and 7.19 can result in 0, 1, and 2 where the truck-train, the truck-ship, and the truck-only are selected as the first selected mode, respectively.

$$\text{South_Train1_TEU_In} = \text{IF Mode_Check} = 0 \text{ THEN Final_TEU_at_LC_from_South} \\ \text{ELSE } 0 \quad (7.18)$$

$$\text{Northeast_Train1_TEU_In} = \text{IF Mode_Check} = 0 \text{ THEN Final_TEU_at_LC_from_} \\ \text{Northeast ELSE } 0 \quad (7.19)$$

$$\text{South_Train_TEU_Transport_per_Day} = \\ \text{Final_TEU_at_LC_from_South/Train_Working_Day} \quad (7.20)$$

$$\text{Northeast_Train_TEU_Transport_per_Day} = \\ \text{Final_TEU_at_LC_from_Northeast/Train_Working_Day} \quad (7.21)$$

$$\text{South_Train_Round_per_Day} = \\ \text{South_Train_TEU_Transport_per_Day/TEUs_per_Round_by_Train} \quad (7.22)$$

$$\text{Northeast_Train_Round_per_Day} = \\ \text{Northeast_Train_TEU_Transport_per_Day/TEUs_per_Round_by_Train} \quad (7.23)$$

Where Final_TEU_at_LC_from_South = Total amount of block rubber export in that year

Train_Working_Day = Number of train operational days in a year

South_Train_TEU_Transport_per_Day = Amount of block rubber transported from the southern part per day by train

Northeast_Train_TEU_Transport_per_Day = Amount of block rubber transported from the northeast part per day by train

TEUs_per_Round_by_Train = Maximum amount of block rubber that can be transported by one round of train

Total rounds transported by the first selected mode are then calculated using Equations 7.24-7.27. Leftover amount of block rubber, if any, is calculated using Equations 7.28 and 7.29. Logistics cost of the first selected mode is then achieved (see Equations 7.30 and 7.31).

$$\text{South_Train_Round_Used_per_Day} = \text{IF } \text{South_Train_Round_per_Day} \leq \text{Max_Train_Rounds_per_Day} \text{ THEN } \text{ROUND}(\text{South_Train_Round_per_Day}-0.5) \text{ ELSE } \text{Max_Train_Rounds_per_Day} \quad (7.24)$$

$$\text{Northeast_Train_Round_Used_per_Day} = \text{IF } \text{Northeast_Train_Round_per_Day} \leq \text{Max_Train_Rounds_per_Day} \text{ THEN } \text{ROUND}(\text{Northeast_Train_Round_per_Day}-0.5) \text{ ELSE } \text{Max_Train_Rounds_per_Day} \quad (7.25)$$

$$\text{South_Train1_TEU_Out} = \text{TEUs_per_Round_by_Train} * \text{South_Train_Round_Used_per_Day} * \text{Train_Working_Day} \quad (7.26)$$

$$\text{Northeast_Train1_TEU_Out} = \text{TEUs_per_Round_by_Train} * \text{Northeast_Train_Round_Used_per_Day} * \text{Train_Working_Day} \quad (7.27)$$

$$\text{South_Train1_TEU_Left} = \text{South_Train1_TEU_In} - \text{South_Train1_TEU_Out} \quad (7.28)$$

$$\text{Northeast_Train1_TEU_Left} = \text{Northeast_Train1_TEU_In} - \text{Northeast_Train1_TEU_Out} \quad (7.29)$$

$$\begin{aligned} \text{Total_Cost_South_TruckTrain} &= \text{South_Train1_TEU_Out} * \\ \text{Used_South_TruckTrain_Cost_per_TEU} & \end{aligned} \quad (7.30)$$

$$\begin{aligned} \text{Total_Cost_Northeast_TruckTrain} &= \text{Northeast_Train1_TEU_Out} * \\ \text{Northeast_TruckTrain_Cost_per_TEU} & \end{aligned} \quad (7.31)$$

Where $\text{South_Train_Round_per_Day}$ = Calculated train rounds in the southern part needed for total block rubber transportation

$\text{Northeast_Train_Round_per_Day}$ = Calculated train rounds in the northeast part needed for total block rubber transportation

$\text{Max_Train_Rounds_per_Day}$ = Maximum train rounds that can be operated per day

$\text{South_Train1_TEU_In}$ = Total amount of block rubber in the southern part that is expected to be transported by train

$\text{South or Northeast_Train1_TEU_In}$ = Total amount of block rubber in the northeast part that is expected to be transported by train

$\text{South_Train1_TEU_Out}$ = Total amount of block rubber in the southern part that can be transported by train

$\text{South or Northeast_Train1_TEU_Out}$ = Total amount of block rubber in the northeast part that can be transported by train

$\text{Used_South_TruckTrain_Cost_per_TEU}$ = Logistics cost of truck-train transportation in the southern part

$\text{Used_Northeast_TruckTrain_Cost_per_TEU}$ = Logistics cost of truck-train transportation in the northeast part

In case that the truck-ship mode is selected as the first selected multimode (see Equation 7.32), then the calculated rounds using this multimode are achieved (see Equations 7.33-7.36). Leftover amount of block rubber, if any, is calculated using Equation 7.37. Logistics cost of the first selected mode is then achieved (see Equation 7.38). Please note that the truck-ship mode is only available in the southern part transportation.

$$\text{South_Ship1_TEU_In} = \text{IF Mode_Check} = 1 \text{ THEN Final_TEU_at_LC_from_South} \\ \text{ELSE } 0 \quad (7.32)$$

$$\text{South_Ship_TEU_Transport_per_Day} = \\ \text{Final_TEU_at_LC_from_South/Ship_Working_Day} \quad (7.33)$$

$$\text{South_Ship_Round_per_Day} = \\ \text{South_Ship_TEU_Transport_per_Day/TEUs_per_Round_by_Ship} \quad (7.34)$$

$$\text{South_Ship_Round_Used_per_Day} = \text{IF } \text{South_Ship_Round_per_Day} \leq \\ \text{Max_Ship_Rounds_per_Day} \text{ THEN } \text{ROUND}(\text{South_Ship_Round_per_Day}-0.5) \\ \text{ELSE Max_Ship_Rounds_per_Day} \quad (7.35)$$

$$\text{South_Ship1_TEU_Out} = \text{TEUs_per_Round_by_Ship} * \\ \text{South_Ship_Round_Used_per_Day} * \text{Ship_Working_Day} \quad (7.36)$$

$$\text{South_Ship1_TEU_Left} = \text{South_Ship1_TEU_In} - \text{South_Ship1_TEU_Out} \quad (7.37)$$

$$\text{Total_Cost_South_TruckShip} = \text{South_Ship1_TEU_Out} * \\ \text{Used_South_TruckShip_Cost_per_TEU} \quad (7.38)$$

Where Ship_Working_Day = Number of ship operational days in a year

South_Ship_TEU_Transport_per_Day = Amount of block rubber transported per day by ship

TEUs_per_Round_by_Ship = Maximum amount of block rubber that can be transported by one round of ship

South_Ship_Round_per_Day = Calculated ship rounds needed for total block rubber transportation

Max_Ship_Rounds_per_Day = Maximum ship rounds that can be operated per day

South_Ship1_TEU_In = Total amount of block rubber that is expected to be transported by ship

South_Ship1_TEU_Out = Total amount of block rubber that can be transported by ship

Used_South_TruckShip_Cost_per_TEU = Logistics cost of truck-ship transportation

In case that the truck-only mode is selected as the first selected multimode (see Equations 7.39 and 7.40), then the calculated rounds per day is achieved (see Equations 7.41-7.44). Total rounds transported by the first selected mode are then calculated using Equations 7.45 and 7.46. Leftover amount of block rubber, if any, is calculated using Equations 7.47 and 7.48. Logistics cost of the first selected mode is then achieved (see Equations 7.49 and 7.50). Please note that one truck serves for one TEU of block rubber transportation.

South_Truck1_TEU_In = IF Mode_Check = 2 THEN Final_TEU_at_LC_from_South
ELSE 0 (7.39)

Northeast_Train1_TEU_In = IF Mode_Check = 2 THEN Final_TEU_at_LC_from_
Northeast ELSE 0 (7.40)

South_Truck_TEU_Transport_per_Day =
Final_TEU_at_LC_from_South/Truck_Working_Days (7.41)

Northeast_Truck_TEU_Transport_per_Day =
Final_TEU_at_LC_from_Northeast/Truck_Working_Days (7.42)

Number of Trucks per Day = South_Truck_TEU_Transport_per_Day (7.43)

Number of Trucks per Day = Northeast_Truck_TEU_Transport_per_Day (7.44)

$$\frac{\text{South_Truck1_TEU_Out}}{\text{Truck_Working_Days}} = \frac{\text{Rounded_Up_Number_of_Trucks_per_Day}}{\text{Truck_Working_Days}} * \quad (7.45)$$

$$\frac{\text{Northeast_Truck1_TEU_Out}}{\text{Truck_Working_Days}} = \frac{\text{Rounded_Up_Number_of_Trucks_per_Day}}{\text{Truck_Working_Days}} * \quad (7.46)$$

$$\text{South Truck1 TEU Left} = \text{South_Truck1_TEU_In} - \text{South_Truck1_TEU_Out} \quad (7.47)$$

$$\text{Northeast Truck1 TEU Left} = \text{Northeast_Truck1_TEU_In} - \text{Northeast_Truck1_TEU_Out} \quad (7.48)$$

$$\frac{\text{Total Cost South Truck Only}}{\text{Used_South_Truck_Only_Cost_per_TEU}} = \frac{\text{South_Truck1_TEU_Out}}{\text{Used_South_Truck_Only_Cost_per_TEU}} * \quad (7.49)$$

$$\frac{\text{Total Cost Northeast Truck Only}}{\text{Northeast_Truck_Only_Cost_per_TEU}} = \frac{\text{Northeast_Truck1_TEU_Out}}{\text{Northeast_Truck_Only_Cost_per_TEU}} * \quad (7.50)$$

Where $\text{Final_TEU_at_LC_from_South}$ = Total amount of block rubber export from the southern part in that year.

$\text{Final_TEU_at_LC_from_Northeast}$ = Total amount of block rubber export from the northeast part in that year

$\text{Truck_Working_Days}$ = Total truck operational days, which is 200 days per year

$\text{South_Truck1_TEU_In}$ = Total amount of block rubber in the southern part that is expected to be transported by truck

$\text{South_Truck1_TEU_In}$ = Total amount of block rubber in the northeast part that is expected to be transported by truck

$\text{South_Truck1_TEU_Out}$ = Total amount of block rubber in the southern part that can be transported by truck

$\text{South_Truck1_TEU_Out}$ = Total amount of block rubber in the northeast part that can be transported by truck

$\text{Used_South_Truck_Only_Cost_per_TEU}$ = Logistics cost of truck-only transportation in the southern part

$\text{Used_South_Truck_Only_Cost_per_TEU}$ = Logistics cost of truck-only transportation in the northeast part

7.5.2.4 Section 4: The Next Available Multimode Selection for Leftover Amount

The leftover amount of block rubber (in TEUs), if any, are then considered with the next available mode. This leftover amount may come from the exceeded capacity or the not a full-round capacity (i.e., the not-integer round) of the previous selected multimode. All possible multimode (truck-train, truck-ship, and truck-only) are considered, if available or if the full capacity is yet achieved, to calculate the logistics cost, and the mode with minimum logistics cost is selected (see Figures 7.19 to 7.21).

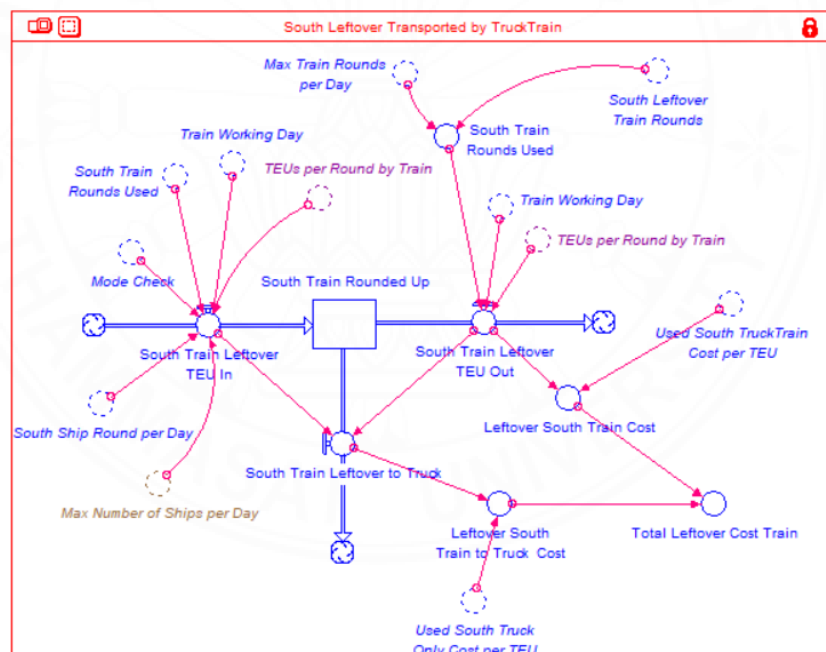


Figure 7.19 Examples of Leftover Block Rubber in the Southern Region Transported by Truck-Train mode as the Next Available Multimode

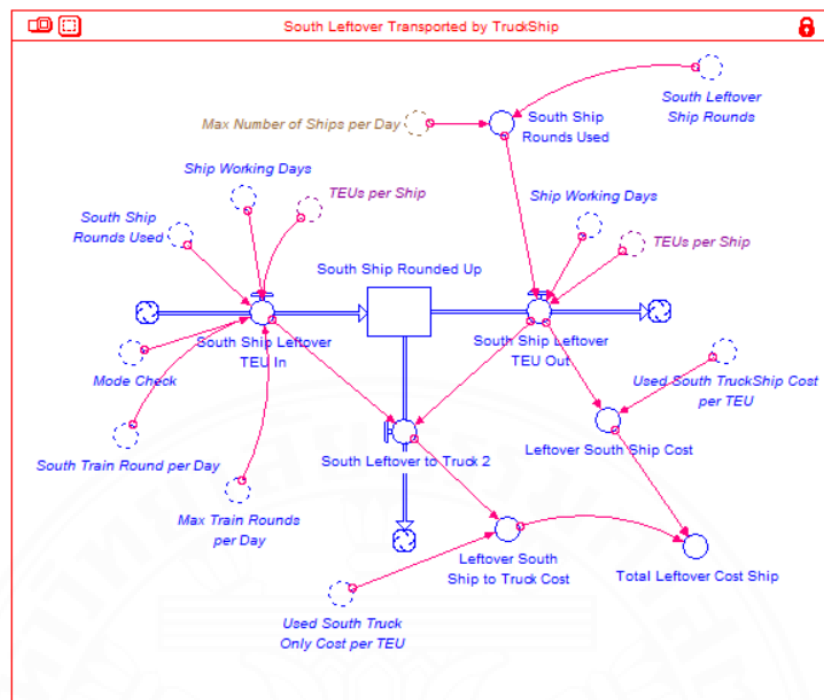


Figure 7.20 Examples of Leftover Block Rubber in the Southern Region Transported by Truck-Ship mode as the Next Available Multimode

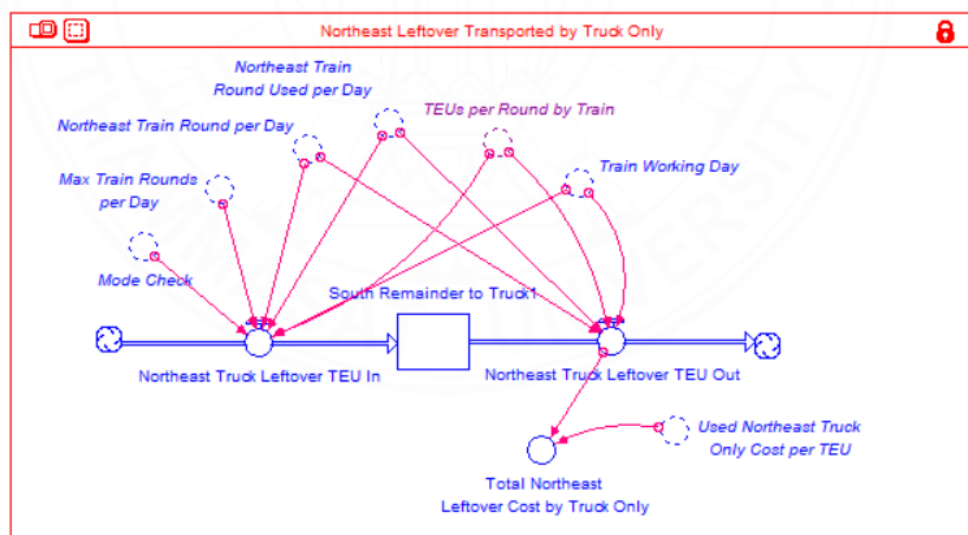


Figure 7.21 Examples of Leftover Block Rubber in the Northeastern Region Transported by Truck-only mode as the Next Available Multimode

If the truck-train mode is the next available multimode in the southern region (see Equations 7.51-7.56), then the logistics cost of leftover amount transported by

truck-train mode is achieved (please note that the “Mode_Check” in Equations 7.51 can result in 0, 1, and 2 where the truck-train, the truck-ship, and the truck-only are selected as the next available mode, respectively). However, there might be the amount of block rubber left if the capacity of this selected mode is not satisfactory. In that case, the leftover amount of the block rubber will again be considered with the next available multimode, where the logistics costs are compared, and the mode with minimum logistics cost is selected. The process is repeated until all block rubber are transported to Laem Chabang port for the exporting process.

$$\begin{aligned} \text{South_Train_Leftover_TEU_In} = \\ \text{IF Mode_Check} = 0 \text{ THEN } 0 \text{ ELSE South_Ship1_TEU_Left} \end{aligned} \quad (7.51)$$

$$\begin{aligned} \text{South_Train_Leftover_TEU_Out} &= \text{South_Train_Rounds_Used} * \\ \text{Train_Working_Day} * \text{TEUs_per_Round_by_Train} \end{aligned} \quad (7.52)$$

$$\begin{aligned} \text{South Train Leftover to Truck} \\ = \text{South_Train_Leftover_TEU_In} - \text{South_Train_Leftover_TEU_Out} \end{aligned} \quad (7.53)$$

$$\begin{aligned} \text{Leftover_South_Train_Cost} = \\ \text{South_Train_Leftover_TEU_Out} * \text{Used_South_TruckTrain_Cost_per_TEU} \end{aligned} \quad (7.54)$$

$$\begin{aligned} \text{Leftover_South_Train_to_Truck_Cost} = \\ \text{South_Train_Leftover_to_Truck} * \text{Used_South_Truck_Only_Cost_per_TEU} \end{aligned} \quad (7.55)$$

$$\begin{aligned} \text{Total_Leftover_Cost_Train} = \\ \text{Leftover_South_Train_Cost} + \text{Leftover_South_Train_to_Truck_Cost} \end{aligned} \quad (7.56)$$

If the truck-ship mode is the next available multimode in the southern region (see Equations 7.57-7.62), then the logistics cost of leftover amount transported by truck-train mode is achieved. Similarly, if there are the amount of block rubber left, the leftover amount of the block rubber will be considered with the next available multimode, where the logistics costs are compared, and the mode with minimum

logistics cost is selected. The process is repeated until all block rubber are transported to Laem Chabang port for the exporting process.

$$\begin{aligned} \text{South_Ship_Leftover_TEU_In} = \\ \text{IF Mode_Check} = 1 \text{ THEN } 0 \text{ ELSE South_Train1_TEU_Left} \end{aligned} \quad (7.57)$$

$$\begin{aligned} \text{South_Ship_Leftover_TEU_Out} = \text{South_Ship_Rounds_Used} * \text{Ship_Working_Day} * \\ \text{TEUs_per_Round_by_Ship} \end{aligned} \quad (7.58)$$

$$\begin{aligned} \text{South Ship Leftover to Truck} \\ = \text{South_Ship_Leftover_TEU_In} - \text{South_Ship_Leftover_TEU_Out} \end{aligned} \quad (7.59)$$

$$\begin{aligned} \text{Leftover_South_Ship_Cost} = \\ \text{South_Ship_Leftover_TEU_Out} * \text{Used_South_TruckShip_Cost_per_TEU} \end{aligned} \quad (7.60)$$

$$\begin{aligned} \text{Leftover_South_Ship_to_Truck_Cost} = \\ \text{South_Ship_Leftover_to_Truck} * \text{Used_South_Truck_Only_Cost_per_TEU} \end{aligned} \quad (7.61)$$

$$\begin{aligned} \text{Total_Leftover_Cost_Ship} = \\ \text{Leftover_South_Ship_Cost} + \text{Leftover_South_Ship_to_Truck_Cost} \end{aligned} \quad (7.62)$$

If the truck-only mode is the next available multimode in the northeastern region (see Equations 7.63-7.65), then the logistics cost of total leftover amount transported by truck-only mode is achieved. Please note that the truck-only mode has unlimited capacity (i.e., unlimited number of trucks could be on the road).

$$\begin{aligned} \text{Northeast_Truck_Leftover_TEU_In} = \\ \text{IF Mode_Check} = 2 \text{ THEN } 0 \text{ ELSE Northeast_Ship1_TEU_Left} + \\ \text{Northeast_Train1_TEU_Left} \end{aligned} \quad (7.63)$$

$$\begin{aligned} \text{Northeast_Truck_Leftover_TEU_Out} = \text{Northeast_Ship1_TEU_Left} + \\ \text{Northeast_Train1_TEU_Left} \end{aligned} \quad (7.64)$$

$$\begin{aligned} \text{Total_Leftover_Cost_Truck} = \\ \text{Northeast_Truck_Leftover_TEU_Out} * \text{Used_Northeast_Truck_Only_Cost_per_TEU} \end{aligned} \quad (7.65)$$

7.5.2.5 Section 5: Final Logistics Cost

After total block rubber is transported with various multimode, the final logistics cost is calculated by summing the logistics cost in each selected mode to achieve the minimum logistics cost of block rubber transportation in each year (see Figure 7.22 and Equations 7.66-7.71).

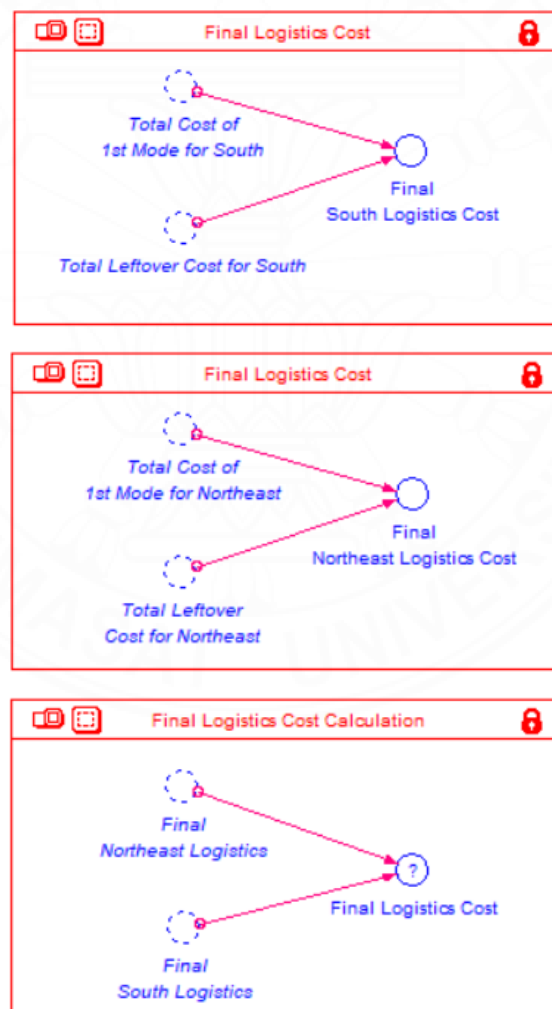


Figure 7.22 Examples of Final Logistics Cost

$$\begin{aligned} \text{Total_Cost_of_1st_Mode_for_South} &= \text{Total_Cost_South_TruckTrain} + \\ &\text{Total_Cost_South_TruckShip} + \text{Total_Cost_South_Truck_Only} \end{aligned} \quad (7.66)$$

$$\begin{aligned} \text{Total_Leftover_Cost_for_South} &= \\ &\text{Total_Leftover_Cost_Train} + \text{Total_Leftover_Cost_Ship} \end{aligned} \quad (7.67)$$

$$\begin{aligned} \text{Final_South_Logistics_Cost} &= \\ &\text{Total_Cost_of_1st_Mode_for_South} + \text{Total_Leftover_Cost_for_South} \end{aligned} \quad (7.68)$$

$$\begin{aligned} \text{Total_Cost_of_1st_Mode_for_Northeast} &= \text{Total_Cost_Northeast_TruckTrain} + \\ &\text{Total_Cost_Northeast_Truck_Only} \end{aligned} \quad (7.69)$$

$$\text{Total_Leftover_Cost_for_Northeast} = \text{Total_Cost_Northeast_Truck_Only} \quad (7.70)$$

$$\begin{aligned} \text{Final_Northeast_Logistics_Cost} &= \\ &\text{Total_Cost_of_1st_Mode_for_Northeast} + \text{Total_Leftover_Cost_for_Northeast} \end{aligned} \quad (7.71)$$

$$\begin{aligned} \text{Final_Logistics_Cost} &= \\ &\text{Final_Northeast_Logistics_Cost} + \text{Final_South_Logistics_Cost} \end{aligned} \quad (7.72)$$

The total logistics cost of each region (i.e., the southern and northeast regions) is calculated by summing the logistics cost in each selected multimode. The final logistics cost is then achieved by summing the total logistics costs of the two regions. It is the minimum logistics cost suggested to be used for the block rubber transportation each year.

The simulation results of the SD model of multimodal transportation of block rubber in Thailand are explained in the next chapter. The comparative results between the conventional transportation (truck-only mode) and the multimodal transportation are provided to express the benefits of multimodal transportation of block rubber in the long term.

CHAPTER 8

SYSTEM DYNAMICS MODEL SIMULATION RESULTS AND POLICY ANALYSIS

The SD model of multimodal transportation of block rubber in Thailand, from production areas in the southern and northeastern regions to the export point i.e., Laem Chabang port in the east of Thailand, is simulated to contribute the effective model design and formulation, address the current issues, and suggest future recommendations for government, related authorities, and business sectors. The policy analysis is also performed through the SD model to achieve the best policy to enhance the efficiency and competitiveness of multimodal transportation compared to conventional road transportation. It is expected that the simulation and analyses results provide robust implications for policymakers of government sector and transportation managers of business sector to plan for multimodal transportation that meets the current and future needs. The results prove that multimodal transportation is a solution to reduce the road transportation problems and limitations, thus reducing logistics costs and enhancing transportation efficiency. SD model not only provides direct decision support for policy analysis, but also provides a means for understanding problems, which in turn informs the way policymakers and transportation managers navigate complex decision-making processes. The recommendations for policymakers and transportation managers based on the simulation results are also presented to successfully increase the modal share of multimodal transportation to achieve sustainability in the long-term. These, in turn, raise companies' profitability and ability to compete in the global market.

8.1 SD Modeling Results and Discussion

The SD model of multimodal transportation of block rubber in Thailand is simulated using the iThink software for the next 20 years according to the 20-year national strategy, which focuses on leveraging government support on multimodal transportation and infrastructure development (Strategic Transformation Office, 2021). The model simulation begins with the selection of the first transportation mode with the lowest logistics cost to support block rubber transportation (see Tables 8.1 and 8.2).

Table 8.1 Comparison of Logistics Cost per TEU for the 1st Mode Selection in the Southern Region

Year	South Truck-Train Cost (Baht)/TEU	South Truck-Ship Cost (Baht)/TEU	South Truck-Only Cost (Baht)/TEU	The 1 st Selected Mode
Initial	12,171.88	11,461.19	15,800.00	Truck-Ship
1	12,823.31	11,902.68	16,782.76	Truck-Ship
2	13,298.40	12,342.73	17,826.65	Truck-Ship
3	13,446.64	12,757.42	18,935.47	Truck-Ship
4	13,455.14	12,943.78	19,600.00	Truck-Ship
5	13,248.04	12,849.63	19,600.00	Truck-Ship
6	12,701.03	12,414.26	19,600.00	Truck-Ship
7	11,465.93	11,289.18	19,600.00	Truck-Ship
8	10,393.73	10,324.99	19,600.00	Truck-Ship
9	10,574.02	10,610.89	19,600.00	Truck-Train
10	10,765.52	10,905.19	19,600.00	Truck-Train
11	10,968.93	11,222.62	19,600.00	Truck-Train
12	11,185.00	11,553.58	19,600.00	Truck-Train
13	11,414.51	11,894.79	19,600.00	Truck-Train
14	11,658.29	12,246.58	19,600.00	Truck-Train
15	11,917.23	12,609.28	19,600.00	Truck-Train
16	12,192.28	12,983.22	19,600.00	Truck-Train
17	12,484.44	13,368.75	19,600.00	Truck-Train
18	12,794.77	13,766.24	19,600.00	Truck-Train
19	13,124.40	14,176.04	19,600.00	Truck-Train
20	13,474.54	14,598.55	19,600.00	Truck-Train

Table 8.2 Comparison of Logistics Cost per TEU for the 1st Mode Selection in the Northeastern Region

Year	North Truck-Train Cost (Baht)/TEU	North Truck-Only Cost (Baht)/TEU	The 1 st Selected Mode
Initial	11,777.84	17,000.00	Truck-Train
1	12,394.58	18,057.40	Truck-Train
2	13,032.24	19,180.57	Truck-Train
3	13,672.80	19,600.00	Truck-Train
4	14,209.75	19,600.00	Truck-Train
5	14,556.39	19,600.00	Truck-Train
6	14,588.00	19,600.00	Truck-Train
7	13,957.51	19,600.00	Truck-Train
8	13,385.84	19,600.00	Truck-Train
9	13,542.09	19,600.00	Truck-Train
10	13,708.06	19,600.00	Truck-Train
11	13,884.35	19,600.00	Truck-Train
12	14,071.61	19,600.00	Truck-Train
13	14,270.51	19,600.00	Truck-Train
14	14,481.79	19,600.00	Truck-Train
15	14,706.21	19,600.00	Truck-Train
16	14,944.58	19,600.00	Truck-Train
17	15,197.79	19,600.00	Truck-Train
18	15,466.74	19,600.00	Truck-Train
19	15,752.42	19,600.00	Truck-Train
20	16,055.87	19,600.00	Truck-Train

For the southern region, the simulation results show that the logistics costs of multimode transportation i.e., truck-ship and truck-train modes are much lower than the conventional road-only transportation, respectively. The truck-ship mode is first selected for the first eight years of simulation as it incurs the lowest logistics cost per

TEU (see Table 8.1). This is consistent with Hanssen et al. (2012) that water transport has the lowest transport cost per ton per kilometer. Boonsuya (2010) added that truck-ship mode is suitable for the rubber transportation in Thailand.

Afterwards, the truck-train mode is the preferred mode of block rubber transportation. This is consistent with the multimodal transportation development plan in (Strategic Transformation Office, 2019) and (Office of Transport and Traffic Policy and Planning, 2019) that the current train capacity and ability to support multimodal transportation are not fully utilized due to the low operational efficiencies and inadequate transportation supported facilities, resulting in delays, limited capacities, and inability to support block rubber transportation. However, the government plans to purchase new locomotives, increase train capacity, and improve services to support multimodal transportation. With this plan, it is expected that the truck-train mode can support multimodal transportation of block rubber in the long term.

For the northeastern region, the simulation results show that the logistics costs multimode transportation i.e., truck-train mode is always lower than the conventional road-only transportation due to its higher fuel efficiency and capability of hauling large loads that leads to cost effectiveness (see Table 8.2).

The first selected mode in each region is utilized to support block rubber transportation. The leftover of block rubber, or a not-full-load, is then transported using the next available mode with the lowest logistics cost. This continues until all block rubber is transported to the export point i.e., Laem Chabang port.

Tables 8.3 and 8.4 summarize the transportation modes used in block rubber transportation and total logistics costs in each region (i.e., the southern and northeastern regions) each year. Comparison of total logistics costs between multimodal transportation and conventional road-only transportation clearly supports the use of multimodal transportation in the long term to save logistics costs and enhance transport efficiency.

Table 8.5 shows final logistics cost of multimodal transportation of block rubber compared with the traditional truck-only transportation. It can be seen that the use of multimodal transportation can save up to one time the logistics cost of the traditional mode. The government, therefore, should support the use of multimodal transportation in the long term to achieve the highest benefit for the industry and the country as a

whole. The support could be in various areas, such as infrastructure development and R&D of agricultural product transportation. These may lead to market competitiveness and market enhancement in the global scale.

Table 8.3 Transportation Modes and Total Logistics Cost of Block Rubber Transportation in the Southern Region

Year	The 1 st Selected Mode	The 2 nd Selected Mode	The 3 rd Selected Mode	Total Logistics Cost (Baht)	Logistics Cost of Truck-only Mode (Baht)	Cost-saving (%)
Initial	Truck-Ship	Truck-Train	—	111,981,279	305,303,400	173
1	Truck-Ship	Truck Only	—	269,308,150	366,753,654	36
2	Truck-Ship	Truck Only	—	318,568,473	428,071,346	34
3	Truck-Ship	Truck Only	—	376,305,762	499,669,182	33
4	Truck-Ship	Truck-Train	—	419,922,995	568,321,600	35
5	Truck-Ship	Truck-Train	—	415,557,863	624,495,200	50
6	Truck-Ship	Truck-Train	—	400,300,404	686,235,200	71
7	Truck-Ship	Truck-Train	—	363,013,449	754,090,400	108
8	Truck-Ship	Truck Only	—	458,202,668	828,609,600	81
9	Truck-Train	—	—	507,552,810	910,557,200	79
10	Truck-Train	Truck Only	—	576,485,736	1,000,540,800	74
11	Truck-Train	—	—	658,136,015	1,099,462,000	67
12	Truck-Train	Truck Only	—	703,263,601	1,208,163,600	72
13	Truck-Train	—	—	821,844,417	1,327,586,400	62
14	Truck-Train	Truck Only	—	887,024,652	1,458,828,000	64
15	Truck-Train	Truck Only	—	1,049,905,035	1,603,064,400	53
16	Truck-Train	Truck-Ship	—	1,137,093,207	1,761,510,800	55
17	Truck-Train	Truck-Ship	Truck Only	1,298,910,958	1,935,656,800	49
18	Truck-Train	Truck-Ship	—	1,470,991,992	2,127,031,200	45
19	Truck-Train	Truck-Ship	Truck Only	1,654,426,445	2,337,280,400	41
20	Truck-Train	Truck-Ship	—	1,844,678,821	2,568,344,800	39

Table 8.4 Transportation Modes and Total Logistics Cost of Block Rubber Transportation in the Northeastern Region

Year	The 1 st Selected Mode	The 2 nd Selected Mode	Total Logistics Cost (Baht)	Logistics Cost of Truck-only Mode (Baht)	Cost-saving (%)
Initial	Truck-Train	Truck Only	90,166,020	121,499,000	35
1	Truck-Train	Truck Only	111,962,994	145,939,907	30
2	Truck-Train	Truck Only	133,471,835	170,361,823	28
3	Truck-Train	Truck Only	164,073,632	191,296,000	17
4	Truck-Train	Truck Only	170,516,942	210,190,400	23
5	Truck-Train	Truck Only	174,676,648	230,986,000	32
6	Truck-Train	Truck Only	193,656,342	253,800,400	31
7	Truck-Train	Truck-Train	211,198,070	278,908,000	32
8	Truck-Train	Truck Only	231,915,236	306,485,200	32
9	Truck-Train	Truck Only	264,072,238	336,767,200	28
10	Truck-Train	Truck Only	299,364,265	370,067,600	24
11	Truck-Train	Truck Only	333,224,344	406,660,800	22
12	Truck-Train	Truck Only	337,718,526	446,860,400	32
13	Truck-Train	Truck Only	363,111,446	491,019,200	35
14	Truck-Train	Truck Only	416,731,291	539,568,400	29
15	Truck-Train	Truck Only	475,448,931	592,900,000	25
16	Truck-Train	Truck Only	538,004,973	651,523,600	21
17	Truck-Train	Truck Only	557,449,524	715,929,200	28
18	Truck-Train	Truck Only	637,907,450	786,704,800	23
19	Truck-Train	Truck Only	725,964,817	864,477,600	19
20	Truck-Train	Truck Only	779,815,578	949,933,600	22

Table 8.5 Final Logistics Cost of Block Rubber Transportation

Year	Final Logistics Cost of Multimodal Transportation (Baht)	Final Logistics Cost of Truck-only Mode (Baht)	Cost-saving (%)
Initial	202,147,299	426,802,400	111
1	381,271,144	512,693,561	34
2	452,040,308	598,433,169	32
3	540,379,394	690,965,182	28
4	590,439,937	778,512,000	32
5	590,234,511	855,481,200	45
6	593,956,746	940,035,600	58
7	574,211,519	1,032,998,400	80
8	690,117,904	1,135,094,800	64
9	771,625,048	1,247,324,400	62
10	875,850,001	1,370,608,400	56
11	991,360,359	1,506,122,800	52
12	1,040,982,127	1,655,024,000	59
13	1,184,955,863	1,818,605,600	53
14	1,303,755,943	1,998,396,400	53
15	1,525,353,966	2,195,964,400	44
16	1,675,098,180	2,413,034,400	44
17	1,856,360,482	2,651,586,000	43
18	2,108,899,442	2,913,736,000	38
19	2,380,391,262	3,201,758,000	35
20	2,624,494,399	3,518,278,400	34

8.2 Policy Analysis

The developed SD model of multimodal transportation must be validated to ensure its use in the real practices. Policy or sensitivity analysis is one of the common validation processes. It reveals the degree of robustness of model behavior and indicates the degree to which policy recommendations may be influenced by uncertainty in

parameter values. Such testing can help to show the risk involved in adopting a model for policymaking (Forrester & Senge, 1980).

In this study, the policy analysis is performed to test various possible government policies to be used in multimodal transportation of block rubber in Thailand. The water and train modes are considered by varying the optimal number of ships and train rounds per day to examine final logistics costs of multimodal transportation.

8.2.1 Policy Analysis by Varying Number of Ships per Day

In the early years of simulation, the truck-ship mode is first selected for block rubber transportation as it has the lowest logistics cost per TEU. Currently, there are three ships operating in the southern region per day. By increasing port and ship efficiency, the water transportation velocity increases, resulting in more products to be transported per day.

The policy analysis is performed by varying possible number of ships to be operated in the southern region to examine final logistics cost of block rubber transportation (Port Authority of Thailand, 2020). The maximum number of ships per day is planned to be six ships per day, thus the possible number of ships per day are three to six ships per day as below:

- Scenario 1 represents three ships operated per day (i.e., the base simulation).
- Scenario 2 represents four ships operated per day.
- Scenario 3 represents five ships operated per day.
- Scenario 4 represents six ships operated per day (i.e., maximum port capacity).

Final logistics costs of block rubber transportation, when number of ships per day are changed, are as shown in Table 8.6 and Figure 8.1. The simulation results show that the increase of number of ships per day does not improve the final logistics cost (i.e., the final logistics cost remains the same). This is because the amount of block rubber to be exported in the next 20 years do not exceed the current capacity of port and ships (i.e., three ships per day). However, if the export amount increases through

government's campaigns, or the ports are shared with other products, then the increase of port capacity might be necessary.

Table 8.6 Final Logistics Cost of Block Rubber Transportation when Number of Ships per Day in the Southern Region are Changed

Year	Total Logistics Cost - Northeast	Total Logistics Cost - South				Final Logistics Cost			
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Initial	90,166,020	111,981,279	111,981,280	111,981,280	111,981,280	202,147,300	202,147,300	202,147,300	202,147,300
1	111,962,994	269,308,150	269,308,151	269,308,151	269,308,151	381,271,145	381,271,145	381,271,145	381,271,145
2	133,471,835	318,568,473	318,568,473	318,568,473	318,568,473	452,040,308	452,040,308	452,040,308	452,040,308
3	164,073,632	376,305,762	376,305,762	376,305,762	376,305,762	540,379,394	540,379,394	540,379,394	540,379,394
4	170,516,942	419,922,995	419,922,995	419,922,995	419,922,995	590,439,937	590,439,937	590,439,937	590,439,937
5	174,676,648	415,557,863	415,557,863	415,557,863	415,557,863	590,234,511	590,234,511	590,234,511	590,234,511
6	193,656,342	400,300,404	400,300,405	400,300,405	400,300,405	593,956,747	593,956,747	593,956,747	593,956,747
7	211,198,070	363,013,449	363,013,450	363,013,450	363,013,450	574,211,520	574,211,520	574,211,520	574,211,520
8	231,915,236	458,202,668	458,202,669	458,202,669	458,202,669	690,117,905	690,117,905	690,117,905	690,117,905
9	264,072,238	507,552,810	507,552,810	507,552,810	507,552,810	771,625,048	771,625,048	771,625,048	771,625,048
10	299,364,265	576,485,736	576,485,736	576,485,736	576,485,736	875,850,001	875,850,001	875,850,001	875,850,001
11	333,224,344	658,136,015	658,136,015	658,136,015	658,136,015	991,360,359	991,360,359	991,360,359	991,360,359
12	337,718,526	703,263,601	703,263,602	703,263,602	703,263,602	1,040,982,128	1,040,982,128	1,040,982,128	1,040,982,128
13	363,111,446	821,844,417	821,844,418	821,844,418	821,844,418	1,184,955,864	1,184,955,864	1,184,955,864	1,184,955,864
14	416,731,291	887,024,652	887,024,652	887,024,652	887,024,652	1,303,755,943	1,303,755,943	1,303,755,943	1,303,755,943
15	475,448,931	1,049,905,035	1,049,905,036	1,049,905,036	1,049,905,036	1,525,353,967	1,525,353,967	1,525,353,967	1,525,353,967
16	538,004,973	1,137,093,207	1,137,093,208	1,137,093,208	1,137,093,208	1,675,098,181	1,675,098,181	1,675,098,181	1,675,098,181
17	557,449,524	1,298,910,958	1,298,910,959	1,298,910,959	1,298,910,959	1,856,360,483	1,856,360,483	1,856,360,483	1,856,360,483
18	637,907,450	1,470,991,992	1,470,991,992	1,470,991,992	1,470,991,992	2,108,899,442	2,108,899,442	2,108,899,442	2,108,899,442
19	725,964,817	1,654,426,445	1,654,426,446	1,654,426,446	1,654,426,446	2,380,391,263	2,380,391,263	2,380,391,263	2,380,391,263
20	779,815,578	1,844,678,821	1,844,678,821	1,844,678,821	1,844,678,821	2,624,494,399	2,624,494,399	2,624,494,399	2,624,494,399

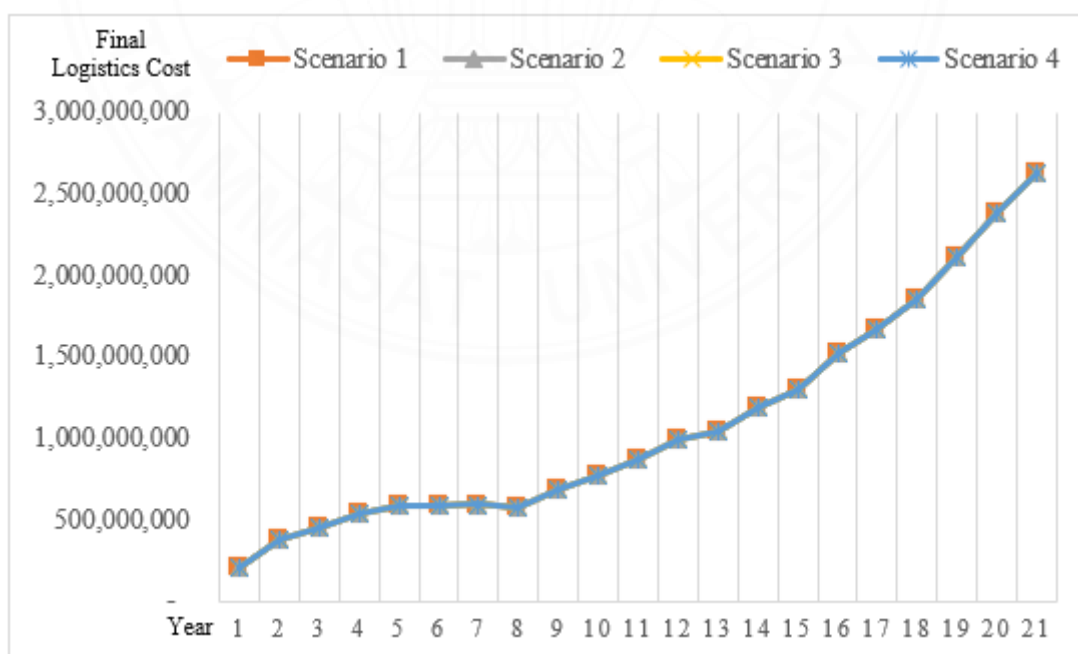


Figure 8.1 Graphical Results of Final Logistics Cost of Block Rubber Transportation when Number of Ships per Day in the Southern Region are Changed

8.2.2 Policy Analysis by Varying Train Rounds per Day

Currently, the rail transportation of block rubber from the southern and northeastern regions to Laem Chabang port operates two rounds per day, with the capacity of 46 TEUs per round (in the southern region) and 30 TEUs per round (in the northeastern region). With the government's double-track railway project to increase multimodal transportation capacity and ability to support the increased export of agricultural products, it is expected that the operating train rounds are increased to six rounds per day for the southern region and four rounds per day for the northeastern region, with a maximum capacity of 60 TEUs per round (The Office of Transport and Traffic Policy and Planning, 2019).

To test possible train rounds to achieve the lowest logistics, the policy analysis is performed by varying the maximum train in the northeastern region, from two (current operating rounds) to six (maximum operating round in the southern region) rounds per day.

- Scenario 1 represents a maximum of two train rounds per day throughout the simulation.
- Scenario 2 represents a change from two to three train rounds per day after year 3 to imitate the government's double track project.
- Scenario 3 represents a change from two to four train rounds per day after year 3 to imitate the government's double track project.
- Scenario 4 represents a change from two to five train rounds per day after year 3 to imitate the government's double track project.
- Scenario 5 represents a change from two to six train rounds per day after year 3 to imitate the government's double track project.

Final logistics costs of block rubber transportation, when number of train rounds per day are changed, are as shown in Table 8.7 and Figure 8.2. The simulation results show that an increase of a maximum train rounds per day in the northeastern region from two to three, four, five, six rounds per day does not change the final logistics cost of block rubber transportation in the first 15 years of simulation. This is because the growing and production capacities of block rubber in the northeastern region is still

low, and that current train capacity (i.e., two train rounds per day) is adequate to support the transportation to the exporting point. After 15 years, however, it is expected that the growing and production capacities of block rubber increase, resulting in the need to expand the train track to increase the train rounds to be at least four rounds per day to support the multimodal transportation and minimize the final logistics cost. This confirms the suitability of the government's double track plan in the northeastern region to be enlarged to four train rounds per day in the future (Office of Transport and Traffic Policy and Planning, 2021).



Table 8.7 Final Logistics Cost of Block Rubber Transportation when Number of Train Rounds per Day in the Northeastern Region are Changed

Year	Total Logistics		Total Logistics Cost - Northeast					Final Logistics Cost				
	Cost - South		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Initial	111,981,279		90,166,020	90,166,020	90,166,020	90,166,020	90,166,020	202,147,299	202,147,299	202,147,299	202,147,299	202,147,299
1	269,308,150		111,962,994	111,962,994	111,962,994	111,962,994	111,962,994	381,271,144	381,271,144	381,271,144	381,271,144	381,271,144
2	318,568,473		133,471,835	133,471,835	133,471,835	133,471,835	133,471,835	452,040,308	452,040,308	452,040,308	452,040,308	452,040,308
3	376,305,762		164,073,632	164,073,632	164,073,632	164,073,632	164,073,632	540,379,394	540,379,394	540,379,394	540,379,394	540,379,394
4	419,922,995		170,516,942	170,516,942	170,516,942	170,516,942	170,516,942	590,439,937	590,439,937	590,439,937	590,439,937	590,439,937
5	415,557,863		174,676,648	174,676,648	174,676,648	174,676,648	174,676,648	590,234,511	590,234,511	590,234,511	590,234,511	590,234,511
6	400,300,404		193,656,342	193,656,342	193,656,342	193,656,342	193,656,342	593,956,746	593,956,746	593,956,746	593,956,746	593,956,746
7	363,013,449		211,198,070	211,198,070	211,198,070	211,198,070	211,198,070	574,211,519	574,211,519	574,211,519	574,211,519	574,211,519
8	458,202,668		231,915,236	231,915,236	231,915,236	231,915,236	231,915,236	690,117,904	690,117,904	690,117,904	690,117,904	690,117,904
9	507,552,810		264,072,238	264,072,238	264,072,238	264,072,238	264,072,238	771,625,048	771,625,048	771,625,048	771,625,048	771,625,048
10	576,485,736		299,364,265	299,364,265	299,364,265	299,364,265	299,364,265	875,850,001	875,850,001	875,850,001	875,850,001	875,850,001
11	658,136,015		333,224,344	333,224,344	333,224,344	333,224,344	333,224,344	991,360,359	991,360,359	991,360,359	991,360,359	991,360,359
12	703,263,601		337,718,526	337,718,526	337,718,526	337,718,526	337,718,526	1,040,982,127	1,040,982,127	1,040,982,127	1,040,982,127	1,040,982,127
13	821,844,417		363,111,446	363,111,446	363,111,446	363,111,446	363,111,446	1,184,955,863	1,184,955,863	1,184,955,863	1,184,955,863	1,184,955,863
14	887,024,652		416,731,291	416,731,291	416,731,291	416,731,291	416,731,291	1,303,755,943	1,303,755,943	1,303,755,943	1,303,755,943	1,303,755,943
15	1,049,905,035		475,448,931	475,448,931	475,448,931	475,448,931	475,448,931	1,525,353,966	1,525,353,966	1,525,353,966	1,525,353,966	1,525,353,966
16	1,137,093,207		539,793,582	538,004,973	538,004,973	538,004,973	538,004,973	1,676,886,789	1,676,886,789	1,675,098,180	1,675,098,180	1,675,098,180
17	1,298,910,958		610,276,083	557,449,524	557,449,524	557,449,524	557,449,524	1,909,187,041	1,909,187,041	1,856,360,482	1,856,360,482	1,856,360,482
18	1,470,991,992		687,506,567	637,907,450	637,907,450	637,907,450	637,907,450	2,158,498,559	2,158,498,559	2,108,899,442	2,108,899,442	2,108,899,442
19	1,654,426,445		772,135,745	725,964,817	725,964,817	725,964,817	725,964,817	2,426,562,190	2,426,562,190	2,380,391,262	2,380,391,262	2,380,391,262
20	1,844,678,821		864,874,589	822,345,083	779,815,578	779,815,578	779,815,578	2,709,553,410	2,709,553,410	2,624,494,399	2,624,494,399	2,624,494,399

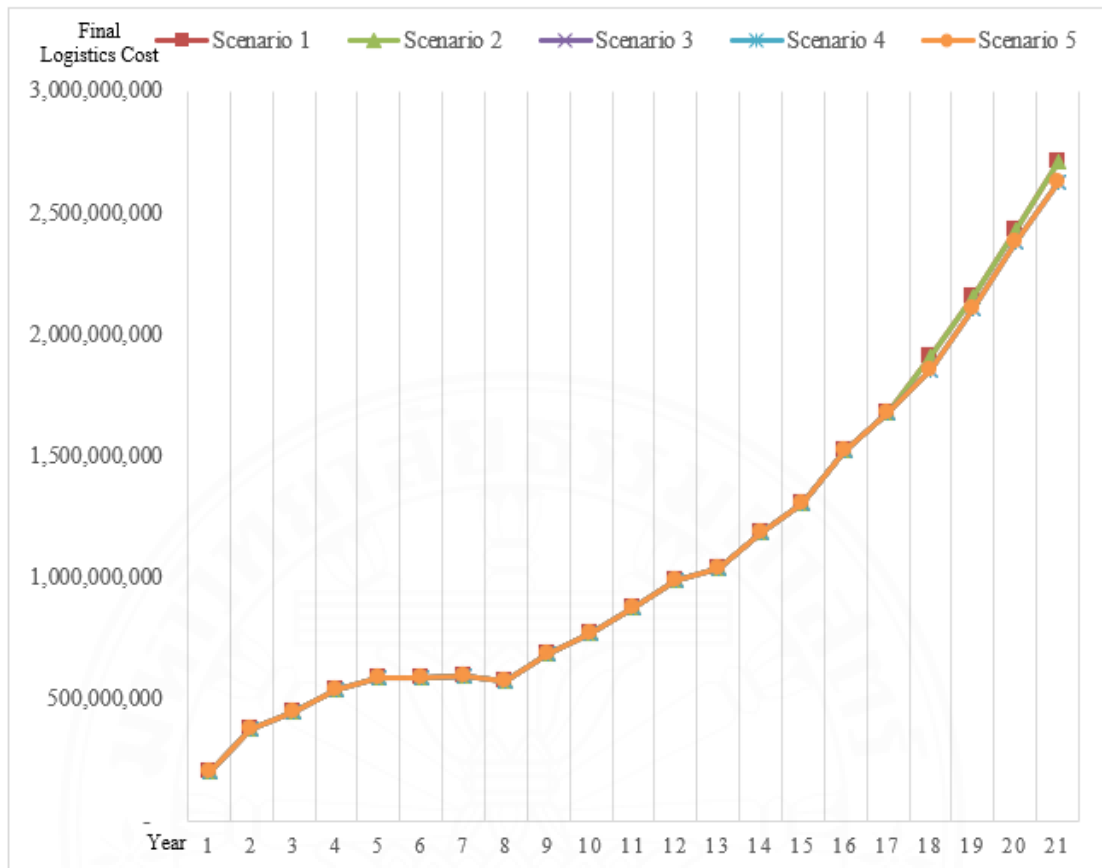


Figure 8.2 Graphical Results of Final Logistics Cost of Block Rubber Transportation when Number of Train Rounds per Day in the Northeastern Region are Changed

The policy analysis results confirm the validity of the developed SD model to be used in the future as only magnitude of the simulation results is changed, while the model behaviour remains the same. The policy analysis results also confirms that the government's policies to support multimodal transportation of block rubber are effective to be implemented in the next 10-15 years. Moreover, continuous support from the government in train's and ship's infrastructure improvement is needed if the demand of block rubber is highly increased from the changes of world's consumption in the future.

CHAPTER 9

CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS FOR FUTURE RESEARCH

This chapter summarizes major findings of this study. Benefits of multimodal transportation, to replace the conventional truck-only transportation, are emphasized in this chapter. The limitations and recommendations for future research are also presented to suggest strategies for long-term development of multimodal transportation efficiency.

9.1 Conclusion

Block rubber, one of Thailand's top exporting agricultural products, is essential to the economic growth of Thailand. To achieve the sustainable growth, the government has embarked on the Free Trade Agreements policy with several countries, such as China, Japan, India, and Australia, thus, bringing the preferential tariffs that lead to the growth in bilateral trade and export opportunities. To this, the government invests in R&D to achieve higher quality products and support in the transport infrastructure and logistics service to reduce the logistics cost and stay competitive in the global market. Several projects, such as multimodal transportation and interconnection facilities, including extensive highway improvement, rail system improvement, and major deep seaports development are established to enhance the transportation network and achieve high transport efficiency (Thailand Board of Investment, 2019).

Multimodal transportation, especially the combinations of truck-train and truck-ship transportation, becomes the government's key plan to reduce the high logistics cost of the traditional truck-only transportation. This is because block rubber, similar to other agricultural products, usually has low price and is transported in big bulks to achieve the economy of scale. Large transport capacities of trains and ships, therefore, are favored to reduce the logistics cost per unit from the production companies to the export point i.e., Laem Chabang, while the transportation from the rubber fields to the production companies still relies on trucks for short-distance transportation. It is expected that multimodal transportation helps utilize the transportation network and

infrastructure to serve high transport demand, reach high transport capacity, achieve the companies' goals in time, costs, and profit aspects, and enhance the country's market competitiveness (Marufuzzaman & Ekşioğlu, 2017; Zhang et al., 2015). Other benefits for both government and business sectors may include energy consumption reduction, transportation efficiency improvement, cargo damage reduction, highway congestion alleviation, energy savings promotion, and greenhouse gas emissions reduction by more than one third of road transportation (Chen et al., 2019; Goh et al., 2008).

To encourage the use of multimodal transportation in Thailand, this study examines insights of multimodal transportation potential in Thailand, including key factors affecting the use of multimodal transportation, the interactions among key multimodal transportation factors, and long-term effects of the use of multimodal transportation to reduce the logistics cost. It is expected that the study results provide the policy recommendations for both government and business sectors to achieve successful multimodal transportation. The study applies the EFA and SEM methods to extract significant factors affecting multimodal transportation usage and examine complex relationships among them. The EFA results summarize five key factors influencing multimodal transportation efficiency of block rubber in Thailand, namely Multimodal Transportation Infrastructure, Operation, Multimodal Service Provider, Market, and Road Constraints factors. The SEM results confirm strong and significant relationships among the five key factors through direct and indirect relationships. Better multimodal transportation-related operations, multimodal transportation market is improved through less use of road transportation and more multimodal service providers in the market. Multimodal transportation-related facilities and infrastructures, such as container yards, track and port improvement, road access to train station and port should also be improved to encourage multimodal service providers to use multimodal transportation in the long term. The results also show that successful multimodal transportation relies on both government and business sectors. Government's improvement in multimodal connection and transportation network attracts more transport service providers to use multimodal transportation. This, in turn, enhances the transport efficiency, reduces the logistics cost, turns Thailand into a major hub of logistics and transportation in the Southeast Asia, and ultimately raises the country's industrial competitiveness on a global scale.

To further investigate the relationships among key multimodal transportation factors, examine logistics cost, and plan for multimodal transportation of block rubber in the long term, the SD model is developed utilizing the SD modeling approach. The developed SD model is simulated, and the results compare the final logistics cost of multimodal transportation with that of the conventional truck-only transportation. It is confirmed that the use of multimodal transportation through truck-ship and truck-train modes minimizes the final logistics cost of block rubber transportation from the origin (rubber fields) to destination (export point i.e., Laem Chabang) in the long term. With the increase of block rubber demand and several government support in multimodal transportation improvement, such as double-track enlargement and port expansion, it is expected that the use of multimodal transportation may help reduce the final logistics cost of block rubber transportation, when compared with the cost of traditional transportation, by 30-100% per year in the next 20 years. It is, therefore, clear that with continuous supports from government in promoting the use of multimodal transportation, the multimodal transportation will bring the great benefit to the country in terms of cost-saving, thus, raising the country's competitiveness in a global scale and achieving sustainable growth and development in the long term.

9.2 Research Contributions

The study provides robust implications for policymakers of government sector and engineering managers of business sector to plan for multimodal transportation that meets the current and future needs. The results prove that multimodal transportation is a solution to reduce the road transportation problems and limitations, thus improving logistics costs and increasing transportation efficiency. These, in turn, raise companies' profitability and ability to compete in the global market.

This study discovers that the successful development of multimodal transportation requires seamless collaboration among government, production companies and transport service providers. The provision of multimodal transportation infrastructure from the government and effective multimodal transportation operations are considered crucial in achieving the multimodal transportation and logistics management efficiencies. The government policymakers should establish a number of supporting policies to attract the use of multimodal transportation to save logistics and

transportation costs (SCB Economic Intelligence Center, 2015). Such policies should focus on the infrastructure improvement and maintaining long-term relationships between production companies and transport service providers to grow the multimodal transportation market. With the government supporting policies, alternative routes with various modes of transportation become more competitive, resulting in challenges in services and costs competitiveness among transport service providers, which eventually lead to reduction of logistics and transportation costs in the long-term. These, as a result, encourage engineering managers to seek suitable combination of transportation modes among road, rail, and water modes, as well as develop long-term relationships with transport service providers to achieve the most benefits of multimodal transportation in the long-term.

In the engineering management perspectives, the selection of combination of transportation modes can be performed systematically utilizing the study results (see Table 6.7). Each combination of transportation modes, for example, truck-train, truck-ship, and truck-train-ship can be assessed and evaluated based on weights (or factor loadings) achieved from the best fit structural model. This will provide the numerical results that are easy to understand and interpret. This assessment helps engineering managers in deciding on transportation modes and routes selection in order to design optimal transportation strategies for a highly volatile market to reduce logistics costs and enhance the market competitiveness. Agricultural production companies in Thailand, regardless of size, may apply the study results in making decisions regarding the multimodal transportation.

9.3 Limitations and Recommendations for Future Research

This research study has some limitations. Key factors affecting the use of multimodal transportation are extracted from literatures that are not specific in Thai context. Some data used in the SD model development are from international literatures and are adjusted to suit with Thai context. Transportation behavior in each country is different depending on culture, stage of technology development, supporting policies, economic power, and regulations. Applying the study results in other geographical areas may require some adjustment from experts. Results comparison could also be performed, between developed and developing countries, to examine similarities and

differences of perceptions regarding multimodal transportation efficiency. Moreover, the lead time of multimodal transportation and newcomers could be added to the SD model due to the ship and train characteristics and limitations, as well as the increasing number of multimodal service providers, respectively.

Although the study results are validated for a particular case study of block rubber transportation in Thailand, the proposed methodology is applicable for the multimodal transportation study of products that can be transported in bulk volume or containers to plan for effective multimodal transportation development in the long term.



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The seal of Thammasat University is a large, faint, circular watermark in the background. It features a central emblem with a crown on top, a lotus flower in the middle, and a base with Thai script. The words "THAMMASAT UNIVERSITY" are written in English around the bottom half of the circle, and Thai script is written around the top half.

APPENDICES

APPENDIX A
QUESTIONNAIRE SURVEY



QUESTIONNAIRE SURVEY

Factors Influencing Multimodal Transportation of Block Rubber in Thailand

Thailand is a major export country of block rubber in the Southeast Asia, and is ranked the first of producer and exporter of the block rubber. However, the transportation in Thailand is mostly based on road transportation, though it costs more than two times of the train and water modes. With a possibility of multimodal transportation, it is expected that the logistic cost of block rubber transportation will be reduced, thus increasing the efficiency of the block rubber transportation.

This questionnaire survey, therefore, aims at gathering the data for statistical analysis to examine key factors influencing multimodal transportation of block rubber in Thailand, as well as their interrelationships. Data collection will be kept confidential, only study results will be published. Please set aside 10 minutes to complete this questionnaire survey. The survey is divided into 2 parts:

- Part I: Demographic information about the respondent and his/her company/organization.
- Part II: Factors influencing multimodal transportation of block rubber in Thailand.

Please do not hesitate to contact me if you require further information

E-mail: pimnapa@siit.tu.ac.th

Part I: Demographic information about the respondent and company.

1. What type of company or organization are you currently working?

- ☐ Block Rubbers Processor
- ☐ Transportation Service Provider
- ☐ Government Sector or Association (Please specify.....)

***Please proceed to part II.**

- ☐ Other (Please specify.....)

2. What is your position in the company?

- ☐ Owner ☐ Executive ☐ Manager
- ☐ Officer ☐ Other (Please specify.....)

3. What is your working experience **in your current company?**
- | | | |
|---|--|---|
| ☐ Less than 1 year | ☐ 1 - 5 years | ☐ 6 - 10 years |
| ☐ 11 - 15 years | ☐ 16 - 20 years | ☐ More than 20 years |
4. What is your working experience **in the block rubber industry or the transportation industry?**
- | | | |
|---|--|--|
| ☐ Less than 1 year | ☐ 1 - 5 years | ☐ 6 - 10 years |
| ☐ 11 - 15 years | ☐ 16 - 20 years | ☐ More than 20 year |
5. Does your company export block rubber through Laem Chabang Port?
- ☐ Yes ☐ No
6. What is the mode of transportation currently used to transport products from the company to Laem Chabang Port?
- | | |
|---|--|
| ☐ Road Mode Only | ☐ Road and Rail Modes |
| ☐ Road and Water Modes | ☐ Road, Rail, and Water Modes |
7. What is the current logistic cost for block rubber transportation in your company?
- | |
|--|
| ☐ Less than 0.50 Baht/ton-kilometer |
| ☐ 0.51 - 1.00 Baht/ton-kilometer |
| ☐ 1.00 - 1.50 Baht/ton-kilometer |
| ☐ 1.51 - 2.00 Baht/ton-kilometer |
| ☐ 2.00 - 2.50 Baht/ton-kilometer |
| ☐ 2.51 - 3.00 Baht/ton-kilometer |
| ☐ More than 3.00 Baht/ton-kilometer |

Part II: Items influencing multimodal transportation efficiency of agricultural products in Thailand.

Statements below reflect 20 items influencing multimodal transportation efficiency of agricultural products in Thailand. **Please indicate level of your agreement** on each statement based on your experience.

1 = Strongly Disagree

2 = Disagree

3 = Neither agree nor disagree

4 = Agree

5 = Strongly Agree

NO.	Statement	Level				
		1	2	3	4	5
1.	Government policy supporting the multimodal transportation (GOV)					
2.	Road traffic congestion (TRF)					
3.	Law enforcement on truck driving hours (LAW)					
4.	Accident occurrence during road transportation (ACD)					
5.	Adequacy of multimodal transportation service providers (SER)					
6.	Good relationship between company and transport service providers (REL)					
7.	Punctuality of multimodal transportation (PUN)					
8.	Delivery speed of multimodal transportation from company to the export point (i.e. Laem Chabang Port) (SPD)					
9.	Easy access to Container Yard (CY) or port (ACY)					
10.	Sufficient Capacity of Container Yard (CY) or port (CAP)					
11.	Effective transshipment equipment for the multimodal transportation (EQP)					
12.	Low transshipment cost (TSC)					
13.	Information sharing on tracking system (TRK)					
14.	Volume flexibility in multimodal transportation (VOL)					
15.	Efficient locomotive and carriage or barge (DSN)					
16.	Low logistic cost using the multimodal transportation (LOG)					
17.	Company's green image using the multimodal transportation (IMG)					
18.	Ability to compete in multimodal transportation market (MKT)					
19.	Skilled employees in modal shift processes (EMP)					

NO.	Statement	Level				
		1	2	3	4	5
20.	Less documentation procedure (DOC)					

Please suggest or comment issues related to the multimodal transportation.

.....

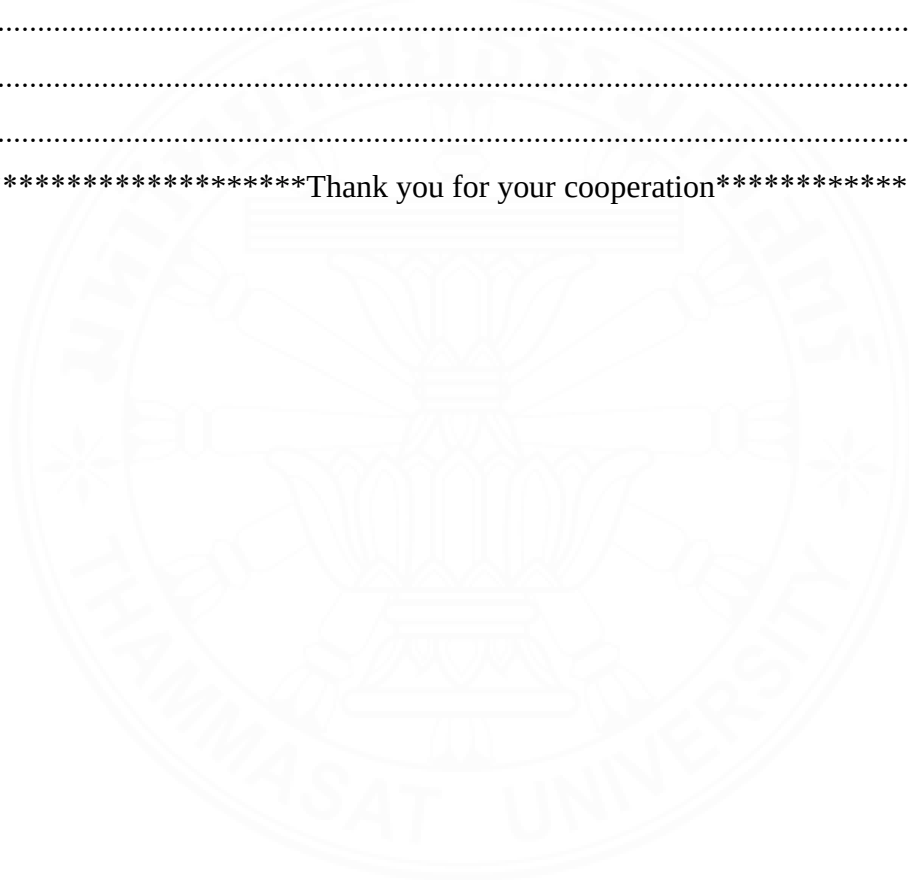
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*****Thank you for your cooperation*****



APPENDIX B

**A LIST OF 287 BLOCK RUBBER COMPANIES, TRANSPORT
SERVICE PROVIDERS, TRANSPORTATION AND RUBBER
POLICY-RELATED GOVERNMENT SECTORS,
AND ASSOCIATIONS**



BLOCK RUBBER COMPANIES

No.	Company's Name
1	Supara Co., Ltd.
2	Thaimac S.T.R. Co., Ltd. (Krabi Branch)
3	Thaimac S.T.R. Co., Ltd. (Headquarter)
4	P. J. Rubber Co., Ltd.
5	Thai Rubber HPNR Co., Ltd. (Chumpon Branch)
6	Thai Rubber HPNR Co., Ltd. (Pang-nga Branch)
7	Thai Rubber HPNR Co., Ltd. (Samut Prakan Branch)
8	Guangken Rubber Co., Ltd. (Satul Branch)
9	Jovi Rubber (Thailand) Co., Ltd.
10	Thaitech Rubber Corporation Co., Ltd. (Trang Branch)
11	Thaitech Rubber Corporation Co., Ltd. (Songkhla Branch)
12	Thaitech Rubber Corporation Co., Ltd. (Pattani Branch)
13	Thungyai Rubber Co., Ltd. (Songkhla Branch)
14	Thungyai Rubber Co., Ltd. (Nakhon Si Thammarat Branch)
15	Trang Latex Co., Ltd. (Headquarter)
16	Trang Latex Co., Ltd. (Phuket Branch)
17	Teck Bee Hang Co., Ltd. (Thung Song Branch)
18	Teck Bee Hang Co., Ltd. (Songkhla Branch)
19	Teck Bee Hang Co., Ltd. (Narathiwat Branch)
20	Teck Bee Hang Co., Ltd. (Pattani Branch)
21	Southland Resources Co., Ltd. (Songkhla Branch)
22	Southland Resources Co., Ltd. (Nakhon Si Thammarat Branch)
23	Srijaroen Karnyang Co., Ltd. (Nakhon Si Thammarat Branch)
24	Srijaroen Karnyang Co., Ltd. (Narathiwat Branch)
25	Mitrathai Holding Co., Ltd.
26	Tong Thai Nabon Co., Ltd.
28	P.K. Rubber Co., Ltd.
29	MT Centertrade Co., Ltd.

30	L.T. Rubber Co., Ltd.
31	Siam Indo Rubber Co., Ltd. (Phatthalung Branch)
32	Siam Indo Rubber Co., Ltd. (Songkhla Branch)
33	Phatthalung Paratex Co., Ltd. (Phatthalung Branch)
34	Phatthalung Paratex Co., Ltd. (Songkhla Branch)
35	Phattex TTR Co., Ltd. (Phatthalung Branch)
36	Phattex TTR Co., Ltd. (Songkhla Branch)
37	J.P. Rubber Co., Ltd.
38	Muang Mai Guthrie Public Co., Ltd. (Phuket Branch)
39	Teck Bee Hang Co., Ltd. (Yala Branch)
40	Mardec – Yala Co., Ltd.
41	Chip Yoo Latex Co., Ltd.
42	A A Rubber Co., Ltd.
43	Yala Latex Industry Co., Ltd.
44	Pan Rubber Industries Co., Ltd.
45	Tavorn T.T.R. Industry Co., Ltd.
46	Maltech Rubber Co., Ltd.
47	Sadao P.S. Ruber Co., Ltd.
48	Bridgestone Natural Rubber (Thailand) Co., Ltd.
49	Top Glove Technology Co., Ltd.
50	E Hup Huat Co., Ltd.
51	Pro Star Rubber Co., Ltd.
52	Hadsyn Latex Co., Ltd.
53	A1 Rubber Co., Ltd.
54	Sumirubber Thai Eastern Corporation Co., Ltd.
55	Teck Lay T.T.R. Co., Ltd.
56	Southland Rubber Co., Ltd.
57	Thaima Rubber Co., Ltd.
58	Hua Tai Rubber Co., Ltd.
59	Thai Goodland Rubber Co., Ltd.

60	Chana Latex Co., Ltd.
61	Chalong Latex Industry Co., Ltd.
62	Hitech Rubber Ventures Co., Ltd.
63	Nam Hur Rubber Co., Ltd.
64	Guangken Rubber Co.,Ltd. (Udon Thani Branch)
65	Guangken Rubber Co.,Ltd. (Nakhon Panom Branch)
66	Guangken Rubber Co.,Ltd. (Surat Thani Branch)
67	Guangken Rubber Co.,Ltd. (Chumpon Branch)
68	Guangken Rubber Co.,Ltd. (Chumpon Branch)
69	Guangken Rubber Co.,Ltd. (Trang Branch)
70	Inter Rabber Latex Co.,Ltd.
71	Euro-Oriental Rubbers Co.,Ltd.
72	YT Rubber Co.,Ltd.
73	Suratsiripiriya (1999) Co.,Ltd.
74	Best Latex Co.,Ltd.
75	Muang Mai Guthrie Co.,Ltd.
76	Thai Hua Rubber Co., Ltd. (Buriram Branch)
77	Thai Hua Rubber Co., Ltd. (Buengkan Branch)
78	Thai Hua Rubber Co., Ltd. (Udon Thani Branch)
79	Thai Hua Rubber Co., Ltd. (Songkhla Branch)
80	Thai Hua Rubber Co., Ltd. (Trang Branch)
81	Thai Hua Rubber Co., Ltd. (Krabi Branch)
82	Thai Hua Rubber Co., Ltd. (Surat Thani Branch)
83	Sri Trang Agro Industry Co., Ltd. (Trang Branch)
84	Sri Trang Agro Industry Co., Ltd. (Songkhla Branch)
85	Sri Trang Agro Industry Co., Ltd. (Nakhon Si Thammarat Branch)
86	Sri Trang Agro Industry Co., Ltd. (Surat Thani Branch)
87	Sri Trang Agro Industry Co., Ltd. (Udon Thani Branch)
88	Sri Trang Agro Industry Co., Ltd. (Ubon Ratchathani Branch)
89	Rubber Land Products Co., Ltd. (Songkhla Branch)

90	Rubber Land Products Co., Ltd. (Buengkan Branch)
91	Rubber Land Products Co., Ltd. (Buriram Branch)
92	Rubber Land Products Co., Ltd. (Mukdahan Branch)
93	Lee Ta Rubber Tree (Thailand) Co., Ltd.
94	Sunny Way Rubber (Thailand) Co., Ltd.
95	Lahan Sai Rubber & Latex Co., Ltd.
96	Thai Savy Rubber Co., Ltd.
97	Vonbundit Co., Ltd. (Udon Thani Branch)
98	Vonbundit Co., Ltd. (Trang Branch)
99	Vonbundit Co., Ltd. (Surat Thani Branch)
100	Vonbundit Co., Ltd. (Phuket Branch)
101	Vonbundit Co., Ltd. (Krabi Branch)
102	Vonbundit Co., Ltd. (Chumpon Branch)
103	Varin Rubber Co., Ltd.
104	GT Rubber Co., Ltd.
105	Chunjaroen Rubber Co., Ltd.
106	Xin Yuan Da Rubber Co., Ltd.
107	South-East Rubber Co., Ltd.
108	Thong Thai A.S. Co., Ltd.
109	Thong Thai N.B. Co., Ltd.
110	Thungsong Sisawad Co., Ltd.
111	Thai Seng Rubber Co., Ltd.
112	Thai Yaree Rubber Co., Ltd.
113	Northeast Rubber Co., Ltd.
114	Niyom Rubber Co., Ltd.
115	B Right Rubber Co., Ltd.
116	P.C. Rubber Co., Ltd.
117	Pianpradit Rubber Co., Ltd.
118	Yonglong Rubber Co., Ltd.
119	Unimac Rubber Co., Ltd.

120	Thai Rubber Joint Venture Co., Ltd.
121	Sangtvon Rubber Co., Ltd.
122	Nteq Polymer Co., Ltd.
123	MT Centertrade Co., Ltd.
124	S. K. Polymer Co., Ltd.
125	S. C. Winner Rubber Co., Ltd.
126	Tongthai Rubber Co., Ltd.
127	Union Rubber Products Corporation Co., Ltd.
128	A. M. Latex Co., Ltd.
129	Tongthai Technical Rubber Co., Ltd.
130	E. Q. Rubber Co., Ltd.
131	Sawang Latex and Ruby Mining Co., Ltd.
132	Prc Compounder Co., Ltd.
133	Pan Asia Bio Technology Co., Ltd.
134	Rubber Planet Co., Ltd.
135	Sinthong Thai Rubber Co., Ltd.
136	Maruey S T R Co., Ltd.
137	Kuriyama-Ohji (Thailand) Co., Ltd.
138	2555VSK Rubber
139	Siam Interrubber Co., Ltd.
140	Euro-Oriental Rubbers Co., Ltd.
141	Krittikan Rubber Co., Ltd.
142	Safe Glove Co., Ltd.
143	Thung Song Si Sawat Co., Ltd.
144	Uni Rubber Co., Ltd.
145	S. Jundee Rubber Inter Trade Co., Ltd.
146	Na Bon Rubber Co., Ltd.
147	GT Rubber Co., Ltd.
148	A.T.S. Rubber Co., Ltd.
149	PP & B Rubber Industial Co., Ltd.

150	T.T. Latex&Products Co., Ltd.
151	Thung Yai Rubber Co., Ltd.
152	Sritong Rubber Latex Co., Ltd.
153	Healthy Glove Co., Ltd.
154	Krabi Para Rubber Co., Ltd.
155	B Right Rubber Co., Ltd.
156	Phangnga Pattanakij Rubber Co., Ltd.



TRANSPORT SERVICE PROVIDERS

No.	Company's Name
1	Asia Logistics Co., Ltd.
2	S.V. Transport and Service Co., Ltd.
3	Four companions of Transportation (1988) Co., Ltd. (Surat Thani Branch)
4	Four companions of Transportation (1988) Co., Ltd. (Nakhon Si Thammarat Branch)
5	Four companions of Transportation (1988) Co., Ltd. (Songkhla Branch)
6	Starlight Express Transport Co., Ltd.
7	Mod Ta Noy Logistics Co., Ltd.
8	V-Serve Transport Co., Ltd. (Songkhla Branch)
9	V-Serve Transport Co., Ltd. (Surat Thani Branch)
10	Smart Way Transport Co., Ltd.
11	RTN Logistics Co., Ltd.
12	T.K. Logistics and Supply Chain (Thailand) Co., Ltd.
13	Hatairat Transport Co., Ltd.
14	C.P.B Transport Co., Ltd.
15	Udjima Transport Limited Partnership
16	S.B.T. Transport Co., Ltd.
17	Kamphang Phetchanapoon Transport Co., Ltd.
18	S P C Service Management Co., Ltd.
19	Pailin Daeng Co., Ltd.
20	V.S.K. Service Group Co., Ltd.
21	Evergreen Container Terminal (Thailand) Co., Ltd.
22	Evergreen Container (Thailand) Co., Ltd.
23	N. V. P. Transport Co., Ltd.
24	Mongkol Service and Transport Limited Partnership
25	Choksomnai Trasport Co., Ltd.
26	Choksommai 914 Transport Co., Ltd.
28	Choke Boonchuay Transport Limited Partnership
29	Inland Container Delivery Co., Ltd.

30	Chaichana Transport Group Co., Ltd.
31	Dynamic Transport Co., Ltd.
32	S. Siri Transport Co., Ltd.
33	Tiffa Co., Ltd.
34	Krungthep Container Service Co., Ltd.
35	Con Center Co., Ltd.
36	Nanon (Thailand) Co., Ltd.
37	Prommas Transport Limited Partnership
38	Theparaj Logistics Co., Ltd.
39	Bangplee Container Limited Partnership
40	Larp Tor Larp Co., Ltd.
41	Tiffa EDI Services Co., Ltd.
42	SP.44 Transport Co., Ltd.
43	Aun Container & Transport Co., Ltd.
44	Aun Container Co., Ltd.
45	World Freight (1986) Co., Ltd.
46	N.R.T. Shipping Co., Ltd.
47	Thong Chai Noppakhun Transport Co., Ltd.
48	Thongsin Logistics Co., Ltd. (Nakhon Si Thammarat Branch)
49	Thongsin Logistics Co., Ltd. (Songkhla Branch)
50	Thongsin Logistics Co., Ltd. (Surat Thani Branch)
51	Roj Thongsin Transport Co., Ltd.
52	Siam First Express Cargo Co., Ltd.
53	Bangpleeyai Transport Co., Ltd.
54	GT Transport Co., Ltd.
55	MSGT & GB Transport Limited Partnership
56	MGT Transport Co., Ltd.
57	GT Transport 2012 Co., Ltd.
58	VMT Transport Co., Ltd.
59	Chalothon Transport (99) Co., Ltd.

60	Srithamarat Transport Co., Ltd.
61	Nakburin Limited Partnership
62	Green Yellow Transport (Thailand) Co., Ltd.
63	MBT Transport Co., Ltd.
64	BCK Logis Co., Ltd.
65	Bo and Orn Transport Co., Ltd.
66	JWD InfoLogistics Public Co., Ltd.
67	V-SERVE Logistics Co., Ltd.
68	SCG Logistics Co., Ltd.
69	Freight Links Express (Thailand) Co., Ltd.
70	Centran International Corporation (Thailand) Co., Ltd.
71	Wen-Parker Logistics Co., Ltd.
72	Handle Inter Expres Co., Ltd.
73	ATG Logistics Co., Ltd.
74	Comprehensive Cargo Management Co., Ltd.
75	MOL Logistics (Thailand) Co., Ltd.
76	Royal Marine – Container Lines Co., Ltd.
77	Grand Emporium Logistics Co., Ltd.
78	V-Friend Logistics Co., Ltd.
79	Tkr Shipping International Co., Ltd.
80	LiDi Express Co., Ltd.
81	Tongsuen Logistics Co., Ltd.
82	Hitachi Transport System Vantec (Thailand) Co., Ltd.
83	WICE Logistics Public Co., Ltd.
84	CPL Inter-Logistics Co., Ltd.
85	Sixth Party Logistics Co., Ltd.
86	Damco Logistics (Thailand) Co., Ltd.
87	Ratchasi Co., Ltd.
88	KTC Global Logistics Co., Ltd.
89	Asuto Global Logistics (Thailand) Co., Ltd.

90	MKC (Thailand) Co., Ltd.
91	Seals Thai Inter Co., Ltd.
92	Prakredee Transport Co., Ltd.
93	Cheera Distribution&Logistics Limited Partnership
94	Unique Translink Co., Ltd.
95	SK Transport Co., Ltd.
96	Pornvatana Shipping Services Co., Ltd.
97	Byond Logistics Co., Ltd.
98	Freight Rangers Co., Ltd.
99	Good Freight and Transports Co., Ltd.
100	PJR - Logistics Co., Ltd.
101	Pornvatana Shipping Services Co., Ltd.
102	88 Logistics Co., Ltd.
103	Sakoonmunrungrueng Transport Limited Partnership
104	Lnxgistics Inter Freight Co., Ltd.
105	Siam Shipping Co., Ltd.
106	P&P Inter Transport Co., Ltd.
107	Maersk Line (Thailand) Co., Ltd.

TRANSPORTATION AND RUBBER POLICY-RELATED GOVERNMENT SECTORS AND ASSOCIATIONS

No.	Company's Name
1	Office of the National Economic and Social Development Council
2	The Office of Transport and Traffic Policy and Planning
3	State Railway of Thailand
4	Port Authority of Thailand
5	Rubber Authority of Thailand
6	State Enterprise Policy Office
7	Department of Highways
8	Department of Rural Roads
9	Nong Ta Kai CY Train Station
10	Ban Thung Pho CY Train Station
11	Panja Port, Surat Thani Province
12	N P Marine Port, Surat Thani Province
13	Laem Chabang Port, Bangkok
14	Department of Land Transport
15	Department of International Trade Promotion, Ministry of Commerce
16	Imports-Export Transport Association
17	Southern Transport Association
18	Northeastern Transport Association
19	Transportation and Logistics Association
20	Inland Transportation Association
21	Water Transportation Association
22	Rail Transportation Association
23	Thai Rubber Association
24	Thai Federation of Logistics

APPENDIX C
STANDARDIZED SCORES (Z – SCORES) RESULT



Response NO.	z-score															
	zGOV	zTRF	zLAW	zACD	zSER	zREL	zPUN	zSPD	zACY	zCAP	zEQP	zTSC	zTRK	zVOL	zDSN	zLOG
36	0.25	-0.66	-0.47	0.44	1.32	1.48	-0.21	-0.12	0.20	0.15	1.36	0.05	0.31	-0.97	-0.73	-2.25
37	-0.98	0.41	0.63	-0.62	1.32	-0.99	-0.21	-2.82	0.20	0.15	-1.52	0.05	0.31	-0.97	1.56	-1.03
38	0.25	0.41	-1.58	0.44	0.11	1.48	1.05	-0.12	0.20	-0.93	-0.08	1.31	0.31	1.60	0.42	-2.25
39	0.25	0.41	-1.58	-0.62	1.32	1.48	1.05	-1.47	0.20	-0.93	-1.52	1.31	1.54	0.32	0.42	-2.25
40	0.25	-0.66	-0.47	0.44	0.11	1.48	1.05	1.23	0.20	0.15	-0.08	1.31	1.54	0.32	1.56	0.18
41	-2.20	0.41	0.63	0.44	1.32	0.25	-0.21	-1.47	-0.92	0.15	-0.08	1.31	1.54	0.32	-1.87	1.40
42	1.47	0.41	-0.47	-0.62	-1.11	-0.99	-1.46	-1.47	-0.92	0.15	-0.08	0.05	0.31	0.32	1.56	-1.03
43	0.25	0.41	1.74	0.44	-1.11	0.25	1.05	-1.47	-0.92	-0.93	-1.52	-1.21	0.31	0.32	-0.73	-1.03
44	1.47	0.41	0.63	0.44	1.32	0.25	-1.46	-1.47	-0.92	-0.93	-1.52	0.05	0.31	0.32	0.42	0.18
45	-0.98	-1.72	-1.58	-1.69	-2.33	-0.99	1.05	1.23	1.33	1.23	1.36	1.31	1.54	-0.97	0.42	1.40
46	0.25	0.41	-0.47	0.44	-1.11	0.25	-0.21	-0.12	-0.92	1.23	-0.08	-1.21	0.31	0.32	0.42	0.18
47	0.25	1.47	0.63	-0.62	0.11	-0.99	-1.46	-0.12	0.20	-0.93	1.36	1.31	0.31	-0.97	0.42	1.40
48	0.25	1.47	0.63	-0.62	-1.11	0.25	-1.46	-1.47	-0.92	-2.01	-2.96	-1.21	-0.92	0.32	-0.73	1.40
49	0.25	0.41	1.74	1.51	1.32	1.48	1.05	1.23	-0.92	-0.93	-1.52	-1.21	0.31	-0.97	0.42	0.18
50	0.25	-0.66	0.63	-1.69	-1.11	-0.99	-1.46	-1.47	-0.92	-0.93	-0.08	-1.21	1.54	-0.97	-0.73	-1.03
51	1.47	0.41	0.63	0.44	0.11	0.25	1.05	1.23	1.33	0.15	-0.08	1.31	1.54	0.32	0.42	0.18
52	0.25	0.41	0.63	1.51	0.11	1.48	1.05	1.23	0.20	0.15	1.36	-1.21	0.31	-0.97	-0.73	1.40
53	0.25	0.41	-0.47	-1.69	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	0.32	0.42	1.40
54	0.25	1.47	0.63	0.44	0.11	0.25	-2.72	-1.47	-0.92	-2.01	-2.96	-1.21	-2.16	-2.26	-0.73	-2.25
55	0.25	1.47	0.63	0.44	0.11	0.25	-1.46	-1.47	-0.92	-0.93	-0.08	-2.47	-2.16	-2.26	-0.73	-2.25
56	-0.98	1.47	0.63	0.44	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	0.32	0.42	0.18
57	-0.98	0.41	-0.47	-0.62	-1.11	-0.99	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	0.32	-1.87	-1.03
58	0.25	1.47	0.63	0.44	0.11	-0.99	1.05	1.23	-0.92	-0.93	-1.52	0.05	-0.92	0.32	-1.87	0.18
59	-0.98	-0.66	-0.47	-0.62	-1.11	0.25	-1.46	-2.82	-0.92	-0.93	-1.52	-1.21	-0.92	-0.97	-0.73	-1.03
60	0.25	-0.66	0.63	-1.69	0.11	0.25	-0.21	-0.12	-0.92	0.15	-0.08	1.31	1.54	0.32	-1.87	1.40
61	0.25	1.47	-0.47	1.51	1.32	1.48	1.05	1.23	1.33	1.23	1.36	1.31	1.54	0.32	1.56	1.40
62	-0.98	-0.66	-0.47	-0.62	0.11	-0.99	-1.46	-0.12	-0.92	-0.93	-1.52	0.05	0.31	0.32	-0.73	-1.03
63	0.25	1.47	0.63	1.51	1.32	1.48	1.05	1.23	0.20	1.23	1.36	1.31	1.54	1.60	1.56	1.40
64	0.25	0.41	0.63	0.44	1.32	1.48	1.05	1.23	0.20	0.15	-0.08	1.31	0.31	0.32	0.42	0.18
65	0.25	0.41	0.63	0.44	1.32	1.48	1.05	-0.12	1.33	1.23	-0.08	1.31	0.31	-2.26	0.42	0.18
66	0.25	0.41	0.63	0.44	1.32	1.48	1.05	-0.12	1.33	1.23	-0.08	1.31	0.31	-2.26	0.42	0.18
67	-2.20	-0.66	0.63	0.44	-1.11	-0.99	-1.46	-0.12	-0.92	-0.93	-1.52	0.05	-0.92	-0.97	-0.73	-1.03
68	-0.98	0.41	0.63	0.44	0.11	-0.99	-1.46	-1.47	-0.92	-0.93	-0.08	0.05	-0.92	-0.97	-0.73	0.18
69	-0.98	1.47	1.74	0.44	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	-0.92	-0.97	0.42	1.40
70	-0.98	-0.66	0.63	-0.62	0.11	0.25	-1.46	-0.12	0.20	0.15	-0.08	0.05	-2.16	-0.97	-0.73	-1.03

Response NO.	z-score																			
	zGOV	zTRF	zLAW	zACD	zSER	zREL	zPUN	zSPD	zACY	zCAP	zEQP	zTSC	zTRK	zVOL	zDSN	zLOG	zIMG	zMKT	zEMP	zDOC
71	-0.98	0.41	0.63	0.44	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	0.32	0.42	0.18	0.28	0.26	0.52	0.40
72	-0.98	-0.66	0.63	-0.62	-1.11	-0.99	-1.46	-1.47	-0.92	0.15	-1.52	-1.21	-0.92	0.32	-0.73	-1.03	-0.89	-0.93	-0.63	-0.83
73	-2.20	-0.66	0.63	0.44	0.11	-0.99	-0.21	-0.12	0.20	0.15	-0.08	1.31	0.31	-0.97	-0.73	0.18	0.28	1.45	0.52	0.40
74	0.25	1.47	0.63	1.51	1.32	0.25	-0.21	-0.12	0.20	0.15	1.36	1.31	1.54	0.32	1.56	1.40	0.28	1.45	0.52	1.63
75	0.25	0.41	0.63	0.44	0.11	-0.99	1.05	1.23	0.20	0.15	-0.08	1.31	0.31	0.32	-0.73	0.18	0.28	0.26	-0.63	0.40
76	0.25	0.41	-0.47	0.44	0.11	0.25	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-1.87	0.18	0.28	0.26	0.52	0.40
77	0.25	0.41	-0.47	0.44	0.11	1.48	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-1.87	0.18	0.28	0.26	0.52	0.40
78	0.25	0.41	0.63	1.51	1.32	1.48	1.05	-0.12	-0.92	-0.93	-0.08	0.05	0.31	0.32	-0.73	0.18	0.28	0.26	0.52	0.40
79	0.25	0.41	-0.47	0.44	1.32	1.48	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-0.73	0.18	0.28	0.26	0.52	0.40
80	0.25	0.41	-0.47	0.44	0.11	0.25	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-1.87	0.18	0.28	0.26	0.52	0.40
81	-0.98	0.41	1.74	0.44	0.11	0.25	-0.21	1.23	0.20	0.15	-0.08	0.05	0.31	0.32	0.42	0.18	0.28	0.26	0.52	1.63
82	1.47	1.47	-0.47	0.44	0.11	-0.99	-0.21	-0.12	0.20	0.15	-0.08	1.31	0.31	-3.02	1.56	1.40	1.45	1.45	1.67	1.63
83	1.47	1.47	0.63	0.44	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	-2.26	1.56	0.18	1.45	0.26	0.52	0.40
84	-0.98	-0.66	-0.47	-0.62	-1.11	-0.99	-1.46	-1.47	-0.92	-0.93	-1.52	-1.21	-0.92	-0.97	-0.73	-1.03	0.28	0.26	0.52	-0.83
85	1.47	-2.78	-2.69	-2.76	1.32	1.48	1.05	1.23	1.33	1.23	1.36	1.31	1.54	1.60	1.56	1.40	1.45	1.45	-1.78	-0.83
86	0.25	-2.78	-2.69	0.44	-2.33	0.25	-0.21	-0.12	-2.04	1.23	1.36	0.05	-0.92	0.32	1.56	-1.03	0.28	0.26	-2.93	0.40
87	0.25	0.41	-0.47	0.44	0.11	0.25	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-1.87	0.18	0.28	0.26	0.52	0.40
88	0.25	0.41	-0.47	0.44	1.32	1.48	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-0.73	0.18	0.28	0.26	0.52	0.40
89	0.25	0.41	0.63	1.51	1.32	1.48	1.05	-0.12	-0.92	-0.93	-0.08	0.05	0.31	0.32	-0.73	0.18	0.28	0.26	0.52	0.40
90	0.25	0.41	-0.47	0.44	0.11	1.48	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-1.87	0.18	0.28	0.26	0.52	0.40
91	0.25	0.41	-0.47	0.44	0.11	0.25	-0.21	-0.12	-2.04	-2.01	-0.08	0.05	0.31	0.32	-1.87	0.18	0.28	0.26	0.52	0.40
92	0.25	0.41	0.63	0.44	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	0.32	0.42	1.40	1.45	1.45	1.67	1.63
93	-3.05	-1.72	0.63	1.51	-1.11	-0.99	1.05	1.23	1.33	1.23	1.36	1.31	1.54	0.32	0.42	1.40	1.45	1.45	0.52	1.63
94	1.47	1.47	1.74	1.51	1.32	0.25	1.05	1.23	1.33	1.23	1.36	1.31	-0.92	1.60	1.56	1.40	1.45	-0.93	1.67	-0.83
95	0.25	-0.66	-0.47	-0.62	0.11	-0.99	1.05	1.23	-0.92	0.15	-0.08	0.05	-0.92	-0.97	-0.73	0.18	-0.89	-0.93	1.67	-0.83
96	-0.98	0.41	-0.47	-0.62	-2.33	0.25	-0.21	1.23	0.20	0.15	-1.52	0.05	1.54	1.60	-0.73	0.18	1.45	1.45	-1.78	-0.83
97	0.25	-0.66	0.63	1.51	1.32	0.25	1.05	1.23	-0.92	-2.01	-1.52	-2.47	-2.16	-0.97	-0.73	-1.03	-2.06	-2.12	-0.63	-2.05
98	-0.98	0.41	0.63	-0.62	0.11	0.25	-0.21	-0.12	1.33	0.15	-0.08	1.31	1.54	1.60	0.42	1.40	0.28	0.26	-0.63	1.63
99	1.47	1.47	1.74	1.51	1.32	1.48	1.05	1.23	1.33	1.23	1.36	1.31	1.54	1.60	1.56	1.40	0.28	1.45	0.52	-0.83
100	0.25	-0.66	0.63	0.44	0.11	1.48	1.05	-0.12	0.20	-0.93	-0.08	0.05	0.31	0.32	0.42	0.18	1.45	0.26	-0.63	0.40
101	-0.98	0.41	-0.47	0.44	0.11	0.25	-0.21	-0.12	0.20	-0.93	-0.08	-1.21	0.31	0.32	0.42	0.18	0.28	0.26	-0.63	0.40
102	0.25	0.41	0.63	0.44	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	-0.97	0.42	0.18	-0.89	0.26	-0.63	0.40
103	0.25	1.47	0.63	0.44	-1.11	0.25	-0.21	-1.47	0.20	0.15	-0.08	0.05	0.31	0.32	-0.73	-1.03	0.28	-0.93	0.52	0.40
104	1.47	0.41	1.74	0.44	1.32	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	1.60	0.42	1.40	1.45	0.26	0.52	0.40
105	1.47	0.41	0.63	0.44	1.32	0.25	1.05	-0.12	0.20	0.15	1.36	0.05	0.31	0.32	1.56	0.18	0.28	0.26	0.52	1.63

Response NO.	z-score																			
	zGOV	zTRF	zLAW	zACD	zSER	zREL	zPUN	zSPD	zACY	zCAP	zEQP	zTSC	zTRK	zVOL	zDSN	zLOG	zIMG	zMKT	zEMP	zDOC
106	1.47	1.47	0.63	1.51	0.11	1.48	1.05	-0.12	0.20	1.23	1.36	1.31	1.54	0.32	0.42	0.18	1.45	0.26	0.52	0.40
107	-0.98	-0.66	-1.58	-0.62	0.11	0.25	1.05	1.23	0.20	1.23	1.36	0.05	-0.92	0.32	0.42	0.18	0.28	0.26	0.52	-0.83
108	-0.98	0.41	-0.47	-0.62	-1.11	0.25	-1.46	1.23	0.20	0.15	1.36	0.05	0.31	0.32	0.42	0.18	0.28	1.45	0.52	0.40
109	0.25	-0.66	-0.47	-0.62	0.11	0.25	-0.21	-0.12	0.20	0.15	1.36	0.05	0.31	0.32	0.42	0.18	1.45	0.26	0.52	0.40
110	0.25	0.41	-0.47	-0.62	-1.11	0.25	-1.46	-1.47	-0.92	-0.93	-1.52	-1.21	-0.92	-0.97	0.42	0.18	1.45	0.26	0.52	0.40
111	-0.98	0.41	-0.47	-0.62	-1.11	0.25	-0.21	-0.12	0.20	-0.93	-1.52	0.05	-0.92	-0.97	-0.73	-1.03	-0.89	0.26	0.52	0.40
112	0.25	0.41	-0.47	1.51	0.11	0.25	-0.21	-0.12	0.20	-0.93	-0.08	0.05	0.31	0.32	0.42	0.18	0.28	0.26	0.52	0.40
113	1.47	-0.66	-0.47	-0.62	-1.11	-0.99	1.05	-0.12	0.20	1.23	-1.52	-1.21	-0.92	-0.97	-0.73	0.18	-0.89	-0.93	0.52	-0.83
114	-0.98	0.41	-0.47	-1.69	-1.11	0.25	-0.21	-0.12	-0.92	-0.93	-1.52	0.05	0.31	-0.97	-1.87	-1.03	-0.89	-0.93	-0.63	-0.83
115	1.47	-0.66	-0.47	0.44	0.11	0.25	-0.21	-1.47	-0.92	-0.93	-0.08	0.05	0.31	-0.97	0.42	0.18	-0.89	0.26	0.52	0.40
116	0.25	0.41	1.74	1.51	0.11	1.48	1.05	-0.12	1.33	0.15	1.36	0.05	-0.92	0.32	1.56	0.18	0.28	1.45	0.52	1.63
117	0.25	1.47	0.63	0.44	1.32	1.48	-0.21	1.23	-0.92	1.23	-0.08	1.31	0.31	1.60	0.42	0.18	1.45	0.26	1.67	0.40
118	0.25	0.41	1.74	0.44	1.32	0.25	1.05	-0.12	1.33	1.23	1.36	0.05	1.54	0.32	1.56	0.18	0.28	1.45	1.67	0.40
119	0.25	-1.72	-0.47	-2.76	0.11	0.25	1.05	1.23	1.33	0.15	-0.08	0.05	0.31	1.60	1.56	0.18	0.28	1.45	1.67	1.63
120	0.25	-1.72	-0.47	-2.76	0.11	0.25	1.05	1.23	1.33	0.15	-0.08	0.05	0.31	1.60	1.56	1.40	1.45	1.45	0.52	0.40
121	0.25	-1.72	-0.47	-0.62	0.11	-0.99	1.05	1.23	1.33	1.23	1.36	-1.21	-0.92	-0.97	-0.73	0.18	-0.89	-2.12	0.52	-0.83
122	1.47	-0.66	-0.47	-0.62	-1.11	0.25	-0.21	-0.12	1.33	0.15	-0.08	-2.47	-0.92	0.32	0.42	0.18	-0.89	-0.93	-1.78	-0.83
123	0.25	0.41	0.63	-0.62	1.32	0.25	1.05	1.23	1.33	1.23	1.36	1.31	-0.92	1.60	-0.73	1.40	-0.89	-0.93	-0.63	0.40
124	0.25	-1.72	-0.47	-1.69	-1.11	-0.99	1.05	1.23	1.33	1.23	-0.08	0.05	0.31	0.32	-0.73	0.18	-0.89	0.26	-0.63	0.40
125	0.25	-1.72	-1.58	-1.69	-1.11	-2.22	-0.21	-0.12	0.20	0.15	-0.08	0.05	-2.16	-0.97	-0.73	-1.03	-0.89	-0.93	0.52	-0.83
126	-0.98	-1.72	-1.58	-1.69	-1.11	-0.99	1.05	1.23	0.20	1.23	-0.08	0.05	0.31	0.32	0.42	0.18	0.28	-0.93	-0.63	-0.83
127	1.47	-1.72	-0.47	-0.62	0.11	0.25	1.05	1.23	0.20	1.23	1.36	0.05	-0.92	0.32	-0.73	-1.03	-2.06	-2.12	-0.63	0.40
128	-0.98	-1.72	-1.58	-0.62	-1.11	-0.99	-0.21	-0.12	1.33	1.23	-0.08	-1.21	-0.92	0.32	0.42	1.40	-0.89	-0.93	-0.63	0.40
129	0.25	-0.66	0.63	1.51	0.11	0.25	1.05	1.23	1.33	1.23	1.36	1.31	0.31	0.32	-1.87	0.18	0.28	-2.12	-0.63	-0.83
130	1.47	0.41	-0.47	-0.62	-1.11	-0.99	-0.21	-0.12	0.20	0.15	-0.08	-2.47	-2.16	-2.26	-1.87	-1.03	-2.06	-0.93	-1.78	0.40
131	0.25	-0.66	-1.58	0.44	1.32	0.25	1.05	1.23	1.33	1.23	-0.08	-1.21	-0.92	-0.97	-0.73	-1.03	-0.89	-0.93	-1.78	-0.83
132	0.25	0.41	-1.58	-0.62	-1.11	-2.22	-0.21	-0.12	0.20	1.23	-0.08	0.05	0.31	0.32	0.42	0.18	0.28	-0.93	-0.63	0.40
133	1.47	-0.66	-0.47	-0.62	-1.11	-0.99	1.05	1.23	0.20	1.23	-0.08	-1.21	-0.92	-0.97	-0.73	0.18	-0.89	0.26	-0.63	-2.05
134	1.47	-1.72	-1.58	-1.69	-2.33	-2.22	-0.21	-0.12	1.33	1.23	-0.08	-1.21	-2.16	-0.97	-1.87	-1.03	-2.06	-2.12	-1.78	-0.83
135	-0.98	-0.66	-0.47	-0.62	-1.11	-0.99	-0.21	-0.12	0.20	0.15	-0.08	-1.21	-0.92	-0.97	-0.73	0.18	-2.06	0.26	-1.78	0.40
136	0.25	-0.66	-0.47	-0.62	0.11	-0.99	1.05	1.23	1.33	1.23	1.36	1.31	-0.92	0.32	0.42	-2.25	-0.89	-2.12	-0.63	-0.83
137	0.25	-1.72	-1.58	-0.62	0.11	-0.99	1.05	1.23	1.33	1.23	1.36	-1.21	-2.16	-0.97	-1.87	-1.03	-0.89	-2.12	-1.78	-2.05
138	1.47	-0.66	-0.47	-1.69	-1.11	-0.99	-0.21	-0.12	0.20	1.23	1.36	-1.21	-2.16	0.32	-0.73	-1.03	-2.06	-0.93	-1.78	-0.83
139	-0.98	-0.66	-0.47	1.51	0.11	-0.99	1.05	1.23	1.33	1.23	1.36	0.05	-0.92	-0.97	1.56	0.18	-0.89	0.26	0.52	-0.83
140	0.25	0.41	0.63	0.44	0.11	0.25	-0.21	-0.12	0.20	0.15	-0.08	0.05	0.31	0.32	0.42	0.18	0.28	0.26	-1.78	0.40

APPENDIX D

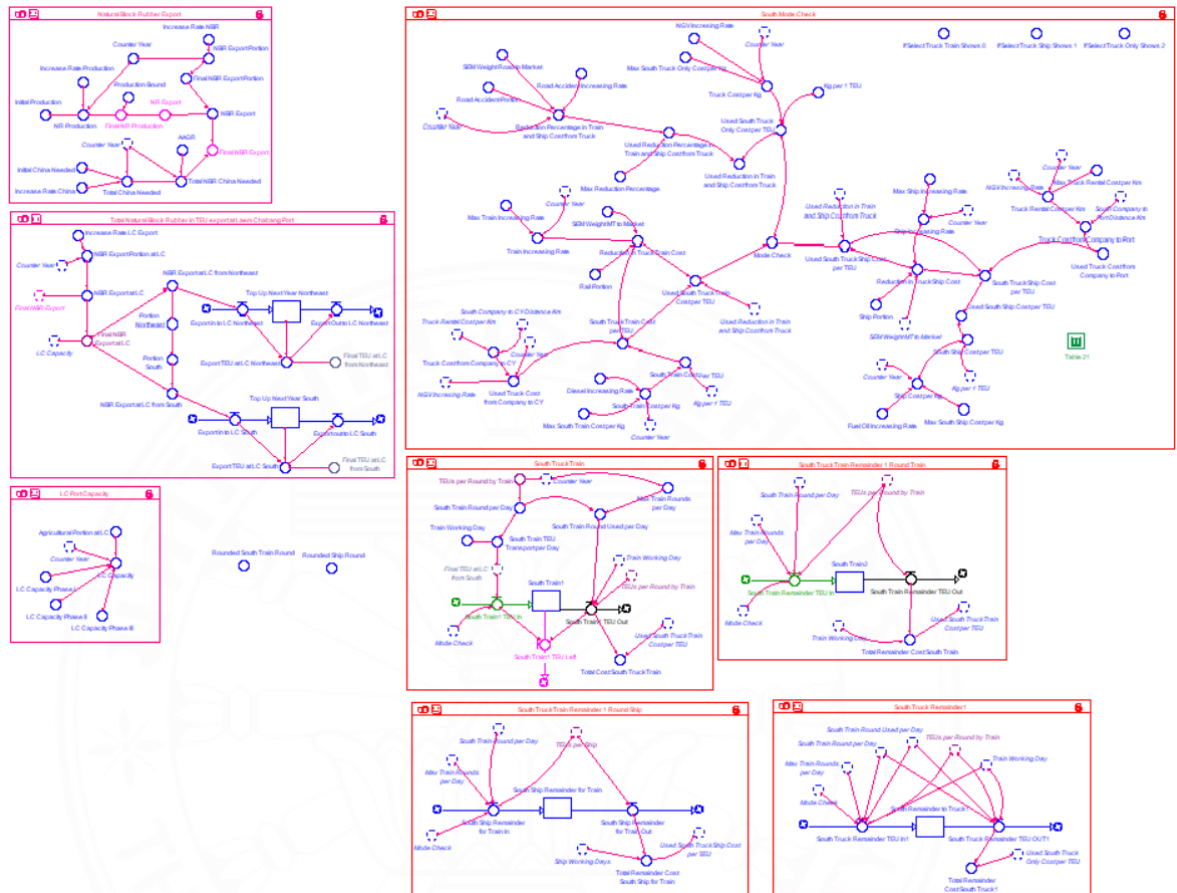
SYSTEM DYNAMICS MODEL FOR SUCCESSFUL

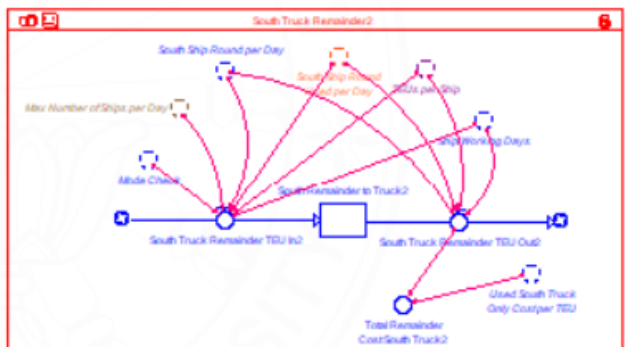
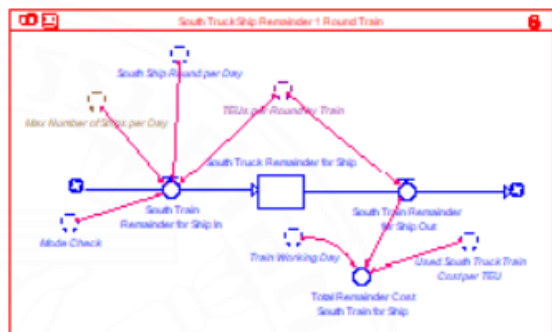
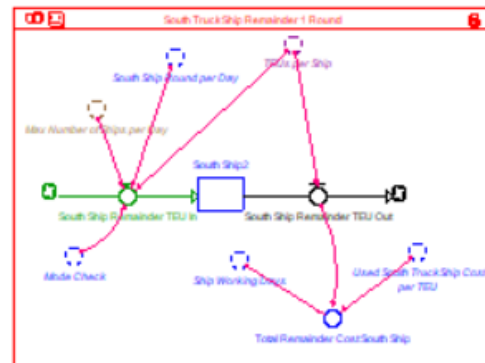
MULTIMODAL TRANSPORTATION OF BLOCK RUBBER IN

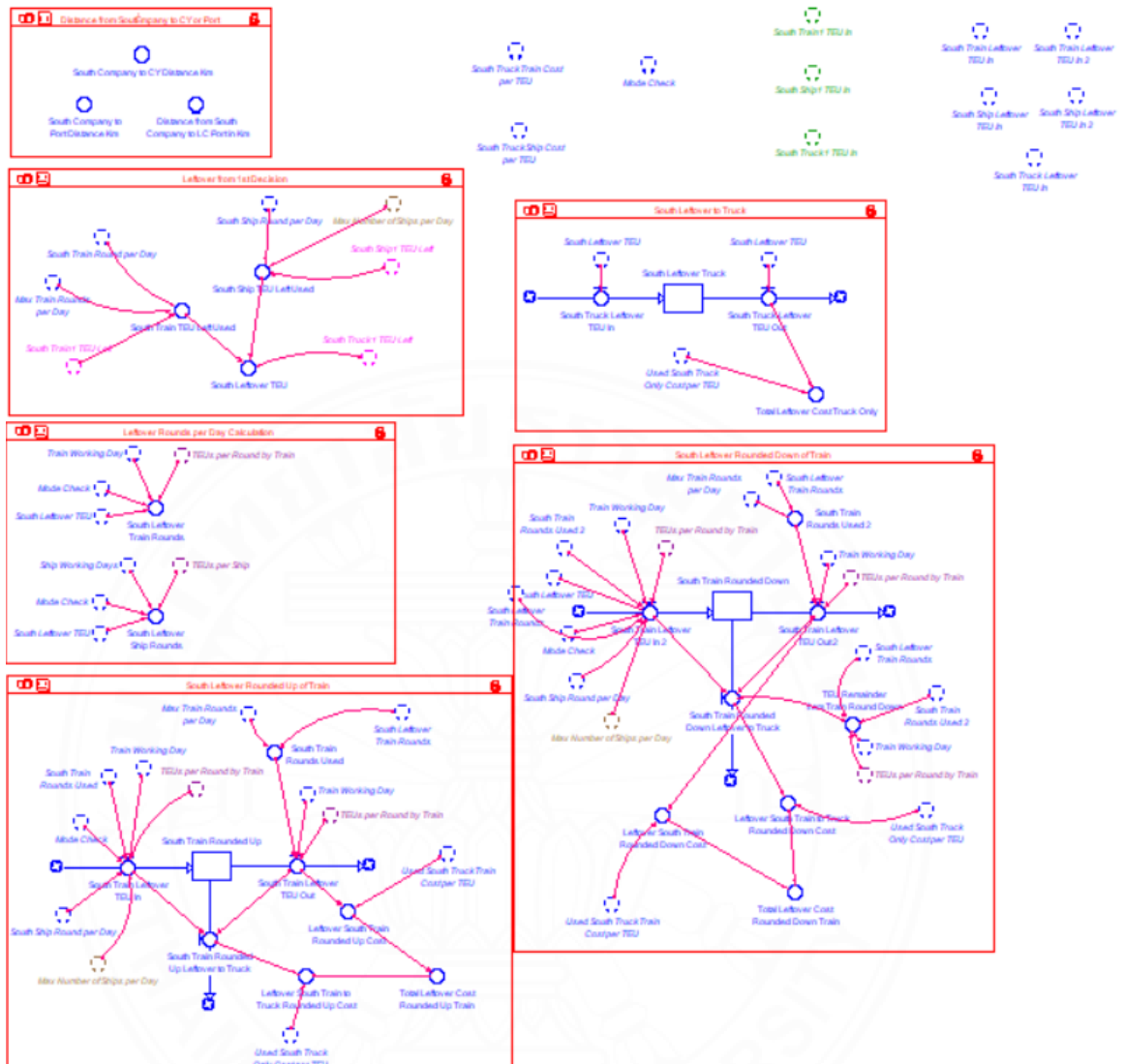
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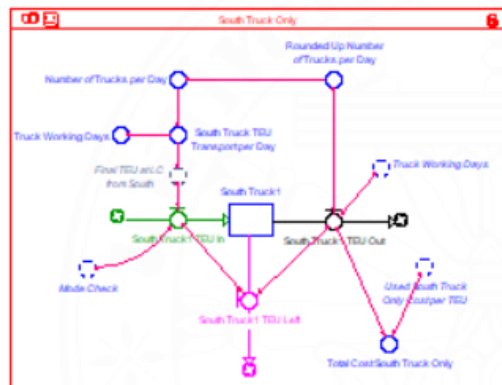
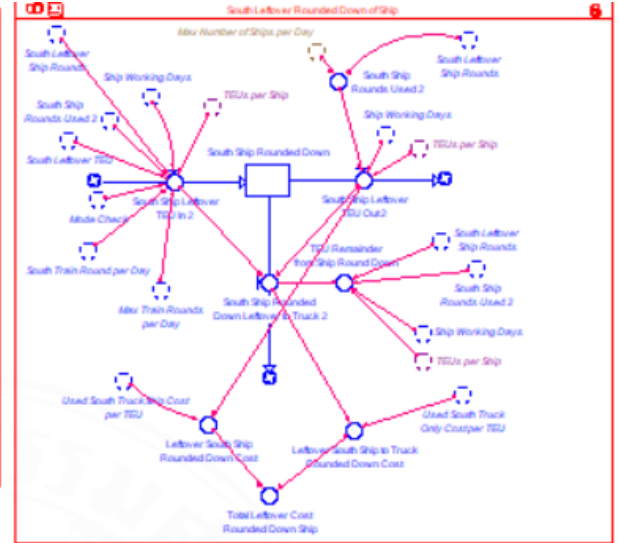
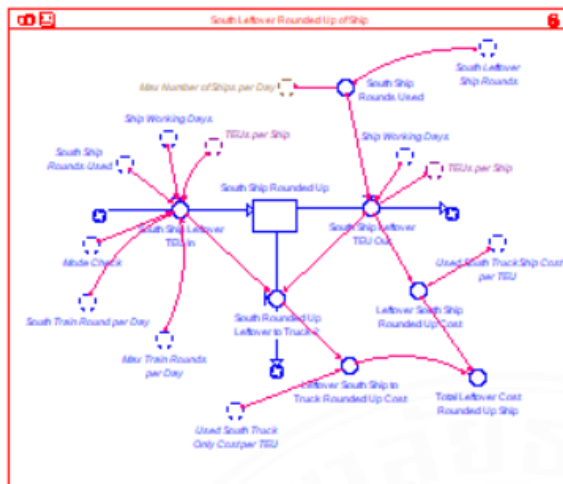


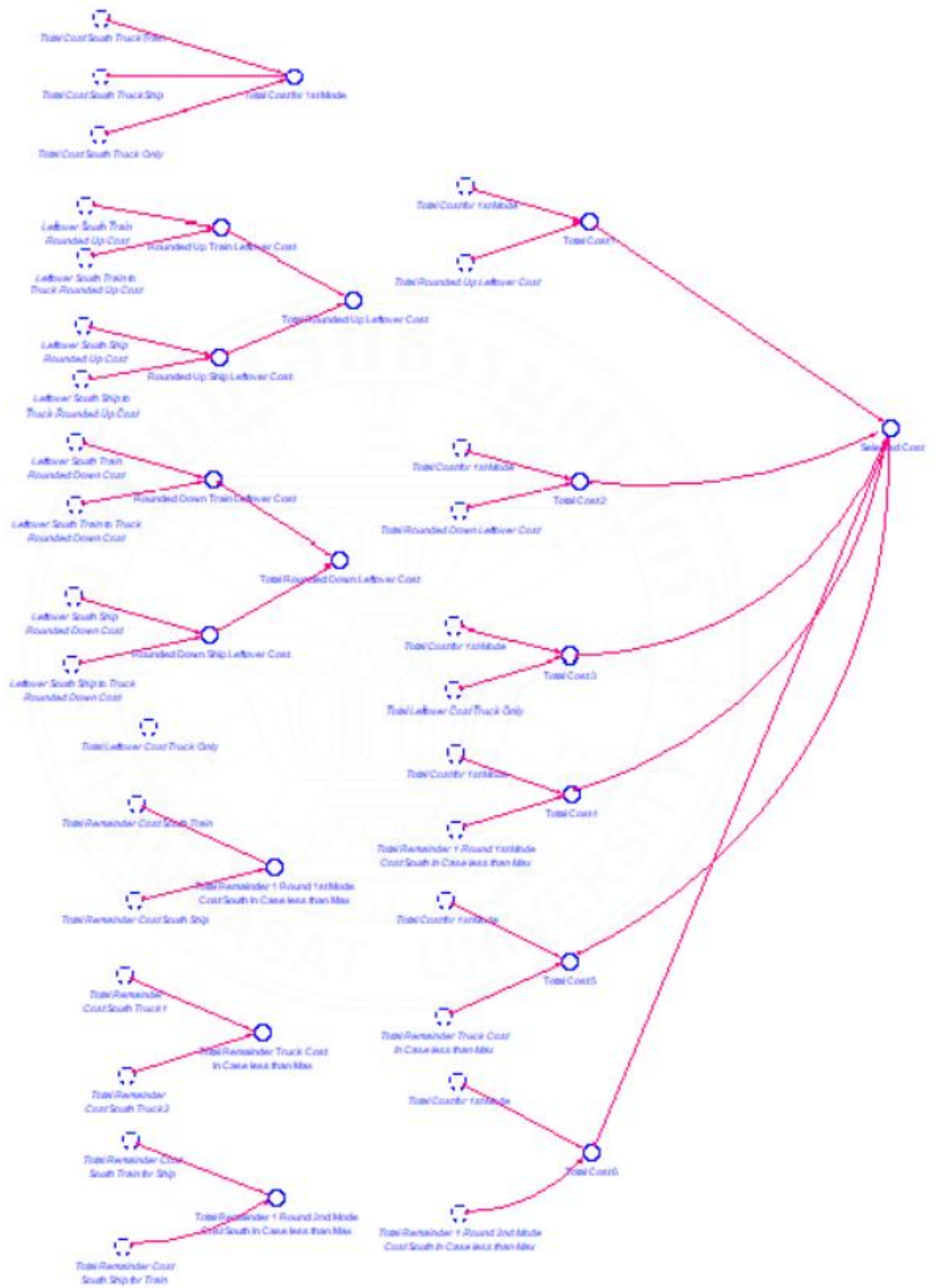
SD Model of Southern Region:



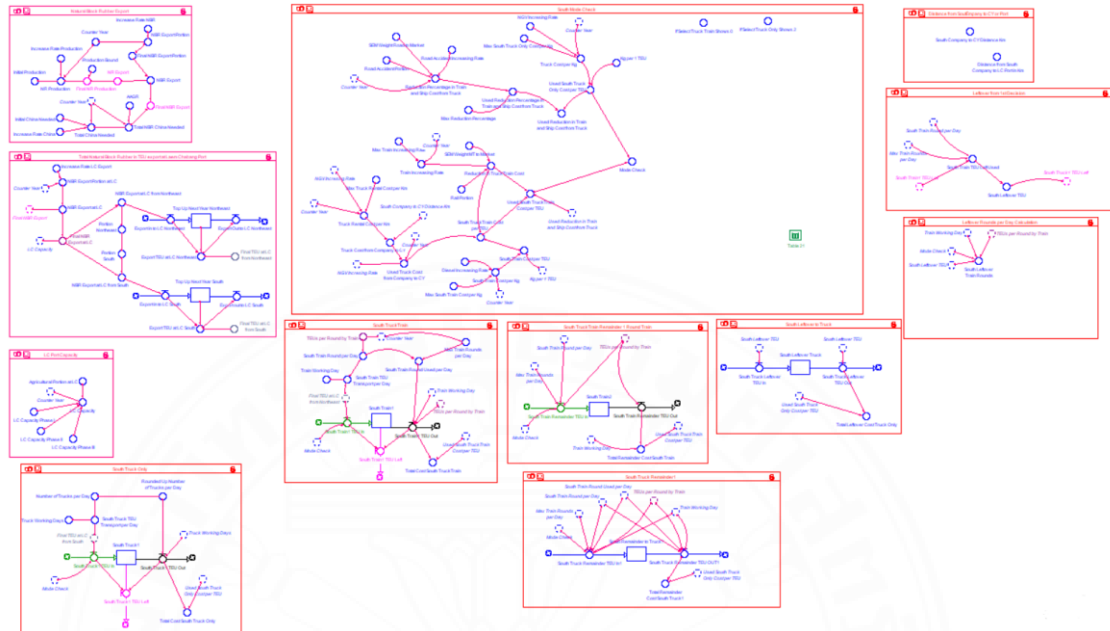


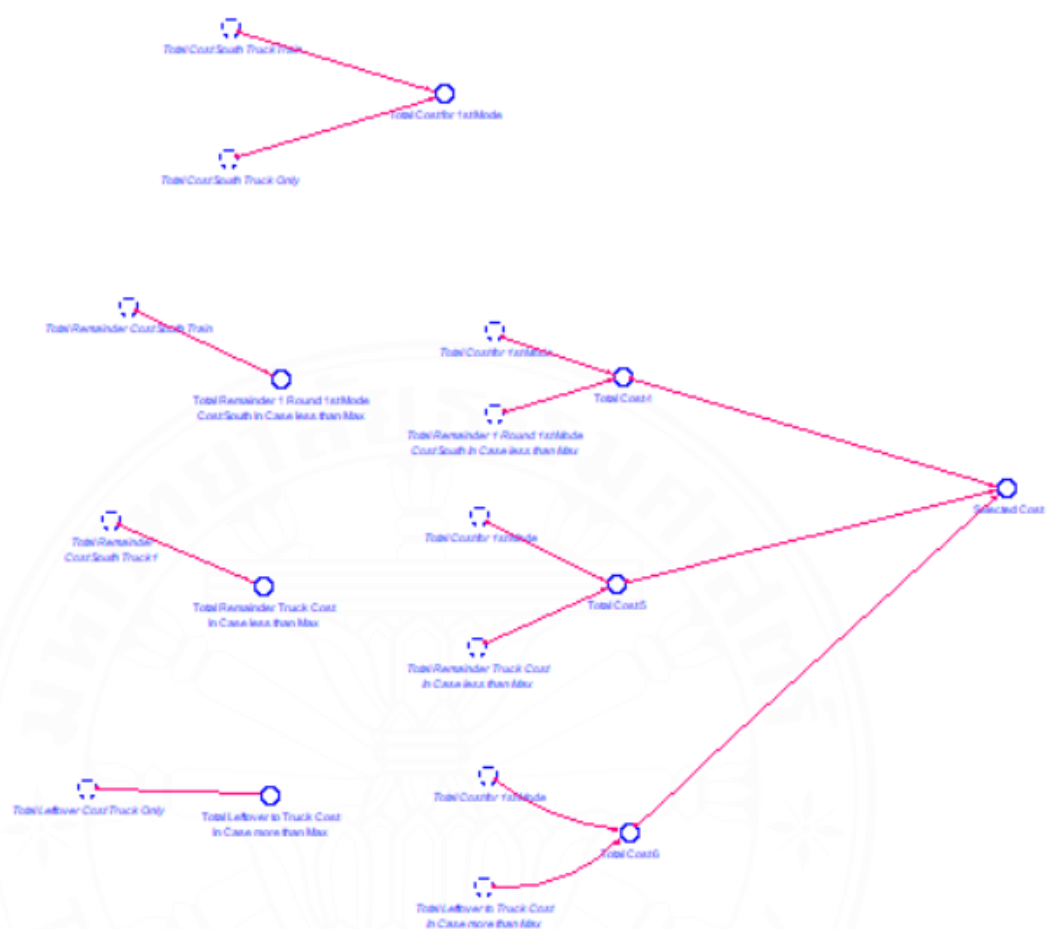






SD Model of Northeastern Region:





BIOGRAPHY

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Education	2009: Bachelor of Engineering (Chemical Engineering) Sirindhorn International Institute of Technology Thammasat University 2010: Master of Science (Environmental Science) Thammasat University

Publications

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