FACTORS AFFECTING THE EFFECTIVENESS OF THE GREEN LOGISTICS POLICY

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ปัจจัยที่มีผลต่อประสิทธิผลของนโยบายโลจิสติกส์สีเขียว

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรดุษฎีบัณฑิต
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FACTORS AFFECTING THE EFFECTIVENESS OF THE GREEN LOGISTICS POLICY

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วุฒิชัย ยังสว่าง: ปัจจัยที่มีผลต่อประสิทธิผลของนโยบายโลจิสติกส์สีเขียว (FACTORS AFFECTING THE EFFECTIVENESS OF THE GREEN LOGISTICS POLICY) อาจารย์ที่ปรึกษา: รองศาสตราจารย์ ดร.สัจจากาจ จอมโนนเขวา, 124 หน้า.

คำสำคัญ: การจัดการโลจิสติกส์สีเขียว, แบบจำลองการวัด, อุตสาหกรรมยานยนต์, แบบจำลองสมการโครงสร้าง, กระบวนการวิเคราะห์เชิงลำดับชั้น

งานวิจัยนี้มีวัตถุประสงค์เพื่อการตรวจสอบความสัมพันธ์ปัจจัยที่มีผลกระทบต่อการจัดการโลจิสติกส์สีเขียวในอุตสาหกรรมยานยนต์ในประเทศไทย นอกจากนี้ยังมีการศึกษา การประเมินกระบวนการวิเคราะห์ลำดับชั้น (AHP) สำหรับการผลิตสีเขียวในกลุ่มอุตสาหกรรมยานยนต์ไทย ซึ่งประกอบด้วย

ส่วนที่ 1 : การสร้างแบบจำลองการวัดโลจิสติกสีเขียว ซึ่งประกอบด้วย 8 ปัจจัย และแต่ละปัจจัยมีตัวชี้วัดรวม 41 ตัวชี้วัด ดังนี้ Green Product design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, Green Communication การศึกษานี้ใช้การวิเคราะห์องประกอบเชิงสำรวจและการวิเคราะห์เชิงยืนยันลำดับที่สอง

ส่วนที่ 2 : การตรวจสอบความสัมพันธ์ปัจจัยที่มีอิทธิพลต่อการจัดการโลจิสติกส์สีเขียวสำหรับกลุ่มอุตสาหกรรมยานยนต์ไทย ปัจจัยที่ใช้ในการศึกษา ได้แก่ โลจิสติกส์สีเขียว, นโยบายด้านสิ่งแวดล้อมของรัฐบาล, นโยบายด้านสิ่งแวดล้อมในองค์กร, ทัศนคติเกี่ยวกับความรู้ความเข้าใจด้านสิ่งแวดล้อม , ความสามารถทางการเงินในองค์กรในการเปลี่ยนแปลงสีเขียว, ความเต็มใจทางการเงินที่จะจ่ายในการบริโภคสีเขียว และ ชื่อเสียงทางสังคมเกี่ยวกับสิ่งแวดล้อม วิธีการศึกษา คือ การวิเคราะห์ปัจจัยเชิงยืนยัน การสร้างแบบจำลองสมการโครงสร้าง.

ส่วนที่ 3 : การประเมินกระบวนการวิเคราะห์ลำดับชั้น (AHP)สำหรับการผลิตสีเขียวในกลุ่มอุตสาหกรรมยานยนต์ไทย ปัจจัยที่ใช้พิจารณาประกอบด้วย 5 เกณฑ์ ดังนี้ Green efficiency , Factor of safety , Ease of Operation , Production cost และ Product Recovery ผลการศึกษาพบว่า ปัจจัยหลัก คือ ประสิทธิภาพสีเขียว และปัจจัยรองเกี่ยวกับกระบวนการประกอบ คือ ข้อต่อ Clinch Joints (CJ) เป็นทางเลือกที่ดีที่สุดสำหรับกระบวนการประกอบชิ้นส่วนยานยนต์สีเขียว วิธีการศึกษา คือ กระบวนการลำดับชั้นเชิงวิเคราะห์ (AHP)

จากการศึกษาปัจจัยที่มีผลต่อประสิทธิผลของนโยบายโลจิสติกส์สีเขียวในครั้งนี้ เพื่อค้นหาตัวบ่งชี้ นโยบายด้านสิ่งแวดล้อมของรัฐบาล, นโยบายด้านสิ่งแวดล้อมในองค์กร, ทัศนคติเกี่ยวกับความรู้ความเข้าใจด้านสิ่งแวดล้อม , ความสามารถทางการเงินในองค์กรในการเปลี่ยนแปลงสีเขียว, ความเต็มใจทางการเงินที่จะจ่ายในการบริโภคสีเขียว และ ชื่อเสียงทางสังคม ที่ส่งผลกระทบต่อการจัดการโลจิสติกส์สีเขียวสำหรับกลุ่มอุตสาหกรรมยานยนต์ไทย นอกจากนี้ยังศึกษาการประเมินกระบวนการวิเคราะห์ลำดับชั้น (AHP)สำหรับการผลิตสีเขียวในกลุ่มอุตสาหกรรมยานยนต์ไทย ผลการศึกษาทั้ง 3 ส่วน นำไปประยุกต์ใช้ในการจัดการเชิงกลยุทธ์ในการบริหารและจัดการการผลิต เพื่อให้ผู้ประกอบการภาคอุตสาหกรรมยานยนต์และภาครัฐสามารถนำไปใช้ใน ส่งเสริม กำกับควบคุม

ดูแล การดำเนินงานในภาคอุตสาหกรรม ในการสร้างความสามารถในการแข่งขันควบคู่กับการผลิตที่เป็นมิตรต่อสิ่งแวดล้อม

สาขาวิชา <u>วิศวกรรมการจัดการพลังงานและโลจิสติกส์</u>
ปีการศึกษา <u>2566</u>

ลายมือชื่อนักศึกษา ....
ลายมือชื่ออาจารย์ที่ปรึกษา ....

WUTTICHAI YOUNGSWAING: FACTORS AFFECTING THE EFFECTIVENESS OF THE GREEN LOGISTICS POLICY. THESIS ADVISOR: ASSOC. PROF. SAJJAKAJ JOMNONKWAO, Ph.D., 124 PP.

Keyword: Green logistics management/ Measurement model/ Automotive industry/ Structural equation model/ Analysis hierarchy process

The research aims to examine relation of factors affecting the effectiveness of the Green Logistics of Thailand's automotive industry. Moreover, there is also the study on Analytic Hierarchy Process (AHP) for the Green Production of Thailand's automotive industry, including:

Part 1: Creation of Green Logistics Measurement Model, consisting of 8 factors and each factor includes 41 indicators in total. Those factors are Green Product Design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication. The study applied Exploratory Factor Analysis and Secondary-order Confirmatory Analysis.

Part 2: Examination on relation of factors affecting the effectiveness of the Green Logistics of Thailand's automotive industry. Factors used in the study are Green Logistics, Government's Environmental Policy, Organization's Environmental Policy, Attitude of Environmental Cognition, Organization's Financial Ability regarding Green Change, Willingness to Pay for Green Consumption, and Social Reputation regarding Environment. Study methods are Confirmatory Factor Analysis and the creation of Structural Equation Model.

Part 3: Assessment of Analytic Hierarchy Process (AHP) for Green Production of Thailand's automotive industry. Considered factors include 5 criteria that are Green Efficiency, Factor of safety, Ease of Operation, Production cost, and Product Recovery. Study results found that the primary factor is Green Efficiency, and the secondary factor related to assembling process is Clinch Joints (CJ) which is the best alternative for Green Assembling Process. Study method is Analytic Hierarchy Process (AHP)

According to the study on factors affecting the effectiveness of the Green Logistics Policy, at this time, it is to seek for indicators, including Government's Environmental Policy, Organization's Environmental Policy, Attitude of Environmental Cognition, Organization's Financial Ability regarding Green Change, Willingness to Pay for Green Consumption, and Social Reputation affecting the Green Logistics Management of Thailand's automotive industry. In addition, there is a study on assessment of Analytic Hierarchy Process (AHP) for the Green Production of Thailand's automotive industry. Study results from 3 parts are taken to apply for strategic management of the production administration and management, to let of automotive industry entrepreneurs and government sectors utilize these to promote, control, and supervise the industrial sector operation, in regard to building competitive ability, along with environmentally friendly production.

School of Energy and Logistics Management Engineering　　Student's Signature ....

Academic Year 2023　　Advisor's Signature ....

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SYMBOLS AND ABBREVIATIONS

α	=	Statistically significant level
β	=	Structural coefficient
λ	=	Factor loading coefficient
χ^2	=	Chi-square
df	=	Degree of freedom
RMSEA	=	Root mean square of approximation
SRMR	=	Standardized root mean residual
CFI	=	Comparative fit index
TLI	=	Tucker Lewis index
SEM	=	Structural equation modelling
CFA	=	Confirmatory factor analysis
EFA	=	Exploratory factor analysis
MVA	=	Mediating variable analysis
CR	=	Composite reliability
AVE	=	Average variance extracted

CHAPER I
INTRODUCTION

1.1 Rationale for the research

Worldwide society is confronting the situation which has never happened before. That is the direct impact of environmental deterioration, resource loss, and climate change, resulting in worldwide higher demand for changes of human and business trends which interact with natural environment (Badi, S. and N. Murtagh 2019). The increasing international concerns regarding environmental sustainability, and climate change are heeding every company to face the challenge of combining environmental issues with business strategies and activities (Nidumolu et al., 2009). The increasing environmental concerns which threaten the core of human existence has emphasized on necessity of environmental saving. Recently, the industrial operation is under inspection by different organizations who demand to order a purchase, and seek to decrease or eliminate processes which harm the environment (Piecyk et al., 2015). The clearly seen environmental pollutions in previous researches had focused on production and transportation sectors while these 2 sectors consume high petroleum energy, causing air pollution and global warming. Even though there are several kinds of environmental initiative to reduce negative environmental impacts, the increasing number and use of vehicles, as well as an increasing traffic congestion, and global warming have indicated the need to focus on transportation sector (Lin and Ho (2011), and production sector in relevant to transportation sector.

Recently, production industry is confronting the crisis of lack of energy, and environmental deterioration which are highly in consideration (Zhang et al., 2014; He et al., 2017). According to the more severe problems of environmental impacts and excessive energy use, derived by industrial development (Kirilova and Vaklieva-Bancheva, 2017), many countries in the world make Green Production as national policy. Logistics system is claimed to be one of the main supporters of Greenhouse Gas (GHG) release, and global energy use (Kim and Han, 2011; Oberhofer and Dieplinger, 2014; Murphy and Poist, 2003; He et al., 2017). Due to Thailand's geolocation is a center of ASEAN nations, and it is also close to growing market countries such as India and China. Thailand is becoming the hub of regional transportation, and product distribution. It is one of world class manufactures that makes consumers in developed countries very widely concern about natural resource conservation, and reduction of the worldwide environmental impacts (Lai and Wong, 2012).

Automotive industry is regarded as a main base of Thailand's economic development. Nowadays, it is worth 5.8 percent of Gross Domestic Product (GDP), and this industry is highly affected by modern technology. So, to support the continuous future growth, it will focus on developing the Electric Vehicle (EV) manufacturing base. It begins with the co-assembly with Original Equipment Manufacturer (OEM), leading to battery industry and electric mobility system to expand business in value chain of automotive industry, especially in terms of the Surface Integration Design & Prototyping, promoting the use of effective production technology and Catalytic Manufacturing, as well as developing electronics tools and auto-part businesses which keep up with world standard e.g. Security System Parts, Transmission System Parts, and motorcycle manufacturing (over 248 cc models) by having the engine part molding (Eastern Economic Corridor , 2018) etc. Thailand automotive industry is continuously growing. In year 2018, there were 18 automotive manufacturers in Thailand (18 trademarks), producing 2,167,694 automobiles, counting for 72 percent of total production capacity, making Thailand ranked number 11 of the world automobile manufacturing volume. Meanwhile, Thailand's most automobile manufacturing was one-ton pickup truck which was 49 percent of total manufacturing. Second was passenger car which was 40 percent, while Passenger Pickup Vehicle (PPV) and Commercial Vehicle manufacturing volume were 8 and 2 percent in order. For domestic automobile sales volume, it was 1,041,739 units while passenger car was the highest which was 46 percent of total sales volume. Second was one-ton pickup truck which was 43 percent of total domestic sales volume. Meanwhile other PPVs and commercial vehicles' sales volume were 6 and 5 percent orderly. And Thailand's export volume was 1,140,640 units while the highest export was one-ton pickup truck which was 54 percent of total export volume. Second was passenger car, following by PPV with 37 and 10 percent of total export volume consecutively. The Oceania and Asia were the largest export markets of Thailand with 31 and 28 market shares in order (Thailand Automotive Institute, 2018). Refer to motorcycle manufacturing, there were 8 motorcycle manufactures (8 trademarks). In year 2018, Thailand manufactured 2,063,076 units of motorcycle which was 69 percent of total production capacity. While 81 percent of manufacturing was Commuter Motorcycle which was for domestic sales. For domestic sales volume of motorcycle, it was 1,788,323 units while 80 percent was the small motorcycle with less than 125 cc engine. For export, the volume was 371,190 units with 1,472 million USD value. For the less than 250 cc motorcycle, its export volume is the highest at 38 percent of total export value (Thailand Automotive Institute, 2018).

Several years ago, the global automotive industry had confronted the challenge toward pollution problem solving in order to conserve the environment. That were both challenging opportunity, and disadvantage for development of Thailand's automotive industry to make the sustainably competitive ability at the world stage. Refer to results of state parties' conference regarding climate change at the 21st Conference of the Parties or COP21 in Paris, France, it required that every country has to submit the operational goal of continuous Greenhouse Gas Mitigation, making Thailand needs to have Greenhouse Gas Mitigation measure. To pursue the goal, in year 2015, Thailand by Ministry of Energy had the measure on decreasing degree of energy use. One of that was a measure on reduction of energy use in transportation sector. Government also had a policy to promote the modern automotive industry as one of 10 targeting industries as it is a driving mechanism of future economy (The Federation of Thai Industries, 2018). For the automotive industry investment in Eastern Economic Corridor (EEC), investment promotion measure by BOI, and investment promotion measure in the EEC have given different privileges to attract big investors from both domestic and overseas. Furthermore, last year, BOI had approved the budget for entrepreneurs to invest in hybrid vehicle, electric vehicle, battery, and auto-part manufacturing. While Japanese investor is regarded as the main investor in this area (around 50 percent of foreign investors in EEC) by emphasizing on investment of automotive and auto-part industries (passenger car, parts, and appliances assembly) (Eastern Economic Corridor, 2018). Also, (Thailand Automotive Institute, 2018) had mentioned that "In year 2030, Thailand will be the important base of regional modern automotive manufacturing with 2.5 million units of automobile. Also, the 1.5 million units will be manufactured for domestic sales while 15 percent will be Battery Electric Vehicle (BEV), and 60 percent will be Level-3 Autonomous Vehicle. For public service vehicles such as bus, tricycle, and motorcycle will be all BEV. For the long-term goal, Thailand will be the base of modern automotive manufacturing with the increasing value of supply chain, by doing research and development, along with the manufacturing base of increasing value of auto-parts e.g. manufacturing of battery, motor, electronics tools and software, tires, and vehicle body with light materials". Also (The Federation of Thai Industries, 2018) had specified direction of automotive industry development as follow. "Thailand is the world automotive manufacturing base, along with increasing value of domestic supply chain and it is also environmentally friendly". In addition, green production in the automotive sector plays an important role in developing an environmentally friendly supply chain. Because it is the main activity that results in the use of resources and the use of energy that have a very negative effect on the environment. The researcher is therefore interested in to find a model for evaluating the automotive parts assembly process that is environmentally friendly.

So, the research has divided into 2 parts of study. Part 1: To study the methods and different activities regarding the Green Project Policy for Thailand's automotive industry by studying key factors which influence the Acceptance of Environmental Practice, along with Green Activity Ranking which will help relevant organizations know about the Green Activities highly accepted by the operators. Part 2: To study workpiece manufacturing and delivery processes which influence the environmental impacts of automotive industry companies to seek for the best alternative for the Green Practice.

1.2 Purpose of the research

1.2.1 To develop Efficiency Measurement Model of Green Logistics.

1.2.2 To seek for factors influencing Green Logistics Efficiency.

1.2.3 To seek for the proper production forms regarding Green Logistic Efficiency.

1.3 Scope of the research

1.3.1 To study about Thailand's automotive industry.

1.3.2 Names of the samples have to be listed in The Federation of Thai Industries.

1.4 Research Questions

1.4.1 Which practices and activities are components of the Green Logistics Efficiency Measurement for Thailand's automotive industry?

1.4.2 Which are factors influencing the Green Logistics Efficiency for Thailand's automotive industry?

1.4.3 Which are the proper production forms of the Green Logistics Efficiency for Thailand's automotive industry?

1.5 Contribution of the research

1.5.1 Able to take the different methods and activities of the Green Project Policy obtained from the research to apply with strategic management of the Green Project Policy for Thailand's automotive industry.

1.5.2 Able to take the factors influencing different practices and activities of the Green Project Policy obtained from the research to apply with strategic management of the Green Project Policy for Thailand's automotive industry.

1.5.3 Able to take the proper production forms for the Green Logistics Efficiency obtained from the research to apply with strategic management of the Green Project Policy for Thailand's automotive industry.

1.6 Organization of the research

This research is divided into 5 chapters as follow.

Chapter I: Introduction, mentioned about reasons and importance, including background of each research part, research objectives, boundary of study, research questions, and research results.

Chapter II: Green Logistics Measurement Model in Motor Vehicle Industry of Thailand.

Chapter III: Key Factors Shaping Green Logistics in Thailand's Auto Industry.

Chapter IV: Analytic hierarchy process (AHP) Assessment of Green Production in Thailand's Auto Industry.

Chapter V: Conclusion and recommendations. This part is to conclude results from Chapter II- Chapter IV and give suggestions which are found in the research.

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CHAPTER II
GREEN LOGISTICS MEASUREMENT MODEL IN MOTOR VEHICLE INDUSTRY OF THAILAND

2.1 Abstract

Low carbon release and environmental protection are key issues of manufacturing industry development in Thailand, due to manufacturing industry sector causes more and more environmental problems. However, there is still a research gap about the systematic method of Green Logistics evaluation and various dimensions in motor vehicle industry. This study aims to develop the Green Logistics Measurement Model in Motor Vehicle Industry of Thailand. Tool used in the research is self-answer questionnaire. There are 1,638 samples which are analyzed by Exploratory Factor and Confirmatory Factor analyzing techniques. Study result found that the Green Logistics Measurement Model in Motor Vehicle Industry of Thailand consists of 8 factors, including Green Product design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication. These factors are parts of the Green Logistics Measurement Model in Motor Vehicle Industry of Thailand with the 0.01 statistically significance. This study can be a method to help government and motor vehicle industry sectors use these indicators to prioritize for efficiency evaluation of the organization's Green Logistics Measurement in order to sustainably reduce environmental effects caused by the industrial sector.

2.2 Introduction

Environmental responsibility is an issue that the government, private sectors and international organizations highly pay attention to. According to rapidly increasing number of populations worldwide, technological development of modern production, and a shorter lifecycle of product consumption, these result in higher number of raw material consumption consecutively. In addition, the climate change, use of natural resource, wastage, and environmental pollution making are the main factors that create environmentally friendly Logistics and Supply Chain Management for better sustainable development in the environment of industrial sector (Younis et al., 2016). A concern that the increasing number of environmental problems will directly affect industrial business sector brings in the idea and practice to decrease environmental pressure in society to the least (Cheng et al., 2023).

Moreover, Motor Vehicle Industry in Thailand is continuously growing and there are 18 (18 Brands) Motor Vehicle Manufacturers in Thailand in total, producing the average of 2,167,694 cars per year, accounting for 72 percent of gross production. This makes Thailand rank the 11th of World's Car Manufacturer (Royal Thai Government, 2023). Nevertheless, in past several years, the worldwide motor vehicle industry had faced a challenge of the pollution problem solving and a promotion of environmental conservation. These are both a challenging opportunity and disadvantage toward the development of Motor Vehicle Industry in Thailand, to be able to compete at global level. So that Thailand needs to have a measure to reduce the greenhouse gas to pursue such goal due to Thailand is a base of world's motor vehicle manufacturing, along with the supply chain that makes domestic value adding, and environmental friendliness of Thailand. So, the Ministry of Energy has measures to reduce the degree of energy use, and one of them is a measure to reduce energy used in transportation and industry sectors.

The interest in a practice of environmentally friendly Logistics and sustainable Supply Chain has rapidly grown in the academic field. Green Logistics is still considered as main part of Green Supply Chain (Pathak et al., 2020; Trivellas et al., 2020). Key role of Green Logistics is the sustainable production and product distribution by considering environmental and social factors (Agyabeng-Mensah et al., 2021). Also, there are methods to determine an environmental responsibility by mainly focus on waste disposal, industrial waste recycling, and use of renewable energy in transportation sector (Rodrigue, 2020). However, nowadays, Green Logistics and Green Supply Chain Management have been continuously developed in pattern and management from various dimensions such as management dimensions of Green Cost Administration, Response to Green Consumer's Demand, Environmentally Friendly Production Process etc.

According to the previous literature review regarding environmentally friendly Logistics in different dimensions, for example, environmentally friendly Reverse Logistics and Product Design factors are the Green Logistics practices that are implemented to activate an ability of Product Design for environment and product reuse. The result was that Reverse Logistics and Product Design are directly relevant (Khor & Udin, 2013). Study on environmentally friendly Purchasing and Production factors partake and support producers to improve the environment, organization's image, and product value adding. In addition, it also helps producers cooperate with suppliers to create Supply Chain process from the beginning to the end, making a better operational efficiency through product, service, and environmentally friendly activities (Basana et al., 2022; Yu et al., 2019).

There is research that studied about Factors of Green Production, Green Marketing, and Green Consumption to adjust to new forms of economic development in terms of strategy, in relevant to environmentally friendly product development and promotion. It also emphasizes on the company to communicate with consumers, and support an efficient energy saving for environmental management sustainability (Ping, 2009). Product transportation is the largest portion of greenhouse gas release. So, to reduce gas release by Green Transportation is to choose forms of transportation and to gain efficiency of transportation network (Barzinpour & Taki, 2018; Beškovnik & Twrdy, 2012). Moreover, a study on Green Communication factor is one of options to reduce energy usage by making the social trend through several media usage e.g. person media, printed media. Nevertheless, there is still a gap to apply the use of Green Communication in Logistics Industry due to there are few researches that mentioned about Green Communication used in manufacturing industry which is important in a support of sustainable energy saving together (Aziz et al., 2023). Therefore, factors of Reverse Logistics, Green Product Design, Green Production, Green Marketing, Green Consumption, Green Purchasing, Green Communication, and Green Transportation are all linked to Green Logistics in terms of promotion and improvement of environment quality, and business performance of producers. In addition, Green Logistic Management partakes in making the sustainably environmental profit (Geiger, 2016).

There are studies on the Evaluation of Green Logistics and Supply Chain in production industry sector that study in different industries such as Prioritizing Analysis of Green Logistics in Plastic Package Industry by AHP method (study factors are Green Supplier, Green Consumer, Green Purchasing, Green Distribution and Transportation, Reverse Logistics etc.) (de Souza et al., 2022), Evaluation and prioritizing of Green Logistics by using method of hybrid fuzzy multi criteria decision making for distinguishing relationships between factors and their degree of importance and combines the techniques quality function deployment (QFD) in petrochemical industry (study factors are Logistics industry, Quality, Risk, Flexibility/Time, Logistics Costs etc.) (Vazifehdan & Darestani, 2019), and Study on Interaction Analysis between major factors of Reverse Logistics in Motor Vehicle Industry by using method of Interpretive Structural Modeling (ISM) (study factors are Reverse logistics, Green purchasing, Support of policy entrepreneurs, Competition in market etc.) (Ravi & Shankar, 2017).

Therefore, it is necessary to do more research about the Measurement Model of Green Logistics to identify indicators of main sustainability in production industry sector of motor vehicle industry. The existing reviews mainly focus on specific Logistics but this study emphasizes on use of holistic evaluation form in various dimensions that is less likely found. So, we had gathered various dimensions of factor of Green Logistics, including factors of Green Product Design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication. The study result will help to fill the literature gap of environmentally friendly Logistics. Also, these indicators can be used for development of policy making which can help to decrease the increasing environmental concerns, and to overcome international trading obstacles, as well as to promote Circular Economy along with gross domestic economic development in different countries (Karaman et al., 2020).

In addition, the article also includes more structures that are Part 2: Literature review, Part 3: Research methods, Part 4: Results, and Part 5: Conclusion and Discussion.

2.3 Literature review

2.3.1 Green product design

Environmentally friendly product design relates to development of utilizing products in new forms by considering ecological system and economic (Navinchandra, 1990), including selection of environmentally friendly materials that are used in the industry to reduce and cause the least environmental impact in the whole useful life (Mayyas et al., 2016). Environmentally friendly product design has to work along with other fields to determine the aspect of environmental management. Main components of environmentally friendly product design management include material selection, resource usage, production criteria, recycling, reuse, and product disposal, as well as selection of the most suitable design option (Huang et al., 2023).

2.3.2 Green Purchasing

Environmentally friendly product and service purchasing means activities in relevant to purchasing, raw materials and service provision, including selection of distributor and material, determination of time period and amount of purchasing, ands well as relationship building with raw material suppliers who cause less environmental impact, in comparison to the similar product and service (Warner & Ryall, 2001). Green purchasing is also considered that it takes an attempt on cost and risk of suitable product characteristic evaluation (Pegan et al., 2023). Basically, environmentally friendly purchasing process includes processes of raw material provision, production, selection of proper energy and technology usage, packaging, transportation, utilization, and waste product management after it is expired

2.3.3 Green Manufacturing

Environmentally friendly manufacturing is the environmentally friendly manufacturing that can be explained as to use appropriate materials with high efficiency in manufacturing which is a necessary method for the design and production activities of new products development and manufacturing with social responsibility to reduce environmental impact, while the organization is able to pursue economic benefits, focus on decrease of environmental impact, reduce greenhouse gas release, eliminate resource wasting, and recycling. These are examples of Green Manufacturing activities (Baines et al., 2012; Orji & Wei, 2016) which are main problems of production such as to follow environmental laws and regulations for natural resource conservation, toxin control, and waste disposal (Zhu & Sarkis, 2004).

2.3.4 Green Transportation

Transportation is a process of moving from one place to another which is an important Logistics activity that highly influences the environment. In the developing countries, they are facing several transportation problems such as traffic jam, lack of reliable and safe public transportation, road accident, and transportation difficulty (Abdel Wahed Ahmed & Abd El Monem, 2020). Green transportation means administration on movement, proper storage or transporting raw material and product, as well as a worth fuel energy management with the least cost and pollution release (Richardson, 1999). Green transportation plays a role in connection among Logistic activities such as structure management of transportation network, transporting vehicle operation, and disposal of transporting vehicle and its damaged parts, and use of petrol energy which causes the release of toxic chemicals in large amount e.g. Carbon Dioxide. In order to make green an effective transportation, there should be the determination of preventive and solving methods for transportation activities to cause the least environmental impact. (Pazirandeh & Jafari, 2013).

2.3.5 Green Reverse Logistics

Green reverse logistics means a process of reverse product management from customer to producer, including calling for returned product, damaged product, product that does not meet standard, or expired product, in order to reproduce, reuse, and recycle, or properly dispose (Hazen et al., 2012; Johnson & McCarthy, 2014). Reverse Logistics strategy aims to create value by utilizing the existing product value, or properly dispose it, that is part of environmentally friendly Supply

Chain (Chen et al., 2019). In addition, organization has to willingly and sincerely manage to promptly receive the returned product in an efficient and effective way, to solve problems for organization's stakeholders. Since many parties pay more attention to Green Reverse Logistics due to the reason that product has to be reversed from customer to product distribution point, producer, and raw material deliverer by several causes such as there are a lot of unsold products, defected products, products delivered in wrong specification or size, best-selling product in one place but it cannot be sold in other places etc.

2.3.6 Green Marketing

Environmental and sustainable problems are becoming main issues of the organization. So that to understand about taking customer's Green marketing into action, or environmentally friendly process, as well as several supporting factors are becoming the main topics (Kumari et al., 2022). Green marketing or environmental marketing means the product promotion or advertisement which indicates or implies the environmental benefits (Polonsky, 2011; Sharma, 2021). Environmentally friendly marketing is related to activities responding to, or fulfilling consumer's demand or wish to have the least negative effect to natural environment (Singh & Pandey, 2012). Green marketing can increase environmental capacity, competition, and advantage of business firm (Nuryakin & Maryati, 2022), as well as improve the organization image and reputation. So, it is considered as an interesting activating force for organization to promote green marketing of environmentally friendly product, as well as a way to promote the form of environmentally friendly consumption among consumers.

2.3.7 Green Consumption

Green consumption is an unavoidable option to relieve environmental pressure, and promote sustainable development (Yang et al., 2023). Green consumption is a volunteer consuming behavior to protect the environment. The activities include purchasing, usage, and disposal of environmentally friendly product (Yingxiu Hong et al., 2023; Wu et al., 2016). Green consumption is a key to develop and recover the sustainable green economic (Ying Hong et al., 2023). Moreover, Green consumption partakes in promotion on global warming reduction (Suki & Suki, 2019). It can also indicate consumer's interest in regard to the surroundings of (Tandon et al., 2023).

2.3.8 Green Communication

Green communication means communicating channel between relevant sectors in the Supply Chain. It is a new strategy to decrease carbon gas release for the least impact to environment (Dabaghi et al., 2017), or communication through e-channel instead of using paper document. Green communication is to offer the self-strategy to let consumer see an ability to manage the environment (Lin et al., 2021). According to consumer's perception, Green communication can gain feeling of satisfaction, and relationship with Green Product (Hasan et al., 2009).

2.3.9 Studies in relevant to Green Logistics

Green Logistics means all managing tools in relevant to Logistics activities, product/raw material movement, and information from beginning to the end of Supply Chain, to make balance between economy and environment (Kurbatova et al., 2020; Setyadi et al., 2023). Objectives of Green Logistics are to reduce environmental impacts caused by Logistics activities, reduce energy usage and waste from production process, improve product brand's value, gain the operational efficiency, and save cost by decreasing alternative energy usage (Agyabeng-Mensah et al., 2020; Mohsin et al., 2022).

Table 1: We present conclusion of the reviewed literature in relevant to Green Logistics factors within context of industrial and service sectors. Main part of article mainly focuses on each part (traditional indicators) or considers the separated factors. While the Green Logistics has got much attention due to the practical benefit of industrial business and environment, especially in developing countries. However, there is still a lack of empirical evidence about the Green Logistics Confirmatory Factor Analysis in such developing countries. This study has gathered indicators obtained from the literature review, to solve the gap problem in order to cover many more dimensions. So, we have offered more holistic indicators by using methods of Exploratory Factor Analysis and Confirmatory Factor Analysis with the following Hypothesis:

Hypothesis 1: Green Logistics in Motor Vehicle Industry of Thailand consists of 8 factors, including Green Product Design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication.

2.4 Research methods

2.4.1 Data Collection and Samples

We had done a survey with workers in Motor Vehicle Industrial Sector to evaluate in accordance with our Hypothesis. Those manufacturing companies were selected by simple random. There are 570 auto-part and motor vehicle assembling companies in Eastern and Central regions. The research had operated by self-survey while the research team had contacted such auto-part and motor vehicle assembling entrepreneurs. We contacted the companies by sending email with the explanation of research purposes through email channel, and we had got the responsive cooperation to answer the questionnaires from 300 companies, accounting for 52.6%. Then we sent our team to do face-to-face questionnaire at the companies. Survey and data collection period was from April to July 2022. When we collected questionnaires, we did the data correction then analyzed data accordingly.

Research tool is questionnaire that consists of: 1) General data of respondents by filling answer for each question, 2) Opinion about components of Green Logistics in Motor Vehicle Industry. There are questions with levels of opinion by determining 5 levels of measurement (5-point Likert scales), from 1 = Do not agree to 5 = Agree. Observed variables that we created to measure Green Product design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication are all slightly modified from previous researches of production industry, to suit the context of Motor Vehicle Industry in Thailand, and 3) Suggestion, filling answer by respondents. Our study has been received ethical certification from Suranaree University of Technology, Thailand. The Reference Code is COA No13/2564. Moreover, all participants consented to join the survey and understood that their participation is an option for academic aspect only, while the data is kept confidentially. After we had removed the duplicated and uncommon questionnaires, we found 1,638 sets of accurate questionnaires. When we considered number of proper samples which is 1 per 15 that is equal to observed variables, while the observed variables of this study are 41 questions. That meant proper samples must be more than 615. So, we can conclude that these samples are proper for the Exploratory Factor Analysis and Confirmatory Factor Analysis.

2.4.2 Respondents' Profile

We gathered analyzing data of respondents and found that there are 78.80% male and 21.20% female. In terms of respondents' age, they are 30 to 39 year-old for 43.22%, and second is age of 20 to 29 year-old for 42.12%. For respondents' position, 65.4% are operation staff, second is engineer for 11.6%. Period of Green Logistics operation that is less than 3 years is 65.4%. Second is 3 to 5 years operation for 22.5%. Business type is automotive parts manufacturer (Tier-1) which is 58.8 % Automotive. Second is manufacturer for 27.3 %.

2.4.3 Data Analysis Techniques

This study has been tested by Exploratory Factor Analysis for extraction or grouping the variables that are still not classified or composited by having the statistic to classify respondents toward their experience and perception by dividing questions of each factor of varimax rotation. For Kaiser-Meyer-Olkin (KMO), the relation is close to 1 (Field, 2013). Confirmatory Factor Analysis is a statistical analysis, aiming to reduce number of data or research variables by relying on combination of relevant variables, in order to create components with the suitable criteria of Goodness-of-fit index, to find statistical value that is used to test the construct validity which consists of criteria as follow. Chi-squared statistic (χ^2) per degrees of freedom (*df*) should be less than 5. Root mean square error of approximation (RMSEA) should be less than or equal to 0.07 (Steiger, 2007). Standardized root mean square residual (SRMR) should be less than or equal to 0.08 (Browne & Cudeck, 1992). Tucker–Lewis coefficient (TLI) should be more than 0.90, and Comparative fit index (CFI) should be more than 0.90 (Hu & Bentler, 1999).

2.5 Results

2.5.1 Measurement Model

Refer to the descriptive analysis of statistical testing result, average observed variable is between 3.649 - 4.407, and standard deviation is between 0.560 - 0.976. For Cronbach Alpha analysis that has to be more than 0.7, it found that it is between 0.7 - 0.8 with a well internal consistency. The analysis found that Kaiser-Meyer-Olkin (KMO) is 0.928 which presents that there is a parameter pattern that can be used to create the reliable factors. Confirmatory Factor Analysis result found that there are number of variable loadings which are more than 0.5. So, in summary, Exploratory Factor Analysis (EFA) of 41 observed variables can separate groups of latent variables in 8 factors, including Green Product design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication as showed in Table 2.3

As presented in Table 2.4, results of Confirmatory Factor Analysis (CFA), estimated by M-Plus program version 7.2 for Green Logistics Measurement Model in Motor Vehicle Industry of Thailand found that the Goodness-of-fit index is (χ^2=3350.998, *df* =676, p< .001, χ^2/ *df* =/4.95, CFI =0.931, TLI =0.916, and SRMR =0.049, RMSEA =0.049). Such statistic is in accordance with empirical data. When we consider all 8 factors, it found that Standardized loading is between 0.952 - 0.584 which is more than 0.5 according to suggestion of (Hair Jr et al., 2010). We also evaluate Construct Reliability (CR) examination, while all factors' values are between 0.678 - 0.909 which are higher than 0.60 (Hair et al., 2014), and Average Variance Extracted: AVE is between 0.587 - 0.765 which is higher than 0.5 (Fornell & Larcker, 1981), consisting of the following factors.

1) Green Product design consists of 5 observed variables, including Q1-Q5. It found that “Q3: Product design by using the least number of diverse parts and material types” has the highest Standardized of γ = 0.745.

2) Green Purchasing consists of 7 observed variables, including Q6-Q12. It found that “Q7: Development of purchasing knowledge for environment promotes an awareness of the environmental problems” has the highest Standardized loading of γ = 0.747.

3) Green Manufacturing consists of 4 observed variables, including Q13-Q16. It found that “Q13: Promotion of training and using clean technology” has the highest Standardized loading of γ = 0.717.

4) Green Transportation consists of 5 observed variables, including Q16-Q21. It found that “Q19: Survey on transportation time to avoid traffic problems” has the highest Standardized loading of γ = 0.771.

5) Green Reverse Logistics consists of 7 observed variables, including Q22-Q28. It found that “Q28: There is a return of defected, expired or unused item from customer to raw material supplier to return to quality improvement” has the highest Standardized loading of γ = 0.822.

6) Green Marketing consists of 4 observed variables, including Q29-Q32. It found that “Q31: Product advertisement and Public Relations include environmentally friendly qualification” has the highest Standardized loading of γ = 0.726.

7) Green Consumption consists of 4 observed variables, including Q33-Q37. It found that “Q35: Support and promote product that causes the least pollution” has the highest Standardized loading of γ = 0.629.

8) Green Communication consists of 4 observed variables, including Q38-Q41. It found that “Q39: Promote the communication that focuses on environmentally friendly practice and product recommendation through website” has the highest Standardized loading of γ = 0.807.

9) Refer to the mentioned results, it showed that all factors can confirm structure loading of each factor. So, it supported Hypothesis 1.

2.6 Conclusion and discussion

Motor Vehicle Industry is a key basis of Thailand economic development. According to an increasing environment impact in the industrial sector, challenge of pollution problem solving for environmental conservation is both challenging opportunity and disadvantage, toward development of Thai motor vehicle industry to make it competitive. So, it must be a cautious action to evaluate Green Logistics, to lead to improvement of environmentally friendly production activities and processes. This study aims to develop Green Logistics Measurement Model to understand the decision in relevant to indicators of Thailand motor vehicle industry group, and to respond to an efficient reduction of environmental impact by using methods of Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA), in order to evaluate consistency by estimating parameter in accordance with the highest probability. Consistency assessment among structure of 8 factors, and empirical data are obtained from a survey with 1,638 managers, engineers, and staff who have work experience in motor vehicle industry in Thailand.

Result of all indicators are in accordance with criteria and theoretically reasonable that confirm consistency between the development of measurement model and empirical data. In summary, the 41 observed variables help to indicate all 8 Green Logistics factors, including Green Product design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication with 0.001 statistical significance as presented in figure 1. For this study, all observed variables can confirm the structure of each factor, while considering Standardized loading that support Hypothesis 1. In addition, the Confirmatory Factor Analysis can also prioritize the indicators of each factor as below.

1) Result of Primary Confirmatory Factor Analysis: Q28: “There is a return of defected, expired or unused item from customer to raw material supplier to return to quality improvement” has the highest Standardized loading of (γ = 0.837), and Q24: “There is the sorting out of defected, expired, and unused product from production process for re-production” has the second Standardized loading of (γ = 0.837). From the observation, it found that Q28 and Q24 are observed variables of Green Reverse Logistics factor that the respondents give their priority. Entrepreneur or organization leaders should be aware about environmental impact and place importance on the reuse of product and debris by transforming and improving them through production process to reuse them in order to create benefit from the inappropriate abandoned resource, help to worthily use the material, and reduce waste amount (Khor & Udin, 2013). The third is 3 Q39: “Promote the communication that focuses on environmentally friendly practice and product recommendation through website” has Standardized loading of (γ = 0.837). The observation found that Q39 is an observed variable of Green Communication factor. Entrepreneur should pay attention to Green Communication regarding product recommendation through website and social media

channels, to make consumers familiarize because we can easily reach consumers through these channels, and motivate them to be interested in the Green Product (Lin et al., 2021).

2) Result of Secondary Confirmatory Factor Analysis: When we consider priority of each factor, it found that Green Manufacturing factor has the highest Standardized loading of (γ = 0.989) which is similar to the previous researches: Bui et al. (2023); Liu et al. (2023) that is environmentally friendly production can improve environmental sustainability by using clean technology in production process, improving recycling management to reduce waste types, and pollution release control. Second is Green Consumption with Standardized loading of (γ = 0.952) which is in accordance with the research of Yang et al. (2023) that is Green Consumption factor is necessary and unavoidable, regarding the environmental pressure reduction, promoting a sustainable development, and activating a support of more Green Consumption. Third is Green Purchasing with Standardized loading of (γ = 0.853) which is conformed to the research of Chen et al. (2023) that is environmentally friendly purchasing can activate the overall behavior, and promote a group-to-group impact between buyer and supplier by having several agreed measures such as following an environmentally friendly purchasing measure, improving operation, and developing operation flexibility that lead to improvement of environmental efficiency. According to this prioritizing analysis, it will make entrepreneur see the key methods to improve Green Logistics operation, regarding a reduction of environmental impact in the industrial sector.

Main participation of this study includes: Firstly, it is the first empirical study on development of Green Logistics Measurement Model in Motor Vehicle Industry of Thailand which is a developing country. Secondly, to examine factors which we gathered that are in relevant to Green Logistics in Manufacturing Industry of developed and developing countries which can be used in Thailand Motor Vehicle Industry. Thirdly, Green Logistics factors which are popular in the industrial sector study consist of Green Product Design, Green Purchasing, Green Manufacturing, Green Transportation, and Green Reverse Logistics. However, this research tries to gather more factors related to Green Logistics, including Green Marketing, Green Consumption, and Green Communication to be conformed to Thailand Motor Vehicle Industry. Fourthly, we use Exploratory Factor Analysis process to extract the factors, and Confirmatory Factor Analysis to understand how much the relationship structure of variables is. Since the previous study on Measurement Modeling did not reflect the diverse dimension characteristics of Green Logistics practice (Kim & Han, 2011), it cannot properly measure all scope of Green Logistics practice so in this study, we try to fill this gap. Purpose of the study is to develop an accurate and reliable measurement model which helps entrepreneur and government sector to use Green Logistics management policy in the efficient and inclusive way.

However, there are still has some limitations in this study. Firstly, even though the study has identified Green Logistics indicators of Motor Vehicle Industry in various dimensions as found in the literature, and it has been checked by the industrial professionals, the limitation is that it is not covered and still incomplete which is difficult to completely identify in detail. The further study may extend this point and the findings, as well as gather additional characteristics of Green Logistics study that affects Organization's business efficiency, or Willingness behavior to follow Green Logistics methods. Secondly, the study is limited to only Motor Vehicle Industry in Thailand. Nevertheless, for the future of research, we suggest to use a comparative analysis on Green Logistics in different industries, or make comparison across the geological regions. To do so, we will ensure that this model can be generally utilized.

Table 2.1 Summary of related study and indicators.

Authors	Location	Green Product design	Green Purchasing	Green Manufacturing	Green Transportatio	Green Reverse Logistics	Green Marketing	Green Consumption	Green Communication	Method
Huang et al. (2023)	China	✓								MADM
Chen et al. (2023)	China		✓		✓					SEM
Pegan et al. (2023)	Italy		✓							Hierarchical regression analysis
Ahmad et al. (2023)	China		✓					✓		SEM
Bag and Gupta (2020)	South Africa					✓				SEM
Ismail et al. (2023)	Tanzania						✓			SEM
Yang et al. (2022)	China							✓		Dynamic decision-making model
Venciute et al. (2023)	Lithuanian							✓		SEM
de Souza et al. (2022)	Brazil		✓		✓	✓				AHP
Aziz et al. (2023)	Malaysia								✓	Systematic review
Bui et al. (2023)	Vietnam			✓						FDM, FDEMATE, ANP
This study	Thailand	✓	✓	✓	✓	✓	✓	✓	✓	EFA, CFA

Note: Multi-attribute decision-making (MADM); SEM = Structural Equation Modeling; EFA = Exploratory Factor Analysis; CFA = Confirmatory Factor Analysis; FDM= fuzzy Delphi method; FDEMATEL= Fuzzy decision-making trial and evaluation laboratory; ANP= Analytic network process.

Table 2.2 Demographic analysis of the respondents

Variables	Categories	Frequency	Percentage
Gender	Male	1290	78.80
	Female	348	21.20
Age	20-29	690	42.12
	30-39	708	43.22
	40-59	225	13.74
	50 & above	21	0.92
Job position	Officer	1,071	65.4
	Engineer	369	22.5
	Manager	198	11.6
Green logistics operating period	Less than 3	1,071	65.4
	3-5	369	22.5
	5-10	198	11.6
Business type	Automotive manufacturer	447	27.3
	Automotive parts manufacturers (Tier-1)	963	58.8
	Automotive parts manufacturers (Tier-2-3)	228	13.9

Table 2.3 Descriptive statistics and Exploratory factor analysis.

Constructs		Item	Code	Mean	SD	EFA: Loadings	Cronbach's α
Green	Product design	Product design by using the most environmentally friendly materials.	Q1	4.366	0.725	0.674	0.815
		Product design by make it reusable for many times.	Q2	4.136	0.716	0.714	
		Product design by using the least number of diverse parts and material types	Q3	4.127	0.717	0.651	
		Product design to avoid harmful materials.	Q4	3.969	0.778	0.713	
		Product design to reduce package space.	Q5	3.825	0.883	0.609	
Green	Purchasing	Environmentally friendly purchasing with an environmental management system.	Q6	3.992	0.843	0.702	0.872
		Development of purchasing knowledge for environment promotes an awareness of the environmental problems.	Q7	4.009	0.808	0.661	
		Development that let purchasing authorities buy energy saving products.	Q8	4.036	0.793	0.656	
		Determine working policy with environmental and purchasing units.	Q9	3.997	0.807	0.613	
		Design and provide an environmentally friendly product's E-Catalog (certified by ISO 9000 or ISO 14001).	Q10	3.973	0.792	0.577	
		Training for purchasing and procurement staff to reduce non-environmentally friendly package.	Q11	4.051	0.752	0.721	
		Cooperation with supplier to promote an action of environmental management.	Q12	4.093	0.783	0.707	

Table 2.3 Descriptive statistics and Exploratory factor analysis. (Continue)

Constructs	Item	Code	Mean	SD	EFA: Loadings	Cronbach's α
Green Manufacturing	Promotion on training and using clean technology.	Q13	4.199	0.772	0.651	0.783
	Production process improvement to cause the least waste.	Q14	4.330	0.768	0.713	
	Promotion on training and practice of 3Rs principle (Reduce, Reuse, and Recycle).	Q15	4.188	0.818	0.796	
	Reusing product and package.	Q16	4.183	0.818	0.714	
Green Transportation	Policy of using the energy saving vehicle.	Q17	3.851	0.811	0.648	0.884
	Select energy saving transportation types such as Backhauling	Q18	3.882	0.810	0.793	
	Survey on transportation time to avoid traffic problems.	Q19	3.901	0.849	0.745	
	Studying and determining the energy saving transportation routes.	Q20	3.937	0.848	0.674	
	Use the raw material from production source that is close to manufacturer, or domestic raw material production source to save transportation energy.	Q21	3.923	0.854	0.591	
Green Reverse Logistics	There is the sorting out of defected, expired, and unused product from production to return to quality improvement.	Q22	3.943	0.834	0.601	0.913
	There is a return of defected, expired or unused item from customer to return to quality improvement.	Q23	3.789	0.916	0.748	
	There is the sorting out of defected, expired, and unused product from production for re-production.	Q24	3.817	0.888	0.691	

Table 2.3 Descriptive statistics and Exploratory factor analysis. (Continue)

Constructs	Item	Code	Mean	SD	EFA: Loadings	Cronbach's α
Green Reverse Logistics	There is a return of defected, expired or unused item from customer for re-production.	Q25	4.044	0.941	0.784	0.913
	There is the sorting out of defected, expired, and unused product from production to raw material supplier to return to quality improvement.	Q26	3.921	0.838	0.779	
	There is the sorting out of defected, expired, and unused product from production to raw material supplier for re-production.	Q27	3.686	0.919	0.792	
	There is a return of defected, expired or unused item from customer to raw material supplier to return to quality improvement	Q28	3.695	0.976	0.738	
Green Marketing	Package design by specifying that it is an outstanding green product.	Q29	4.180	0.843	0.750	0.797
	Product's logo design gives a sense of environmental friendliness.	Q30	4.232	0.765	0.544	
	Product advertisement and Public Relations include environmentally friendly qualification.	Q31	4.407	0.717	0.635	
	There are training and activity to educate people about green product and energy conservation.	Q32	4.168	0.845	0.778	

Table 2.3 Descriptive statistics and Exploratory factor analysis. (Continue)

Constructs	Item	Code	Mean	SD	EFA: Loadings	Cronbach's α
Green Consumption	Support and promote product that can be reused.	Q33	3.844	0.846	0.771	0.851
	Support and promote product that saves energy and environment.	Q34	3.828	0.833	0.719	
	Support and promote product that causes the least pollution.	Q35	3.928	0.560	0.652	
	Support and promote product that has an energy saving label.	Q36	4.067	0.840	0.537	
	Support and promote product that has a green product label.	Q37	3.906	0.829	0.709	
Green Communication	Promote the communication that focuses on environmentally friendly practice and product recommendation through Public Relations sign.	Q38	3.837	0.929	0.673	0.834
	Promote the communication that focuses on environmentally friendly practice and product recommendation through website.	Q39	3.801	0.912	0.755	
	Promote the communication that focuses on environmentally friendly practice and product recommendation in magazine.	Q40	3.794	0.931	0.762	
	Promote the communication that focuses on environmentally friendly practice and product recommendation through radio broadcast.	Q41	3.649	0.933	0.725	

Table 2.4 Measurement model results green logistics.

	Construct	Code	CFA: loading Frist-order	CFA: loading Second-order	CR	AVE
Green logistics	Green Product design	Q1	0.721**	0.757**	0.808	0.674
		Q2	0.731**			
		Q3	0.745**			
		Q4	0.591**			
		Q5	0.584**			
	Green Purchasing	Q6	0.682**	0.853**	0.849	0.667
		Q7	0.747**			
		Q8	0.717**			
		Q9	0.642**			
		Q10	0.590**			
		Q11	0.630**			
		Q12	0.662**			
	Green Manufacturing	Q13	0.717**	0.989**	0.678	0.587
		Q14	0.619**			
		Q15	0.612**			
		Q16	0.589**			
	Green Transportation	Q17	0.624**	0.766**	0.823	0.693
		Q18	0.647**			
		Q19	0.771**			
		Q20	0.675**			
		Q21	0.751**			
	Green Reverse Logistics	Q22	0.705**	0.689**	0.909	0.765
		Q23	0.776**			
		Q24	0.811**			
		Q25	0.752**			
		Q26	0.729**			
		Q27	0.762**			
		Q28	0.822**			
	Green Marketing	Q29	0.627**	0.780**	0.776	0.681
		Q30	0.678**			
		Q31	0.726**			
		Q32	0.693**			
	Green Consumption	Q33	0.599**	0.952**	0.741	0.603
		Q34	0.578**			
		Q35	0.629**			
		Q36	0.609**			
		Q37	0.600**			

Table 2.4 Measurement model results green logistics. (Continue)

Construct	Code	CFA: loading		CR	AVE
		Frist-order	Second-order		
Green Communication	Q38	0.705**	0.734**	0.802	0.709
	Q39	0.807**			
	Q40	0.674**			
	Q41	0.648**			

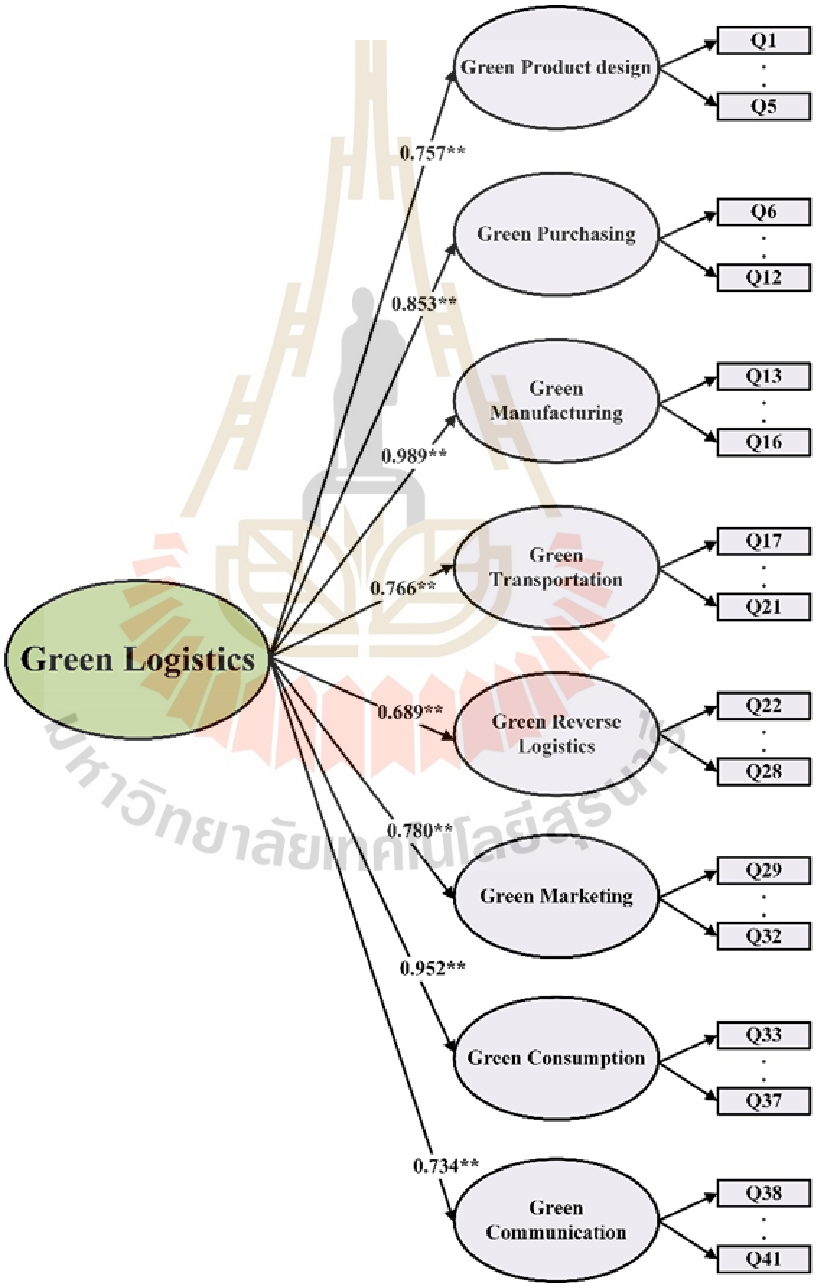

Figure 2.1 CFA model of Green Logistics in Thailand's Auto Industry

2.7 Reference

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CHAPTER III

KEY FACTORS SHAPING GREEN LOGISTICS IN THAILAND'S AUTO INDUSTRY:AN APPLICATION OF STRUCTURAL EQUATION MODELING

3.1 Abstract

Environmental responsibility is a critical focus in business and production. International partners have urged Thai businesses to adhere to global standards in environmental and social accountability. Green logistics management focuses on minimizing costs and boosting competitive efficiency in the industrial sector, while also promoting environmental protection. This study investigates the factors influencing green logistics in the motor vehicle industry. Methods: A self-administered questionnaire was used for data collection from 1638 participants. Confirmatory factor analysis and structural equation modeling were employed to identify causal links impacting green logistics effectiveness. Results: Findings indicate that government and organizational environmental policies, a company's financial ability to implement green initiatives, commitment to eco-friendly investment, and public environmental attitudes significantly and directly affect the efficiency of green logistics. Conclusions: This research provides valuable insights for car manufacturers into key factors in green logistics management. These insights can help in developing strategic plans to achieve environmental sustainability in the context of future market competition.

3.2 Introduction

The motor vehicle industry in Thailand holds a pivotal position within the national economy, contributing approximately 5.4% of the country's gross domestic product (GDP) and constituting around 12.3% of the GDP of the industrial sector. In the year 2023, Thailand's automobile production reached 1.4 million vehicles, securing the 10th global ranking in terms of production volume. Impressively, almost 52% of these manufactured vehicles were exported to a total of 172 countries, with the export value reaching THB 1,300,000, making automobiles Thailand's foremost export commodity (Royal Thai Government, 2023). The swift expansion of the manufacturing sector, closely intertwined with increased consumption of products and services such as transportation, storage, and distribution, has given rise to environmental concerns. Mass consumption patterns have led to issues like inefficient energy utilization, collective sources of pollution, and re-source depletion, all of which have adverse repercussions for the environment (Van Vo & Nguyen, 2023).

The escalating concerns encompassing environmental, social, and economic dimensions have exerted mounting pressure on the automobile industry from governmental bodies, partners, consumers, and environmental advocacy groups. This pressure has prompted policymakers in the production sector to acknowledge the escalating environmental impacts and the necessity for a more sustainable approach. Consequently, the adoption of green logistics management strategies has emerged as a response to redirect the industrial sector's focus towards environmental sustainability (Agyabeng-Mensah, Afum, & Ahenkorah, 2020; Moh'd Anwer, 2022). The role and responsibility of green logistics involve assisting the industrial sector in enhancing its environmental performance and social responsibility. Embracing green logistics not only fosters customer loyalty and brand trust but also enhances profitability (Maji, Mohd Saudi, & Yusuf, 2023). Green logistics practices are indispensable, as they facilitate pollution reduction throughout the production process, product delivery, and customer service, minimize resource shortages, reduce the consumption of resources and renewable energy, and mitigate climate change (Maji et al., 2023; Sharma, Luthra, Joshi, Kumar, & Jain, 2023). Furthermore, green logistics management can positively impact various ecosystems beyond customer expectations and prompt entrepreneurs to recognize the environmental consequences of production, as well as the environmental footprint of suppliers and customers.

Sustainable development involves supportive interaction among different dimensions, including economic, social and environmental aspects. Also, it is the only way to return to environmentally friendly activities such as natural resources conservation, waste management, and reduction of air pollution (Ruggerio, 2021). Government sector regulation, cooperation of supply chain alliance, and various green practices, for example, green production, green design, green purchase, environmentally friendly logistics, etc., are all pushing forward to generate green production in the industrial sector. These elements also decrease dangerous impacts to the environment (Ahmed et al., 2023; Geng, Mansouri, & Aktas, 2017), as well as responding to sustainable consumption and environmentally friendly trading. All of those support the Sustainable Development Goals (SDGs). Moreover, the utilization of green logistics practice and green supply chains are the keys to pursuing SDG number 12: "To ensure sustainable consumption and production patterns" since this goal focuses on supporting the technological capability of developing countries that leads t(Maji et al., 2023)o better sustainable production and consumption patterns of products, such as decreasing waste generated by reusing and recycling processes, decreasing chemicals and toxic waste being released to nature, as well as sustainable purchasing, and efficient use of natural resources, etc. One key to sustainable development that has not received much attention in previous studies is green logistics using technology (Ju, Liu, Xu, & Zhang, 2023).

Prior research on green logistics has explored various industries, including logistics services (such as transportation, warehousing, freight forwarding, and packaging) (C. Liu & Ma, 2022; Maji et al., 2023; Van Vo & Nguyen, 2023), the mining industry (Aibin, Chen, & Wang, 2020), production industries (such as agriculture, beverages, textiles, and pharmaceuticals) (Agyabeng-Mensah et al., 2021), service and production industries (entertainment, logistics, and manufacturing) (Agyabeng-Mensah et al., 2020), and distribution companies (food and beverage, textiles, electronics, pharmaceuticals, and agricultural chemicals) (Agyabeng-Mensah & Tang, 2021). However, in reference to the previously mentioned literature review, it found that there are fewer studies into green logistics in the automobile industry. Green logistics in the automobile industry has a similar pattern to green logistics activities in other manufacturing industries. The research of Agyabeng-Mensah and Tang (2021) has emphasized the management of stakeholder cooperation to solve problems in green logistics (in terms of operation, learning, transportation, and policy control), which is different from our research, which has emphasized logistics management in reducing the environmental impacts caused by logistics activities throughout the supply chain, from the origin and raw material sourcing process, product design and service, production process, transportation process, reverse logistics, consumption, and communication, to the marketing.

Recently, a growing number of scholars have begun to focus on green logistics. Nevertheless, a review of the literature reveals that studies analyzing the factors involved in green logistics management, encompassing its various dimensions, remain fragmented and incomplete. Furthermore, recent research has examined the relationships between green logistics practices and other factors, such as production sustainability and the circular economy in China and Bangladesh (Cheng, Masukujjaman, Sobhani, Hamayun, & Alam, 2023; Jinru, Changbiao, Ahmad, Irfan, & Nazir, 2022), the efficiency of social sustainability and environmental sustainability among production companies in Ghana (Agyabeng-Mensah et al., 2021), and circular economy practices within the manufacturing industry in India (Sharma et al., 2023). The study of S. F. A. Khatib (2023) indicated that sustainable efficiency was developed through the sustainable aspects and performance of stock repurchase. The research results have indicated that environments and societal considerations have influenced stockholders' decisions regarding their investment. However, the main purpose of the stockholders' investment is to focus on the financial pursuit of gain. These studies represent an initial exploration of the impacts of green logistics management on other factors, thereby highlighting a gap in the literature concerning the relationships between several factors that partially influence green logistics management within the motor vehicle industry in developing countries.

The inspiration of this study is the environmental problems caused by the industrial sector. As Thailand is in the top rank of automobile and automobile parts manufacturing exporters, the automobile manufacturers play a key role in pushing forward the economy of Thailand. To reduce the environmental problems in the automobile industry it is important to have a good management system, which recognizes the importance of green logistics in the automobile industry of Thailand, which is a developing country. However, according to the studies identified in the literature review, previous research has not covered logistics management in every dimension. Also, there has been no study of the main sustainable pillars of SDGs, in terms of the environment, which precisely affect logistics management. Therefore, we have conducted this study.

Our study involves three parts: (1) to learn about the main factors relevant to environmentally friendly logistics management from the points of view of staff, engineers, and managers in an automobile industry group; (2) to promote the development of a code of conduct for environmentally friendly logistics in developing countries; and (3) to learn about the key mechanisms that support green logistics management in the automobile industry of Thailand. Furthermore, the study contributes to expanding the existing body of knowledge regarding the roles of the government and organizations and their attempts to implement environmental policy, the financial ability of an organization to implement green change, the financial willingness to pay for green consumption, and the social reputation of organizations regarding their attitudes to the environment. These factors affect environmentally friendly logistics management in different dimensions, including purchasing, production, marketing, consumption, reverse logistics, transportation, and communication. These factors are highly relevant to logistics activities in an environmentally friendly industrial sector.

Data were collected from experienced professionals employed in the motor vehicle industry through a five-point Likert scale questionnaire, employing a convenience-based random sampling method. Data analysis involved descriptive statistical analysis, confirmatory factor analysis, and structural equation modeling (SEM). The findings of this study offer novel insights and emphasize the need for a comprehensive understanding of the factors affecting green logistics management in order to address emerging environ-mental challenges with broader scope and definition. Thus, this research has the potential to garner support from government bodies, entrepreneurs, and stakeholders, and identify the factors influencing logistics management within the motor vehicle industry in Thai-land.

In addition, the article also includes more structures that are Part 2: Literature review, Part 3: Research methods, Part 4: Results, and Part 5: Conclusion and Discussion.

3.3 Theoretical Background and Hypotheses

3.3.1 Green Logistics Management

Logistics in business operations is part of supply chain management, and its roles are to plan, control, and store data and products from their origin to consumption, and to respond to consumers' needs. Most logistics activities focus on procurement, distribution, maintenance, and inventory management, but do not involve marketing activities, new product development, or finance (Van Vo & Nguyen, 2023). Green logistics relates to production and product distribution, packaging, product search, and product distribution management by focusing on material and waste management, energy saving, and fuel-reducing transportation, in terms of environmental and social responsibility (Hernández-Mejía, Torres-Muñoz, Inzunza-González, Sánchez-López, & García-Guerrero, 2022; Sbihi & Eglese, 2010). The main objectives of green logistics are to reduce the environmental impacts of logistics activity, reduce energy and waste, improve product brand value, gain operational efficiency, and reduce costs by using energy at maximum efficiency (Kwak, Cho, Seok, & Yoo, 2020; Rodrigue, 2020; Seroka-Stolka & Ociepa-Kubicka, 2019). Furthermore, green logistics also focuses on reducing carbon production, reducing waste, producing environmentally friendly containers and pack-aging, promoting environmentally friendly transport, and reducing environmental im-pacts in the production supply chain (Agyabeng-Mensah et al., 2020).

Environmentally friendly logistics is a key factor in the green supply chain (Van Vo & Nguyen, 2023). It is a practical method for achieving sustainable development since it also helps different businesses in the supply chain to become efficient by indicating and selecting environmentally friendly material suppliers, suggesting environmentally friendly solutions, and using green transport for customer delivery. In addition, implementing environmentally friendly logistics makes logistics companies more competitive regarding worldwide provision. Regarding the research on green logistics, there are studies of different green logistics factors in numerous forms, e.g., green design (Junjun Liu, Hu, Tong, & Zhu, 2020; Stekelorum, Laguir, Gupta, & Kumar, 2021), green procurement (de Souza, Kerber, Bouzon, & Rodriguez, 2022; Rehman, Elrehail, Poulin, Shamout, & Alzoubi, 2023; Yook, Choi, & Suresh, 2018), green manufacturing (Junjun Liu et al., 2020; Rehman et al., 2023), green marketing (Rehman et al., 2023), green consumption (Paço, Shiel, & Alves, 2019), green reverse logistics (Letunovska et al., 2023; Stekelorum et al., 2021), green transportation (de Souza et al., 2022; Jazairy, 2020; Stekelorum et al., 2021; Venus Lun, Lai, Wong, & Cheng, 2015), and green communication (Dabaghi, Movahedi, & Langar, 2017), etc. However, most factors are used in the manufacturing industry and are widely tested. Thus, they are highly reliable and can create eco-production management efficiency that goes beyond customer expectations, including by impacting the supply chain (Lee & Klassen, 2008). Researchers have hypothesized that green logistics factors in the Thai motor vehicle industry comprise green design, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication.

3.3.2 Government Environmental Policy

The government influences and leads organizational behavior, raises awareness in the public sector of the importance of eco-industry development, and implements strict legalization regarding environmental policy to create effective environmental protection controls by the domestic industry sector (J. Yang & Chen, 2023). Many people believe that the government should protect the environment, which is preferable to handing authority to the private sector, because the private sector will only focus on maximizing profits as their goal. Thus, the government often intervenes in the business operations of the private sector through environmental regulations and different forms of business incentives, e.g., promotional policies for cost reduction, low-interest rate loans for clean technology procurement, support for research grants for green industry promotion (Joo, Seo, & Min, 2018), etc. The government is responsible for enforcing environmental laws and rules, which impact environmental monitoring efficiency and people's security and well-being (Chen, Wang, & Wan, 2023). The government places importance on environmental conservation and recovery for sustainable development by enacting strict regulations regarding the environmental standards of products. These regulations help towards the government's environmental policy, environmental quality management, protecting and treating the environment, and helping it to recover, as well as promoting sustainable efficiency. Examples of research on government green project policies in other countries include the government's environmental policy that played a key role in controlling problems in logistics for the environment in southeast Europe

(Beškovnik & Twrdy, 2012). Studies on government policy changes in many countries have found that environmental policy influenced goal-setting in activities in the manufacturing industry (Shinkle, Hodgkinson, & Gary, 2021). In a study on government promotion of an environmentally friendly logistics policy for the industrial sector, the results found that the government had to work with experienced logistics organizations, especially those in transport and storage, to respond to this policy at maximum efficiency (Maji et al., 2023). Moreover, there are studies on the causal relationships of the Chinese government's pol-icy systems, which positively affected green logistics operations in the coal industry (Aibin et al., 2020), and a study on the effect of the Chinese government's environmental regulations, which caused positive green changes in the production industry related to implementing operations in accordance with the methods arranged by government for environmental technology innovation (Jazairy & von Haartman, 2020). Thus, we expect that the Thai government's environmental policy will positively affect the green logistics management of the Thai Motor Vehicle Industry Group.

Hypothesis 1 (H1). The Government's environmental policy influences green logistics management of the Thai Motor Vehicle Industry Group.

3.3.3 Environmental Policy in the Organization

Changes to the natural environment have a significant influence on business relationships. However, there are different ideas about why companies must use environ-mental management practices (Dibrell, Craig, & Hansen, 2011). Thus, we conducted a review of previous literature on organizational social responsibility or sustainable development policy. The review found that there are studies on employee perceptions of organizational internal environmental policy (Paillé & Raineri, 2015), innovation and sustainable development (Fan et al., 2023), top executives' intentions to encourage organizational ability to comply with of the environmental practice standards (Wei et al., 2023), employees' intentions toward green innovation management and human resource practices (Ahmed et al., 2023), stimulation of voluntary compliance with organizations' green policies (Zafar, Ho, Cheah, & Mohamed, 2022), stimulation for companies to adopt the ISO 14001 is an international certifiable environmental management(Heras-Saizarbitoria & Boiral, 2013) and ISO 9000 framework was created as a quality management system standard, service and process performance measurement and improvement promotional (Bastas & Liyanage, 2019) policy in practice (Opoku-Mensah, Chun, Tuffour, Chen, & Adu Agyapong, 2023), According to an examination of the relationship between organizational internal environmental policy and green logistical management, there is a study of an organization's top executive related to the company response to green logistics and the green supply chain (Jazairy & von Haartman, 2020). The top executive's support is a main factor in environmentally friendly procurement practices (Junqi Liu, Liu, & Yang, 2020). Referring to the literature reviews, we can conclude that organizational internal environmental policy led by top executives plays a key role in driving the organization's environmental caretaking forward. Thus, this study develops a better understanding of the mechanisms influencing organizational internal environmental policy in terms of how the regulations arranged by the executives affect green logistics management in the Thai motor vehicle industry. Thus, we established the next hypothesis as follows:

Hypothesis 2 (H2). Environmental policy in an organization influences green logistics management of the Thai Motor Vehicle Industry Group.

3.3.4 Financial Ability of an Organization to Implement Green Change

Environmental value is mostly considered a national resource obtained from two areas: the people sector (residential wastewater and garbage) and the industrial sector, e.g., pollution emissions, waste from production processes, and wastewater that requires a share of environmental treatment costs, since they are a source of environmental problems (Ji, Ren, & Ulgiati, 2019). In many countries, governments or local agencies support investment in pollution control and allocate budgets for environmental problem-solving. However, funds to help solve environmental problems are required from industrial sector organizations, since they are the greatest source of the pollution problem (Azapagic & Perdan, 2000). A study on organizational financial ability can help strengthen value and add marketing value to organizations (Iqbal, Nadeem, Gull, & Kayani, 2022). The literature review on the relationship between organizational financial ability and green change found that financial ability, technological innovation, and government policy positively affect the green change efficiency of the manufacturing industry in China (Zhai & An, 2020). However, there are few studies on how organizational financial ability to implement green change impacts green logistics management in the Thai motor vehicle industry. Thus, the researchers set the following hypothesis:

Hypothesis 3 (H3). Financial ability in an organization for green change influences the green logistics management of the Thai Motor Vehicle Industry Group2.5. Financial Willingness to Pay for Green Consumption

There are many studies on customer willingness to pay for environmentally friendly products (Saphores, Nixon, Ogunseitan, & Shapiro, 2007). Environmentally friendly product manufacturing affects the green supply chain and leads to higher retail prices. Furthermore, customer willingness to pay for environmentally friendly products motivates retailers and producers to invest in environmentally friendly technology and reduce product manufacturing costs (Xia et al., 2022). Friendly cooperation toward green logistics operations between suppliers and customers of several companies positively impacts sustainable consumption behavior, while expensive transactions negatively affect such a relationship (H.-j. Yang, Fang, Yao, & Su, 2023). According to an examination of the im-pact of financial willingness to pay for green consumption, it was found that willingness to pay positively impacts environmentally friendly transport. This result also indicates that governments must be in control of marketing and educate consumers regarding environmentally friendly transport and energy-saving fuel (Schniederjans & Starkey, 2014). Based on the results of the literature review regarding the impact of willingness to pay Thai motor vehicle entrepreneurs for green logistics management, the researchers established the following hypothesis:

Hypothesis 4 (H4). Financial willingness to pay for green consumption influences the green logistics management of the Thai Motor Vehicle Industry Group.

3.3.5 Social Reputation for Environmental Concern

A low level of trust causes a risk to a business's reputation. It also causes the government to pay more attention to monitoring and examination of the business, which might affect the business's profits in the long term. Organizational social responsibility promotes a good reputation and might benefit future business operations (Komodromos & Melanthiou, 2014). Corporate reputation is affected by various factors, e.g., transparency, human value, employee welfare, the organization's leader's reputations, ability to handle change, and social and environmental standpoint (Mohr & Webb, 2005). An organizations' environmentally friendly reputation is a valuable property that can drive the success of organizational environmental management. Moreover, activities which pro-mote a positive environmental reputation also support creating organizational green innovation. This requires using eco-design principles and using fewer and environmentally friendly materials to develop several products and processes (Agyabeng-Mensah, Afum, & Baah, 2022). However, our review found that there are limitations on how social reputation affects green logistics management. Thus, the researchers established the following hypothesis:

Hypothesis 5 (H5). Social reputation about the environment influences the green logistics management of the Thai Motor Vehicle Industry Group.

Table 1 presents the findings of the literature review, which are mostly related to factors responding to the main sustainable pillars of SDGs in regard to the environment. The relevant study results revealed the limitations of those studies in terms of the different samples' scales, geological areas, and analytical methods. For example, a study on the problems of global warming and climate change was conducted in developing countries where the problems were caused by inefficient government environmental policies. Therefore, the concept of green logistics will help policy makers and researchers to understand the importance of green logistics, to improve society and the economy of the countries, as well as their environmental efficiency (Khan, Sharif, Golpîra, & Kumar, 2019). A study on environmental regulations and laws encouraged several companies to look for new methods of reducing expenditure and costs, and brought positive results for green innovation (Javeed et al., 2023). Another study on green innovation for environ-mental operations led to improvements in the organization's operation, while the result also indicated that the executives would work towards environmental innovation, encouraging changes at an organizational level which led to utilizing environmentally friendly practices (Ahmed et al., 2023). The researchers identified the knowledge gap in the study of the factors responding to the main sustainable pillars that affected green logistics management. We summarize the research from the literature review. The factors affecting green logistics management of the motor vehicle industry consist of government environmental policy, organizations' internal environmental policy, attitudes towards environmental comprehension, organizational financial ability to implement green change, willingness to pay for green consumption, and social reputation regarding the environment. To evaluate the impact of each factor, the five hypotheses are tested ac-cording to the research objectives.

Table 3.1 Scoring Rank to prepare for the main factors' comparison

Authors	Location	Types	Method	Samples	SDGs	Government Environmental Policy	Environmental Policy in the Organization	Financial Ability of an Organization for Green Change	Financial Willingness to Pay for Green Consumption	Social Reputation regarding the Environment
Jazairy and von Haartman (2020)	Sweden	Interviews	Delphi approach	17	Environment	✓				
Fan et al. (2023)	Pakistan	Survey	SEM-PLS	276	Environment		✓			
Maji et al. (2023)	Nigeria	Survey	chi-square and regression	197	Environment		✓			
Beškovnik and Twrdy (2012)	European	Article	-	-	Environment	✓				
Ahmed et al. (2023)	Pakistan	Survey	SEM-PLS	320	Environment		✓			
Iqbal et al. (2022)	USA	Database	Empirical models	46,000	Environment			✓		
Zhai and An (2020)	China	Survey	SEM	500	Environment	✓		✓		
Akhtar, Sultana, Masud, Jafrin, and Al-Mamun (2021)	Malaysia	Survey	SEM-PLS	308	Environment				✓	
Agyabeng-Mensah et al. (2022)	China	Survey	SEM	208	Environment	✓				✓
Khan et al. (2019)	Malaysia	Database	FMOLS and DOLS	-	Environment social and economic	✓				
Javeed et al. (2023)	China	Database	Appropriate econometric	-	Environment	✓	✓			
This study	Thailand	Survey	SEM	1638	Environment	✓	✓	✓	✓	✓

SEM—structural equation modeling; PLS—partial least squares; FMOLS—fully modified ordinary least squares; DOLS—dynamic modified ordinary least squares; ✓ means that variables were used in the studies

3.4 Methodology

Measurement and Data Collection

The survey instrument for this study was designed based on an extensive literature review and relevant research findings. The questions were selected from previous studies that had passed accuracy and trust testing through the IOC method. The survey is divided into three sections: The first section captures the demographic details of the respondents, including job title, organization size, nationality, details about the organization’s share-holders, business nature, duration of involvement in the green project policy practices, among others. The second section delves into activities related to green project policy practices specific to the Thai Motor Vehicle Industry Group. The third section assesses the factors that influence activities concerning green project policy practices within the Thai Motor Vehicle Industry Group, as presented in Table A1. Responses were recorded using a 5-point Likert scale, where 1 signifies ‘Do not agree’, and 5 stands for ‘Totally agree’. Before this survey, the questionnaire was used in a pilot test, which was conducted using 35 samples distributed to companies in the motor vehicle industry. The number of pilot surveys in the sample was similar to the study of Mettathamrong, Upping, and Deeudom (2023). Based on feedback, minor modifications to the questionnaire were implemented.

The respondents must be at least 20 years old, have more than one year of work experience in the motor vehicle industry, and work as an engineer, employee, or manager. The complete samples necessary for model analysis are 1:15, which is equal to observable variables recommended by Golob (2003). There are 82 observable variables in this study; thus, samples must be greater than 1230 to be suitable. We obtained 1638 samples from this survey, which are sufficient for SEM requirements (Hair, Black, Babin, & Anderson, 2014).

We chose our operating method of simple random sampling in central and eastern regions of Thailand because there are many automobile and automobile parts manufacturers located here, with 570 companies in total. We contacted the companies by email and received responses from 300 companies, accounting for 52.6%. Then our team went to the manufactures to conduct the face-to-face surveys and collected data between April and July 2022. Once we collected and checked the accuracy of the questionnaires, we analyzed the data from 1638 samples.

The population data showed that years of work experience are as follows: 5–10 years—513 (31.3%) and 1–3 years—411 (25.1%). Company sizes are 200–1000 employees—828 (50.5%) and more than 1000 employees—441 (50.5%). For company shareholders' nationality, Thais hold more shares than foreigners—798 (48.7%), and there were 450 Thai 100% shareholders (27.5%). For type of business, automotive parts manufacturers represent (Tier-1) 963 (58.8%), and automotive manufacturers represent 447 (27.3%). In terms of job position, there are 1071 employees (65.4%) and 369 engineers (22.5%), as presented in Table 3.2 and Figure 3.1

Table 3.2 The profiles of survey respondents (n = 1638).

Company Characteristics	The Number of Respondents	Percentage
Operating period		
<1 year	207	12.6
1–3 years	411	25.1
4–6 years	513	31.3
7–9 years	342	20.9
>10 years	165	10.1
Company size		
<200 employees	369	22.5
200–1000 employees	828	50.5
>1000 employees	441	26.9
Shareholders' nationality		
100% Thai	450	27.5
Thai > Foreigners	798	48.7
Foreigners > Thais	258	15.8
100% Foreigners	132	8.1
Business type		
Automotive manufacturer	447	27.3
Automotive parts manufacturers (Tier-1)	963	58.8
Automotive parts manufacturers (Tiers-2–3)	228	13.9
Job position		
Officer	1071	65.4
Engineer	369	22.5
Manager	198	11.6

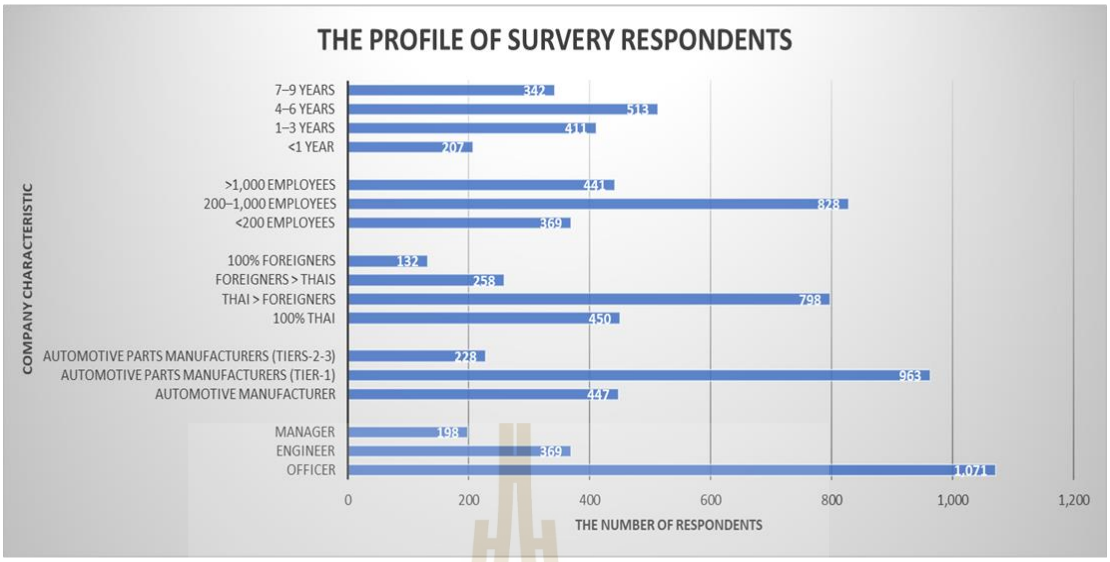

Figure 3.1 The profiles of survey respondents

3.5 Data Analysis and Results

3.5.1 Descriptive Data

According analysis of the results from the preliminary statistical test, the mean is 3.595–4.396, and the standard deviation is 0.743–0.976. Cronbach's alpha is more than 0.7 green design, green procurement, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication are 0.86, 0.873, 0.800, 0.827, 0.782, 0.918, 0.855, and 8.150, respectively. While the government's environmental policy, organizations' internal environmental policy, organizational financial ability for green change, financial willingness to pay for green consumption, and social reputation for the environment were 9.15, 0.852, 0.852, 0.895, 0.858, and 0.865, respectively. In summary, Cronbach's alpha is 0.7–0.8, which is internally consistent. The measurement model analysis using the Kaiser–Meyer–Olkin statistic is 0.876, indicating that there is a type of observable variable that can be used to derive reliable factors.

3.5.2 Measurement Model Assessment

In the context of this study, confirmatory factor analysis (CFA) was carried out using the M-plus program, a suitable tool for comprehensive results analysis (Hair Jr, Sarstedt, Ringle, & Gudergan, 2017). To ensure the reliability and precision of the measurement model, the research team employed a multipronged approach. First, the average variable extracted (AVE) analysis revealed values spanning from 0.619 to 0.818 for the observable variables, all of which exceeded the widely accepted threshold of 0.50 (Hair et al., 2014). Second, construct reliability (CR) analysis indicated values ranging from 0.785 to 0.910, surpassing the recommended minimum of 0.70, in accordance with the guidance of Hair and colleagues (Hair et al., 2014). Additionally, the confirmatory factor analysis (CFA) encompassed both first-order and second-order CFA. In the first-order CFA, the standardized factor loadings of the observable variables ranged from 0.612 to 0.849, and in the second-order CFA, these loadings ranged from 0.692 to 0.895, all of which exceeded the threshold of 0.50 recommended by Hair (Hair et al., 2014). These meticulous analyses collectively confirm the statistical significance of the measurement model, as evidenced by p-values < 0.001, as presented in Table 3.3

The standardized loading values of each variable are as follows.

1) Green design: There are six observed variables. For the highest value of standardized loading, the statistical value is GD2 (γ = 0.755), second is GD3 (γ = 0.747), and the least is GD6 (γ = 0.569).

2) Green procurement: There are eight observed variables. For the highest value of standardized loading, the statistical value is GP7 (γ = 0.712), second is GP2 (γ = 0.704) and the least is GP5 (γ = 0.630).

3) Green manufacturing: There are six observed variables. For the highest value of standardized loading, the statistical value is GM1 (γ = 0.717), second is GM2 (γ = 0.619), and the least is GM5 (γ = 0.549).

4) Green marketing: There are five observed variables. For the highest value of standardized loading, the statistical value is GMA4 (γ = 0.723), second is GMA3 (γ = 0.718), and the least is GMA1 (γ = 0.618).

5) Green consumption: There are four observed variables. For the highest value of standardized loading, the statistical value is GC3 (γ = 0.699), second is GC2 (γ = 0.642), and the least is GC1 (γ = 0.610).

6) Green reverse logistics: There are seven observed variables. For the highest value of standardized loading, the statistical value is GR3 (γ = 0.775), second is GR7 (γ = 0.766), and the least is GR5 (γ = 0.724).

7) Green transportation: There are eight observed variables. For the highest list of standardized loading, the statistical value is GT7 (γ = 0.726), second is GT5 (γ = 0.665), and the least is GT3 (γ = 0.614).

8) Green communication: There are four observed variables. For the highest value of standardized loading, the statistic value is GCO2 (γ = 0.761), second is GCO1 (γ = 0.739), and the least is GCO4 (γ = 0.649).

9) Government environmental policy: There are six observed variables. For the highest value of standardized loading, the statistical value is GE5 (γ = 0.829), second is GE3 (γ = 0.797), and the least is GE1 (γ = 0.709).

10) Environmental policy in the organization: There are seven observed variables. For the highest value of standardized loading, the statistical value is EO2 (γ = 0.676), second is EO7 (γ = 0.664), and the least is EO6 (γ = 0.540).

11) Financial ability in an organization for green change: There are five observed variables. For the highest value of standardized loading, the statistical value is FG1 (γ = 0.849), second is FG3 (γ = 0.838), and the least is FG5 (γ = 0.786).

12) Financial willingness to pay for green consumption: There are six observed variables. For the highest value of standardized loading, the statistical value is FWP3 (γ = 0.792), second is FWP4 (γ = 0.711), and the least is FWP1 (γ = 0.646).

13) Social reputation for the environment: There are seven observed variables. For the highest value of standardized loading, the statistical value is SE1 (γ = 0.724), second is SE7 (γ = 0.723), and the least is SE4 (γ = 0.633).

The secondary results of the CFA are as outlined below:

14) Green logistics: There are eight observed variables. The highest value of standardized loading is green consumption, (γ = 0.895), second is green marketing; (γ = 0.883), and the least is green reverse logistics (γ = 0.692).

Table 3.3 Results of descriptive statistics and confirmatory factor analysis.

Latent Variables/ Factor Code	Code of Observed Variables	Mean	SD	Standardized Loadings		CR	AVE	Cronbach 's α
				1st-Ordered	2nd-Ordered			
(a) Endogenous Latent Variables								
Green design/(GRDE)	GD1	4.361	0.728	0.732 **	0.721 **	0.825	0.661	0.86
	GD2	4.115	0.711	0.755 **				
	GD3	4.112	0.697	0.747 **				
	GD4	4.212	0.734	0.590 **				
	GD5	3.946	0.772	0.574 **				
	GD6	3.995	0.845	0.569 **				
Green procurement/(GRPR)	GP1	3.875	0.839	0.627 **	0.797 **	0.868	0.671	0.873
	GP2	3.964	0.838	0.704 **				
	GP3	3.988	0.803	0.685 **				
	GP4	4.009	0.789	0.664 **				
	GP5	3.973	0.803	0.630 **				
	GP6	3.952	0.785	0.661 **				
	GP7	4.029	0.746	0.712 **				
	GP8	4.074	0.777	0.687 **				
Green manufacturing/(GRMA)	GM1	4.197	0.696	0.717 **	0.716 **	0.789	0.619	0.800
	GM2	4.154	0.757	0.619 **				
	GM3	4.183	0.775	0.612 **				
	GM4	4.330	0.768	0.589 **				
	GM5	4.178	0.821	0.549 **				
	GM6	4.167	0.819	0.630 **				

Table 3.3 Results of descriptive statistics and confirmatory factor analysis. (Continue)

Latent Variables/ Factor Code	Code of Observed Variables	Mean	SD	Standardized Loadings 1st-Ordered	Standardized Loadings 2nd-Ordered	CR	AVE	Cronbach 's α
Green marketing/(GRKE)	GMA1	3.851	0.819	0.618 **	0.883 **	0.814	0.683	0.827
	GMA2	3.789	0.836	0.667 **				
	GMA3	3.769	0.820	0.718 **				
	GMA4	3.879	0.853	0.723 **				
	GMA5	4.030	0.842	0.690 **				
Green consumption/(GRCO)	GC1	4.149	0.844	0.610 **	0.895 **	0.785	0.635	0.782
	GC2	4.158	0.842	0.642 **				
	GC3	4.212	0.767	0.669 **				
	GC4	4.396	0.718	0.618 **				
Green reverse Logistics/(GREL)	GR1	3.774	0.877	0.725 **	0.692 **	0.910	0.747	0.918
	GR2	3.934	0.834	0.758 **				
	GR3	3.777	0.915	0.775 **				
	GR4	3.804	0.888	0.754 **				
	GR5	4.033	0.947	0.724 **				
	GR6	3.907	0.839	0.731 **				
	GR7	3.667	0.917	0.766 **				
	GR8	3.678	0.977	0.746 **				
Green transportation/(GRTR)	GT1	4.008	0.814	0.632 **	0.870 **	0.852	0.646	0.855
	GT2	3.816	0.799	0.632 **				
	GT3	3.856	0.800	0.614 **				
	GT4	3.874	0.844	0.617 **				
	GT5	3.913	0.843	0.665 **				

Table 3.3 Results of descriptive statistics and confirmatory factor analysis. (Continue)

Latent Variables/ Factor Code	Code of Observed Variables	Mean	SD	Standardized Loadings 1st-Ordered	Standardized Loadings 2nd-Ordered	CR	AVE	Cronbach 's α
Green transportation/(GRTR)	GT5	3.913	0.843	0.665 **				
	GT6	3.896	0.849	0.658 **				
	GT7	4.055	0.819	0.726 **				
	GT8	3.953	0.896	0.626 **				
Green communication /(GCOM)	GCO1	3.793	0.922	0.739 **	0.728 **	0.808	0.715	8.15
	GCO2	3.760	0.904	0.761 **				
	GCO3	3.747	0.927	0.712 **				
	GCO4	3.595	1.092	0.649 **				
(b) Exogenous Latent Variables								
Government environmental Policy/(GOVE)	GE1	4.117	0.973	0.709 **	-	0.903	0.780	9.15
	GE2	4.027	0.931	0.792 **				
	GE3	4.073	0.919	0.797 **				
	GE4	3.923	0.933	0.776 **				
	GE5	3.940	0.949	0.829 **				
	GE6	3.874	0.954	0.775 **				
Environmental policy in the organization/(ENPO)	EO1	4.081	0.771	0.615 **	-	0.808	0.613	0.852
	EO2	4.055	0.757	0.676 **				
	EO3	4.101	0.798	0.612 **				
	EO4	4.139	0.832	0.596 **				
	EO5	4.125	0.836	0.586 **				
	EO6	4.288	0.812	0.540 **				
	EO7	4.033	0.800	0.664 **				

Table 3.3 Results of descriptive statistics and confirmatory factor analysis. (Continue)

Latent Variables/ Factor Code	Code of Observed Variables	Mean	SD	Standardized Loadings 1st-Ordered	Standardized Loadings 2nd-Ordered	CR	AVE	Cronbach 's α
Financial ability in an organization in the green change/(FAOG)	FG1	3.903	0.898	0.849 **	-	0.910	0.818	0.895
	FG2	3.863	0.833	0.801 **				
	FG3	3.877	0.822	0.838 **				
	FG4	3.929	0.850	0.814 **				
	FG5	3.963	0.866	0.786 **				
Financial willingness to pay in green consumption/(FWPG)	FWP1	3.943	0.750	0.646 **	-	0.874	0.705	0.858
	FWP2	4.018	0.758	0.710 **				
	FWP3	4.027	0.754	0.792 **				
	FWP4	3.960	0.788	0.711 **				
	FWP5	4.046	0.792	0.700 **				
	FWP6	3.907	0.856	0.705 **				
	FWP7	3.859	0.854	0.669 **				
Social reputation about the environment/(SRAE)	SE1	3.608	0.924	0.724 **	-	0.870	0.699	0.865
	SE2	3.794	0.881	0.709 **				
	SE3	3.890	0.851	0.677 **				
	SE4	3.863	0.956	0.633 **				
	SE5	4.038	0.817	0.718 **				
	SE6	3.901	0.785	0.710 **				
	SE7	3.738	0.877	0.723 **				

** significant at = 0.001

Furthermore, the investigation was extended to assess the relationships between different factors in the study. Pearson’s correlation analysis was employed, revealing correlation coefficients that ranged from 0.289 to 0.980. These results underscore the positive and statistically significant interrelationships between the study’s factors, demonstrating their meaningful associations according to the 0.05 significance level, as illustrated in Table 3.4 These rigorous analyses contribute to the robustness and validity of the research findings, enhancing the overall quality of the study.

Table 3.4 Pearson correlation coefficients.

Constructs	1	2	3	4	5	6
2. GRPR	0.545 **					
3. GRMA	0.412 **	0.526 **				
4. GRKE	0.473 **	0.537 **	0.507 **			
5. GRCO	0.536 **	0.587 **	0.503 **	0.449 **		
6. GREL	0.467 **	0.514 **	0.349 **	0.573 **	0.388 **	
7. GRTR	0.497 **	0.564 **	0.545 **	0.617 **	0.566 **	0.542 **
8. GCOM	0.497 **	0.564 **	0.545 **	0.617 **	0.566 **	0.542 **
9. GOVE	0.433 **	0.452 **	0.489 **	0.558 **	0.567 **	0.402 **
10. ENPO	0.431 **	0.492 **	0.559 **	0.504 **	0.464 **	0.391 **
11. FAOG	0.464 **	0.529 **	0.289 **	0.377 **	0.620 **	0.373 **
12. FWPG	0.433 **	0.474 **	0.442 **	0.538 **	0.499 **	0.433 **
13. SRAE	0.512 **	0.515 **	0.409 **	0.616 **	0.479 **	0.565 **

Constructs	7	8	9	10	11	12
2. GRPR						
3. GRMA						
4. GRKE						
5. GRCO						
6. GREL						
7. GRTR						
8. GCOM	0.980 **					
9. GOVE	0.617 **	0.617 **				
10. ENPO	0.597 **	0.597 **	0.523 **			
11. FAOG	0.451 **	0.451 **	0.457 **	0.403 **		
12. FWPG	0.605 **	0.605 **	0.547 **	0.544 **	0.471 **	
13. SRAE	0.625 **	0.625 **	0.644 **	0.535 **	0.491 **	0.619 **

** significant at = 0.001.

3.5.3 Structural Model and Hypotheses Testing

The present study employed structural equation modeling (SEM) with the highest probability method to scrutinize the relationships between the variables within the con-text of the Thai Motor Vehicle Industry Group's green logistics management. The results of the goodness of fit analysis demonstrated a commendable fit, with an χ^2 value of 10,574.997 and 2686 degrees of freedom (*df*), yielding a highly significant p-value of less than 0.001. Furthermore, the χ^2/df ratio of 3.937, which is below the conventional thresh-old of five and signifies a robust fit of the model to the data (Hu & Bentler, 1999). The fit indices also provided corroborative evidence, as the root mean square error of approximation (RMSEA) exhibited a value of 0.042, well below the recommended cutoff of 0.07 (Steiger, 2007). Additionally, the comparative fit index (CFI) was 0.909, surpassing the minimum acceptance threshold of 0.90 (Hu & Bentler, 1999), and the Tucker–Lewis index (TLI) achieved a value of 0.891, exceeding the 0.80 benchmark (Hooper, Coughlan, & Mullen, 2008). Moreover, the standardized root mean square residual (SRMR) was 0.050, within the acceptable range of 0.08 or less (Hu & Bentler, 1999). Taken together, these findings affirm the congruence of the SEM model with the empirical data, providing a strong foundation for the subsequent hypothesis evaluations. The hypotheses presented in Table 3.5 and Figure 3.2 are assessed as follows.

Turning to the assessment of the formulated hypotheses, the empirical results rein-force the theoretical constructs under investigation. Firstly, the government's environ-mental policy, acting as an influential factor in the green logistics management of the Thai Motor Vehicle Industry Group, exhibited a significant standardized path coefficient of 0.187 at a level of $p < 0.01$, providing robust support for Hypothesis 1 (H1). Similarly, Hypothesis 2 (H2) is substantiated because the internal environmental policy within the organization, affecting green logistics management, is associated with a substantial standardized path coefficient of 0.386, accompanied by a significance level of $p < 0.01$. Furthermore, Hypothesis 3 (H3) finds empirical validation, as the organization's financial efficiency for green change, influencing green logistics management, is underscored by a standardized path coefficient of 0.084 at $p < 0.01$ significance. Likewise, Hypothesis 4 (H4) is reinforced, with the financial willingness to pay for green consumption, impacting green logistics management, characterized by a noteworthy standardized path coefficient of 0.179 and a significance level of $p < 0.01$. Finally, Hypothesis 5 (H5) gains empirical support because the social reputation for environmental endeavors, influencing green logistics management, is marked by a substantial standardized path coefficient of 0.218 at $p < 0.01$ significance.

These collective findings provide valuable insights into the intricate relationships governing the green logistics management within the Thai Motor Vehicle Industry Group.

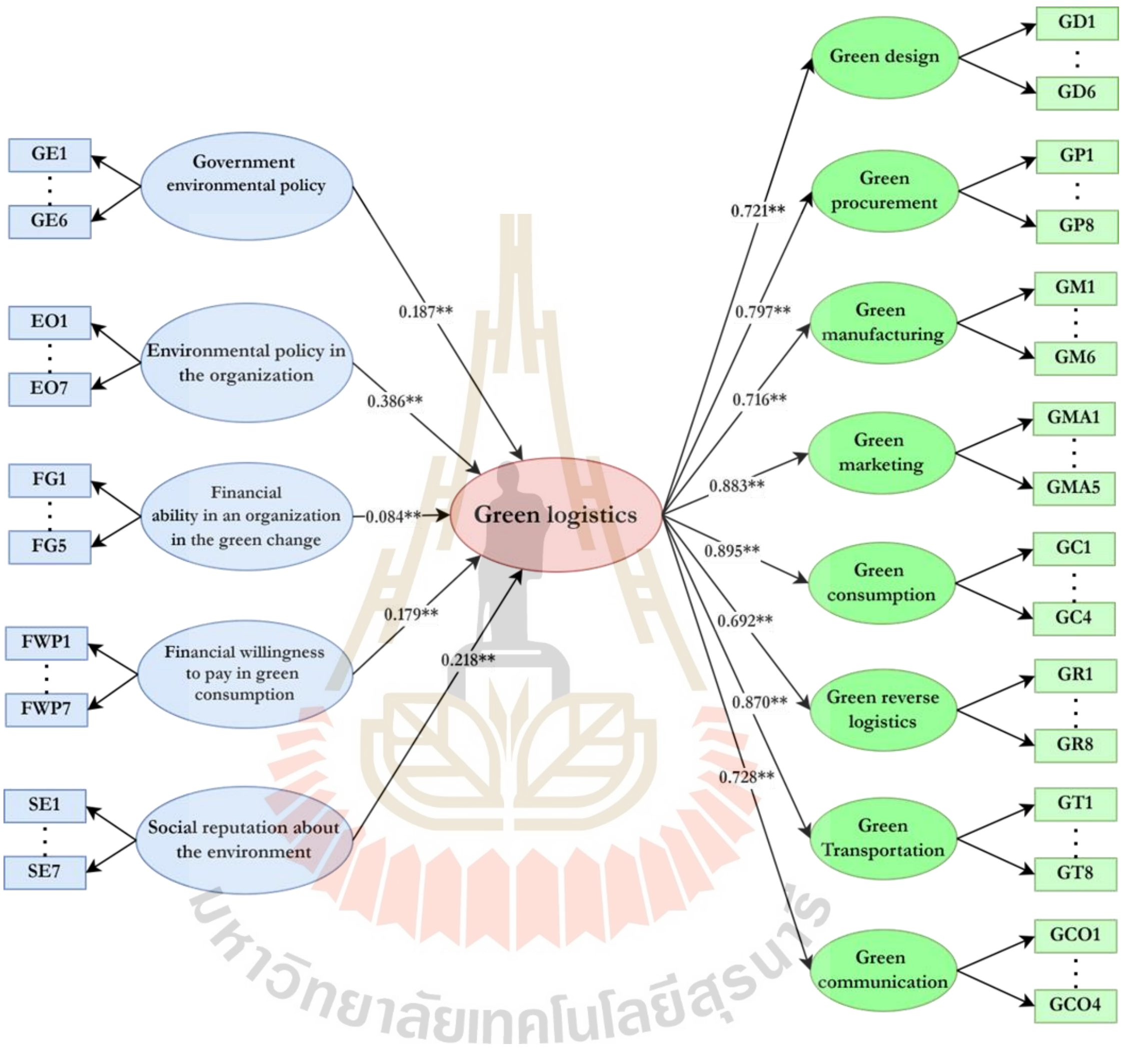

Figure 3.2 SEM of green logistics in Thailand's auto industry for entrepreneurs to use as a guideline for planning logistics management. strategies. ** Significant at 0.01 level.

Table 3.5 Summary of hypothesis testing.

Hypothesis	Standardized Coefficient	Remark
H1: Government environmental policy Green logistics	0.187 **	Supported
H2: Environmental policy in the organization Green logistics	0.386 **	Supported
H3: Financial ability in an organization in the green change Green logistics	0.084 **	Supported
H4: Financial willingness to pay in green consumption Green logistics	0.179 **	Supported
H5: Social reputation about the environment Green logistics	0.218 **	Supported

** significant at = 0.001.

3.6 Discussion

The principal objective of this study is to investigate the influence of various factors shaping policies affecting green logistics projects within the Thai Motor Vehicle Industry Group, employing Structural Equation Modeling (SEM). The analysis revealed a consistent index of item objective congruence within the research model. All the studied factors are significantly relevant to the hypotheses, which can be explained as follows.

According to the structural equation model, for the result of Hypothesis 1—government's environmental policy positively affects green logistics, we found that the standardized path coefficient value is $\gamma = 0.187$. This research finding underscores the substantial impact of governmental environmental policies on green logistics initiatives, a result consistent with prior studies that emphasize the role of stringent environmental law enforcement and the implementation of punitive measures to incentivize and bolster environmentally responsible logistics operations. Such policies not only serve to protect the environment but also facilitate industrial growth and development (Aibin et al., 2020; Beškovnik & Twrdy, 2012). For Hypothesis 2—environmental policy in the organization positively affects green logistics, we found that the standardized path coefficient value is $\gamma = 0.386$. The influence of an organization's internal environmental policies on green logistics management resonates with earlier research highlighting the pivotal role of executive intent in promoting and charting the direction of green logistics activities that align with government regulations. This corroborates the findings of (Jazairy, 2020; Opoku-Mensah et al., 2023). For Hypothesis 3—financial ability in an organization to implement green change positively affects green logistics, we found that the standardized path coefficient value is γ = 0.084. This shows that the factor related to an organization's financial capacity to drive green transformation, thus affecting green logistics management, which aligns with the findings of Azapagic and Perdan (2000).

For Hypothesis 4—financial willingness to pay for green consumption positively affects green logistics, we found that the standardized path coefficient value is γ = 0.179. This shows the necessity for organizations to formulate precise policy plans for internal pollution control investments, recognizing organizations as sources of environmental pollution. Furthermore, the finding pertaining to the financial commitment to support environmentally responsible consumption, which in turn influences green logistics management, corresponds with earlier research highlighting the significance of intentions to cooperate in funding energy and environmental conservation initiatives, thereby influencing sustainable green logistics management. It corroborates the findings of (Schniederjans & Starkey, 2014; H.-j. Yang et al., 2023).

Lastly, for Hypothesis 5—financial willingness to pay for green consumption positively affects green logistics, we found that the standardized path coefficient value is γ = 0.179. The observed influence of the social reputation for environmental concerns regarding green logistics management is in harmony with previous studies underscoring the impact of participation in environmental public relations, engagement in governmentled educational initiatives, contributions to environmental conservation, and the conduct of organizational environmental assessments as contributors to green logistics operations in accordance with organizational social responsibilities. These findings are similar to those of (Agyabeng-Mensah et al., 2022; Mohr & Webb, 2005).

Furthermore, the outcomes of the measurement model with regards to green logistics management within the Thai Motor Vehicle Industry Group encompass dimensions such as green design, green procurement, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication. This comprehensive model aligns with earlier research that has elucidated various factors contributing to the enhancement of green logistics management efficiency, including principles such as the 3Rs (Recycle, Reproduce, and Reuse), the promotion of clean technology usage, and the improvement of production processes to minimize waste generation, all of which are integral components of green manufacturing (Junjun Liu et al., 2020). Additionally, product design strategies aimed at reducing environmental im-pact, such as product design for recycling and the reduction of unnecessary materials, align with the green design dimension, consistent with previous research findings (Junjun Liu et al., 2020; Stekelorum et al., 2021; Zeng, Chen, Xiao, & Zhou, 2017). Collaborative efforts with suppliers for environmentally friendly procurement practices and the establishment of environmentally conscious procurement systems are integral to the green procurement dimension, a concept consistent with prior research (Afum et al., 2020; Yook et al., 2018). These findings are in harmony with earlier studies that underscore the im-portance of green logistics activities in enhancing environmentally friendly production efficiency, reducing pollution, and conserving natural resources (Trivellas, Malindretos, & Reklitis, 2020). Moreover, the study reinforces the notion that green logistics activities should prioritize green procurement as a means to introduce environmentally friendly materials into the production process, thereby promoting sustainability and environ-mentally responsible practices within the industry (Jinru et al., 2022).

In summary, the results indicated that the analysis of factors of government environmental policies, organizational environmental policies, an organization's financial capacity to embrace green transformations, willingness to invest in environmentally re-sponsible consumption, and societal perceptions related to environmental concerns, affect logistics management in the automobile industry. These factors play important roles for entrepreneurs and government sectors in determining the environmental policies of the automobile parts manufacturing industry and evaluating the consistency between development pattern and empirical pattern.

3.6.1 Theoretical Implications

In the context of Thailand, the domain of green logistics management has been rela-tively underexplored in previous research (Aroonsrimorakot, Laiphrakpam & Mungkun, 2022). Furthermore, there have been shortcomings identified in the existing literature when it comes to comprehensively examining the concepts of green procurement and reverse logistics (Badi & Murtagh, 2019). The majority of prior studies have often focused on specific aspects within this field. Consequently, our research endeavors to address this gap by systematically collating and categorizing the key factors relevant to green logistics management, taking into account the perspectives of employees, engineers, and managers within the Thai Motor Vehicle Industry Group. Utilizing a measurement model, we have sought to unravel the intricate relationships among these factors that influence green logistics. Our findings have identified several pivotal factors that exert a substantial in-fluence on green logistics management:

Firstly, we used agency theory in this study. Agency theory means that agents or organizational management will manage the organization to give it the highest returns and avoid damage to shareholders. These are relevant to the studied factors of environ-mental policy in organizations, financial ability in an organization for green change, financial willingness to pay for green consumption, and social reputation for caring about the environment. This theory helps to explain the follow-up roles and monitoring mechanisms of green logistics management that are in accordance with the research of S. F. Khatib, Abdullah, Elamer, and Hazaea (2022), Agency theory is a key aspect of the study and of monitoring. However, organizational monitoring involves understanding the roles of cultural difference, business, and environmental dimensions, which are important to study further in the future. Therefore, this study partly helps to fill the gaps left by previous research.

Secondly, this study contributes significantly to the extant body of knowledge by shedding light on the factors that impact green logistics within the motor vehicle industry in Thailand. Given the nation's highly competitive auto parts production sector, the findings of this research hold particular significance in terms of encouraging the development of green logistics practices in developing economies.

Third, our study provides empirical evidence that government environmental policies, internal environmental policies within organizations, an organization's financial capacity for enacting green initiatives, willingness to invest in environmentally conscious consumption, and the societal reputation related to environmental stewardship, collectively serve as pivotal mechanisms that underpin organizational green logistics management. This outcome resonates with research conducted in other nations, thus indicating that the factors influencing green logistics management are not constrained by geographic boundaries or the nature of manufacturing industries. It further underscores the importance of both government and private sector emphasis on these influencing factors to promote sustainable environmental development within Thailand's motor vehicle industry. In essence, this research extends the realm of factors affecting green logistics management.

Lastly, our research advances our understanding of the direct relationships between government environmental policies, internal organizational environmental policies, attitudes towards environmental consciousness, an organization's financial capability for instigating green transformation, willingness to invest in environmentally responsible consumption, and the societal perception of environmental concerns in alignment with green logistics management. The results signify the pivotal roles played by these influencing factors in enhancing the efficiency of green logistics management within Thailand's motor vehicle industry. This finding aligns with prior research efforts that seek to establish the impact of green logistics management and other factors on sustainable production and the circular economy (Cheng et al., 2023; Jinru et al., 2022). It underscores the multi-faceted influence of green logistics management on environmental, business, and societal aspects (Agyabeng-Mensah et al., 2021). In summary, this research framework enriches the discourse on the roles and endeavors associated with government environmental policies, organizational environmental policies, financial capabilities within organizations undergoing green transformations, financial commitments to green consumption, and the societal reputation surrounding environmental stewardship. These factors collectively bolster green logistics management across various dimensions, including green design, green procurement, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication. Most of these factors are highly pertinent to logistics activities within the environmentally friendly industrial sector.

In essence, our study enhances the existing literature by offering a comprehensive understanding of the core factors that facilitate sustainable green logistics management, particularly within the context of the production industry in developing nations. Our empirical evidence substantiates the direct influence of government environmental policies, internal organizational environmental policies, an organization's financial capability for green transformations, willingness to invest in environmentally conscious consumption, and the societal perception of environmental concerns on the promotion of green logistics practices within Thailand's motor vehicle industry.

3.6.2 Practical Implications

This study serves as a valuable resource for stakeholders by illuminating the intricate complexities of green logistics in manufacturing. It provides a detailed examination of each influencing factor across various dimensions, offering a level of granularity not previously provided by the existing research. Entrepreneurs within the motor vehicle industry can leverage the insights gained from this study to tailor indicators that align with their respective organizations. They can then prioritize the enhancement of green logistics management practices to promote sustainable production and environmental stewardship. The study's findings can prove to be instrumental in assisting motor vehicle industry stakeholders in comprehending the multifaceted nature of green logistics (PAGELL & WU, 2009).

Furthermore, this research holds significance for policy makers, both in the governmental sector and within organizations. It empowers them with a deeper understanding of the primary factors that drive green logistics management. Practical changes and the transformation of green logistics management often hinge on government policies (Jazairy & von Haartman, 2020). Similarly, organizational policies play a crucial role in fostering an environment conducive to enhanced environmental care and sustainability practices (Opoku-Mensah et al., 2023). Additionally, an organization's financial capacity, willingness to invest in environmentally responsible consumption, and its reputation within the industry can significantly influence its ability to effectively implement green logistics management practices. Therefore, collaboration between the government sector and industry entrepreneurs becomes imperative. A coordinated effort and a coherent plan, coupled with rigorous monitoring, are essential for advancing the cause of organizational logistics management. Such cooperation not only addresses resource scarcity issues but also enables businesses to create value, reduce environmental contamination, and contribute to the preservation of the environment by facilitating the circular usage of products.

3.7 Conclusions

Responsibility for the environment is a leading issue in business and the automotive manufacturing industry. Partners from various countries have requested that Thai entrepreneurs follow international standards regarding their environmental and social responsibilities. Green logistics system management aims at reducing costs and increasing competitive efficiency in the industrial sector, as well as contributing to protecting the environment. However, there is still a lack of empirical research into the factors that in-fluence responding to the main sustainable pillar(s) of SDGs, which affect the logistics management of the motor vehicle industry, from the points if view of the staff, engineers, and managers. We operated simple random sampling at industrial factories in central and eastern regions of Thailand. There are 1638 samples in our survey. We have used structural equation model analysis.

These study results are informative for entrepreneurs and government sectors, indicating see key factors that push forward the development of green logistics management in the motor vehicle industry. The results are as follows.

First, we found that government environmental policy, according to the staff, engineers, and manager's expectations, begins when the government announces regulations and rules, promotes operational development, determines the standard, and determines tax structure in order to support green logistics operations. So, government policy makers have to place importance on these practices in order to drive the implementation of green logistics management.

Second, we found that organizations' environmental policy, according to the staff, engineers', and managers' expectations, begins with executives' intentions (high, middle, and low levels) supported by the practice of organizational green logistics management. Moreover, there are also the requirements of issuing operations, policy and objectives, requesting an ISO 14001 certificate, and coplanning with suppliers with regard to the organizational environment. So, entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

Third, we found that an organization's financial ability to adopt green change ac-cording to the staffs', engineers', and manager's expectation begins with the organization's green investment, and compensation (of shareholders, sales, investment, returned profit and net profit ratios). All of these do not affect green change, so entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

Fourth, we found that financial willingness to pay for green consumption, according to the staffs', engineers', and managers' expectations, begins with willingness to pay more for different objectives, such as environmentally friendly products, long term product usage, purchase of energy saving and environmental products etc. So, entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

Lastly, we found that social reputation regarding care for the environment, according to the staffs', engineers', and managers' expectations, begins with management or participation in environmental activities, e.g., donation for environmental conservation, responding seriously to complaints and requests to solve environmental problems, public relations of educational and environmental activities organized by government sectors or other organizations, and joining environmental protection activities, etc. So, entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

In addition, we also conducted factor analysis of green logistics management. For this study, the main factors consisted of green design (six factors), green procurement (eight factors), green manufacturing (six factors), green marketing (five factors), green consumption (four factors), green reverse logistics (eight factors), green transportation (eight factors), and green communication (four factors). These factors are affected by government environmental policies, organizational environmental policies, an organization's financial capacity to embrace green transformations, willingness to invest in environmentally responsible consumption, and societal perceptions related to environmental concerns.

Limitations and Future Research Directions

This research, while contributing valuable insights into the realm of green logistics management, has certain limitations that warrant acknowledgment. Firstly, the study's findings are based on the perceptions of stakeholders within a specific motor vehicle industry context in Thailand. Consequently, the generalizability of these findings to other production industries or across various countries may be constrained. Future research endeavors should aim to expand the scope by conducting surveys on green logistics management in different countries and within diverse production sectors to provide a more comprehensive understanding.

Secondly, this research adopts a cross-sectional study design, collecting data at a single point in time. Such an approach has inherent limitations in capturing dynamic and evolving phenomena. To obtain a more accurate and nuanced depiction of the subject matter, future research should consider longitudinal studies that track the evolution of green logistics management practices over time.

Thirdly, a further study may use decision tools with multiple criteria as one future research method, such as analytic network process (ANP), analytic hierarchy process (AHP), multiple-criteria decision analysis, or fuzzy analytic hierarchy process (FAHP), etc.

Lastly, the perspectives solicited in this study primarily represent the viewpoints of engineers, employees, and managers directly associated with the production sector. Other stakeholder groups, such as company owners, governmental authorities, and local agencies, may possess distinct perspectives and roles in shaping green logistics management practices. Future research endeavors could aim to incorporate a broader spectrum of viewpoints to enrich the understanding of green logistics management from a more comprehensive and holistic standpoint.

Table 3.6 Questionnaires.

Code	Items
	Green Design
GD1	Product design to reduce materials that affect the environment
GD2	Product design for reuse, recycling, and others
GD3	Product design to reduce quantity and type of material used
GD4	Product design to reduce use of dangerous/toxic materials
GD5	Product design for storage area during transportation
GD6	Building/factory design by using nontoxic material
	Green Procurement
GP1	Determining environmentally friendly procurement as part of the environmental management system
GP2	Developing basic knowledge of environmental purposing procurement to raise awareness of environmental problems
GP3	Developing person(s) in charge of procurement to buy energy-conserving product
GP4	Determining cooperate working structure between environmental agency and procurement sector
GP5	Preparing E-Catalog of environmentally friendly products (with ISO 9000 or ISO 14001 certified)
GP6	Training suppliers to reduce non-recycling package
GP7	Cooperating with suppliers for environmental objectives
GP8	Promoting ISO 14000 certification of supplier
	Green Manufacturing
GM1	Using environmental (saving) packaging
GM2	Reusing packaging
GM3	Reducing and altering materials to support green manufacturing
GM4	Controlling dangerous substances in production process
GM5	Following the practice of 3Rs (recycle, reproduce, and reuse)
GM6	Recycling the production resource as much as possible
	Green Marketing
GMA1	Advertising and Public Relations on environmentally friendly product qualification
GMA2	Product's logo design that indicates environmental friendliness
GMA3	Package design that clearly identifies as a green product
GMA4	Organizing social service activities regarding energy and environmental conservation
GMA5	Organizing educational activities regarding green products and the environment
	Green Consumption
GC1	Support the recycling product
GC2	Support the least-pollution generating product
GC3	Support an energy and environmental conserving product
GC4	Support the product with an energy-saving label

Table 3.6 Questionnaires. (Continue)

Code	Items
	Green Reverse Logistics
GR1	There is the sorting out for defected, expired, and unused products from production process to return them into quality improvement process
GR2	There is the sorting out for defected, expired, and unused products from production process for reproduction
GR3	There is the return of defected, expired, and unused products from customers to return them into quality improvement process
GR4	There is the return of defected, expired, and unused products from customers for reproduction
GR5	There is sorting out for defected, expired, and unused products from production process to raw material suppliers, to return them into quality improvement process
GR6	There is sorting out for defected, expired, and unused products from production process to raw material suppliers for reproduction
GR7	There is the return of defected, expired, and unused products from customers to raw material suppliers to return them into quality improvement process
GR8	There is the return of defected, expired, and unused products from customers to raw material suppliers for reproduction
	Green Transportation
GT1	Using vehicles in energy-saving mode
GT2	Using alternative energy
GT3	Determining energy-saving transport route
GT4	Selecting types of transportation with the least use of energy such as backhauling
GT5	Adjusting transportation schedule to avoid traffic problem
GT6	Maintaining vehicle by using preventive system
GT7	Selecting suitable vehicle’s size and fuel
GT8	Using raw material from a close-distance of factory or domestic material to save transportation energy
	Green Communication
GCO1	Communication by focusing on environmentally friendly practices and product recommendations through magazine publication
GCO2	Communication by focusing on environmentally friendly practices and product recommendations through radio broadcast
GCO3	Communication by focusing on environmentally friendly practices and product recommendations through Public Relations sign
GCO4	Communication by focusing on environmentally friendly practices and product recommendations through newspaper
	Government environmental policy
GE1	Government enacts the strict law and regulation regarding the environment

Table 3.6 Questionnaires. (Continue)

Code	Items
GE2	Government enforces environmental regulation at the regional level
GE3	Government promotes the development and promotion of green logistics operations
GE4	Government funds on research and application of green logistics operation technology
GE5	Government determines industrial logistics standard as the main factor of green logistics operation
GE6	Government determines taxation structure to promote green logistics operation
	Environmental policy in the organization
EO1	Intention of the Top Executive for green supply chain management
EO2	Intention of the Middle Executive for green supply chain management
EO3	Intention of a Low-level Executive green supply chain management
EO4	Statement of environmental policy in writing
EO5	Environmental objectives in writing
EO6	Organization has the ISO 14001 certification
EO7	Supplier's environmental planning
	Financial ability in an organization in the green change
FG1	Organization has an actual Green Investment
FG2	Shareholder's return does not affect the green change
FG3	Sales return does not affect the green change
FG4	Investment return does not affect the green change
FG5	Returned profit ratio and net profit do not affect the green change
	Financial willingness to pay in green consumption
FWP1	Willing to pay more for environmentally friendly products
FWP2	Willing to pay more for long-term use products
FWP3	Willing to pay more for the least-pollution generating products
FWP4	Willing to pay more for a product that has the recycling package
FWP5	Willing to pay more for a product that saves energy and environment
FWP6	Willing to pay more for a product with an energy-saving label
FWP7	Willing to pay more for a product with the green product label
	Social reputation about the environment
SE1	There is the donation for environmental conservation
SE2	Participating in complaints and appealing to seriously solve environmental problems
SE3	Participating in the public relations of environmental and educational activities held by government or different organizations
SE4	Participating in environmental protection activities held by civil environmental groups
SE5	Agree to have an environmental inspection at the organization
SE6	Research projects and exposure of environmental problems
SE7	Activities held for social responsibility, regarding energy and environmental conservation in the targeted community

3.8 Reference

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CHAPTER IV
ANALYTIC HIERARCHY PROCESS (AHP) ASSESSMENT OF GREEN PRODUCTION INTHAILAND'S AUTO INDUSTRY

4.1 Abstract

Recently, the green production is highly gotten high attention since it is practically beneficial to industrial business and environment, especially in the developing countries. However, Thailand is confronting so many limitations in regard to the control of environmental impacts caused by the production. This study aims to develop assessment on complexity of factors by using Analytic Hierarchy Process (AHP) for Green Production of Thailand's Automotive Industry. In Thailand, there is the increasing number of automotive manufacturing for export. So, this research article has an attempt to improve the methods of sustainable green production operation by selecting the best alternative(s) from an assessment on assembling process of auto-part companies. Considering factors consist of 5 criteria that are: Green Efficiency, Factor of Safety, Ease of Operation, Production Cost, and Product Recovery. Study results found that the primary factor is Green Efficiency, and secondary factor of assembling process is Clinch Joints (CJ) as it is the best alternative for a green auto-part assembling process.

4.2 Introduction

Thailand's Automotive Industry is the most important industry of country in terms of economic drive, labor, and value-adding, as the highest export value counting for approximately 5.9% of the GDP. In 2022, there was 1.4 million of automobiles that were manufactured in Thailand, ranking as no. 11th of the world. 50% of the manufacture was exported to 170 countries worldwide. The total export value was 919,000 million Baht which was number 1 of Thailand's export products (Royal Thai Government, 2023). Thailand's automotive manufacturing industry is acknowledged by worldwide markets, including North America, the Middle East, Europe, and Asia. The growth of automotive industry is still continuously increased, resulting in increasing demands of natural resource and energy, in the rate that has never seen before, to respond to demands of the continuously growing production industry sector. However, the rapid growth by using resource and energy also results in very bad environmental effects, leading to high level of pollution, greenhouse gas release, and increasing number of waste production (Khan, Hou, & Le, 2020)

The automotive industry worldwide has the direction of more environmentally friendly product development and process, causing the increasing environmental, social, and economic concerns, leading to higher pressure from government sector, partners, consumers, and environmental activists. These also make the policy makers of manufacturing industry sector aware of environmental impacts. Moreover, manufacturing entrepreneurs is under the pressure regarding reduction of negative impact on environmental operation, as the result from government and increasing social concerns in regard to the assurance of sustainable surrounding. Similarly, the more strict environmental regulations of Organization of Convention on Climate Change has demanded for acknowledgement of Green Production Management Strategy. So, it is important to reduce CO_2 release that causes greenhouse gas, reduce energy use, reduce waste and pollution, as well as increase the use of alternative energy in production sector (Centobelli, Cerchione, & Esposito, 2017).

According to the study of previous research, there was a study of multi-criteria decision making regarding green production management in the industrial sector. It found that Analytical Hierarchy Process (AHP) can be applied to seek for operational method of green production project for the company by considering factors in relevant to Goal, procurement process, Green raw material, consisting of Logistics management, Marketing, Procurement etc. (Sarmiento & Thomas, 2010). There are a study on the increase of Business capacity with environmentally friendly production by using Analytical Hierarchy Process (AHP), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), by considering factors of Determination, and Support, Organization operation method, Pressure from government, Social pressure, Customer characteristics, Environmentally friendly supply chain management, Government support etc. (Singh, Singh, & Sethi, 2020). and the study on Disadvantages of smart green production in taking 4.0 Industry by using Analytical Hierarchy Process (AHP) by considering factors of Monetary limitation, Concern of data safety, Staff lacking of training, Determination of top executive, Limitation of technology etc. (Agarwal et al., 2024). Environmentally friendly production requires a flexible change in assembling line by using genetic algorithm-II (NSGA-II) to solve problem of balancing adjustment by provision of operational distribution plan (Fan, Zheng, Jiang, Liu, & Lou, 2024). According to the mentioned researches, most of them focus on the management of green production perspective, causing a main research gap that needs to be fulfilled, and a lack of research on considering factor of auto-part assembly by using Analytical

Hierarchy Process (AHP) that can lead to sustainable green production. Because Thailand's automotive industry production is important for the expansion of existing industry, and the economic growth, it is highly important to overcome the challenges in relevant to Green Logistics management. In order to fulfill the research gap, we had indicated an important research question as follow.

RQ1: What are important factors for auto-part assembling process that affect the operation of green production industry of Thailand's Automotive Industry?

So, this study aims to classify parameter of auto-part assembling process that affects the success of green production management by using Analytical Hierarchy Process (AHP) to support decision of the best primary alternative. That is to take an alternative of auto-part assembly into subdivided level. While the relevant variables will be combined and weighed in terms of relation with an identified target, as well as opinions from experts. By this method, the company can see errors of their production process, and they can identify resource and ability that are necessary to utilize in production process, including to create the presented framework to help stakeholders clearly understand about necessity of using the environmentally friendly operation method and a design of production process in a successful way.

4.3 Literature review

4.3.1 Green Production Management

Green Production is to upgrade production process to reduce negative environmental impacts to the least, and to conserve natural resources through environment. It involves the whole production process from raw material to final product (Li et al., 2023), including circulated resource usage, energy saving process, and waste recycling, as well as to reduce environmental impacts from production, while still responding to customer demand and maintaining the profit making ability for industrial business (Adomako & Nguyen, 2023). Green Production can promote sustainable development at local and international levels. Several businesses now consider the environment so worldwide businesses have conducted various ways of environmental operation management (Lee, Noh, Choi, & Rha, 2017; Toke & Kalpande, 2019) Environmentally friendly production management is considered as a method that gains value to organization, and creates advantage of long-term competition. Environmental and sustainable concerns are getting the notability of business operation, management, production, and decision making on new product development (Afum, Zhang, Agyabeng-Mensah, & Sun, 2021; Yildiz Çankaya & Sezen, 2019; Yusliza et al., 2020). Nevertheless. Environmentally friendly production is significantly getting attention worldwide since it is a management that can mitigate negative environmental impacts such as reducing air and water pollutions, garbage recycling, and the proper waste management caused by conventional production process. There were the studies on Green Production in different industries e.g. textile industry (Bui, Nguyen, Wu, Lim, & Tseng, 2024; Sarker & Bartok, 2024) automotive industry (Liu et al., 2023; Sunmola, Mbafotu, Salihu-Yusuf, & Sunmola, 2024) electronics industry (Gao, Ju, Santibanez Gonzalez, & Zhang, 2020) etc. Even though researcher had done the broad research on environmentally friendly production in automotive industry, it is necessary to do more research in a field of Green Production in Thailand.

4.3.2 Analytical Hierarchy Process

Multi-criteria decision making is the best applicable hierarchy or alternative selecting process for one problem, aiming to seek for a precise method to respond to question in order to support the decision making. The analysis can be used in various methods but a popular method that researcher used in this research is Analytic Hierarchy Process (AHP) which was developed by Forman (1993). It can be used at any time when there are problems for making decision, representing by hierarchy or group of hierarchy, depending on hypotheses of the objective or goal. It has a simple principle that is to divide problem's structure into layers. Layer 1 is to set Goal then set Criteria, set Sub-criteria, and set Alternatives in order (Saaty & Vargas, 1980). After that, we analyze to seek for the best alternative by Trade-off method, using criteria of Pairwise selection to ease the decision on what criteria is more important than others. While the scoring depends on a significance or liking. After giving score to rearrange the criteria, we will consider and analyze each pairwise alternative in accordance with each criterion until we complete all criteria. If the scoring of such significance or liking is consistent, we can rearrange alternatives to seek for the best alternative.

4.4 Methodology

4.4.1 Profile of organization

The ABC company, as a case study, is a Japanese automotive manufacturing company. It used to rank number 1 of the 12 biggest companies of the world. It manufactured several series of automobiles. In April 2023, the factories covered 240,475 square meters, including Samut Prakarn, Chachoengsao, and Chonburi provinces, Thailand. The recent production capacity is 1,758,000 4-wheel automobiles a year. Moreover, it has more than 3,000,000 million Baht investment. Production process of ABC company, as a case study, involves three main parts: Frame production, Engine production, and Final assembly. First process is frame production by material molding through compressing, and cutting processes, making different forms of frame. Then the frames will be delivered to assemble by wielding as the engines. Last step is the final assembly and packaging. However, the company is very aware of environmental protecting production, and tries to focus on environment conservation, and better production process improvement by aiming to improve the production process which can save energy and resource, as well as recycling.

4.4.2 Alternatives for Automotive Assembling Process

Assembly means wielding among metal and non-metal components, electric wire and so on, to make a complete structure. Considered possible alternatives for assembly are as follow.

1) Spot weld (SW) is a wielding that relies on a type of pressing which is famous in complex layer of metal wielding with the maximum of 3-millimeter thickness. During wielding, two pieces of electrodes will conduct electricity to workpieces and press them in the meantime. Advantage of this process is it uses less energy, and it does not damage shapes of the workpiece, it works fast as it is easy to make it automatic, and there is no need to use the same wire. But the obtained strength of welding line is lower than other wielding processes e.g. metal-inert gas wielding, tungsten-inert gas wielding, spot wielding, manual metal-arc wielding and so on. Often, these wielding methods are dangerous sources of pollution such as smoke, metal, ozone, Nitrogen Oxide, CO_2 and Lead smokes etc. So, company has to consider disadvantages of welding as other alternatives that are environmentally friendly. Also, production staff are the inspiration for researcher to plan on Green Production assessment for auto-part assembly by having the experts select the green production alternatives through the face-to-face interview.

2) Mechanical Fastener means to fasten by mechanism. It is a process of two or more pieces of material wielding without glue or any sticking substances. Mechanical fastening is related to a use of physical force or different tools such as screw, bolt, nut, pin or clip, to fasten materials together. To fasten by mechanism is a modern and reliable wielding method which ensures the strong and durable fastening. It can be used in automobile assembly without piercing such as Foldable Joint, and Clinch Joints. They are used for wielding the thin and sticky metal with no other required components. Bolt & Nut (BN) are functioning character of bolt and nut, used to fasten two or more materials together. There are several forms and materials for selection to fasten different kinds of material such as woodwork, metal sheet, plastic, or general assembly. Self-Piercing Rivet (SPR) can be fastened without piercing.

Workpieces that prefer to use Self-piercing rivet to fasten different raw materials together such as Aluminum and Steel because they are a hardly fastened raw materials. It requires no color painting to cover the heating stains since it does not use heat while wielding. It does not cause spark, smoke, and scrap iron from fastening. So, it is an environmentally friendly fastening method. Rivets (R) is used to permanently fastened pieces together. It made of different materials e.g. steel, copper, brass, aluminum, stainless, and plastic, consisting of the head part in round-shape, and a base in bar-shape.

4.4.3 Development of Alternative Selection Process

From what is related to Analytical Hierarchy Process (AHP), it can be divided into 6 processes.

1) Considering decision making components, this research has divided decision making criteria into main criteria and sub-criteria as presented in Figure 1.

2) Creating hierarchy chart, hierarchy chart is divided into layer 1 that is objective layer which is Green Product Assembly. Layer two includes factors of Green Efficiency, Safety, and Ease of Operation. And the last layer is alternatives of assembling method that are metal and non-metal wielding process, Self-Piercing Rivet process, and Foldable joint process.

3) The comparative diagnosis on significance of decision making: This process will begin with creation of relation of matrix between components to use with Pairwise comparison. In general, the relation of matrix is as follow.

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ {}^{1}/_{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ {}^{1}/_{a_{1n}} & {}^{1}/_{a_{2n}} & \cdots & 1 \end{bmatrix}$$

When a_{ij} is Pairwise comparative score of components i and j in order, obtained from significance scoring data collection in 9 scales by AHP method as presented in Table 1.

After that we calculate the criteria loading of assessment for each row of A by using Geometric Mean method, as formula presented in the equation.

$$V_i = (\pi_{j=1}^{n} a_{ij})^{1/2}$$

When V_i is Geometry Mean.

4) To seek for criteria loading, next step is a normalization of each loading criterion since each component has different scales so they have to be at the same scale.

$$w_i = \frac{V_i}{\sum_{i=1}^{n} v_i}$$

While: $\sum_{i=1}^{n} w_i = 1$

5) Check the Consistency Ratio (C.R.)

$$\lambda_{max} = \sum_{i=1}^{n} a_{ij} w_j$$

$$CI = (\lambda_{max} - 1)/(n - 1)$$

$$CR = CI/RI$$

While:

n = Number of alternatives

λ_{max} = Consistency Mean of every alternative

CI = Consistency Index

RI = Random Consistency Index, varied by number of alternatives as in Table 2

CR = Consistency Ratio

6) Alternative ranking by considering the loading.

4.4.4 AHP data Collection and Measurement

We had done literature review and the research in relevant to Green Production in production industry to design this research tools which is the interview form. Then we send it to 5 experts to check its Index of item objective congruence (IOC). And we had improved interview questions in accordance with the experts' suggestions who check the IOC. Research team has selected the experts who had over 15 years of experience in automotive industry. 9 of them are manager, business owner, and scholar, details of qualifications of experts who assessed the research are as presented in Table 4.3 And they had compared the alternatives, primary factors, and secondary factors of different criteria as specified in AHP interview form.

4.5 Result and analysis

This research has created questionnaire by studying of documents, articles, and relevant researches in regard to selection of environmentally friendly auto-part assembling process. We also gathered relevant factors by obtaining primary factors of Green efficiency (GE), Factor of safety (FOS), Ease of Operation (EOO), Production Cost (PDC), and Product Recovery (PR). Also, secondary factors include Bolt & Nut (BN), Clinch Joints (CJ), Rivets (R), Self-Piercing Rivets (SPR), and Spot Welding (SW).

4.5.1 Analysis Results on Selecting Factors of Green Auto-part Assembling Process of Primary and Secondary Factors.

Criteria that are used in alternative selection of primary and secondary are obtained from 9 experts. While respondents will be the expertized and experienced people in decision of selection. Analysis results as presented in Table 4 found that priority score of primary factors: Green efficiency (GE) is 0.235, Production cost (PDC) is 0.208, Factor of safety (FOS) is 0.192, Product Recovery (PR) is 0.184, and Ease of Operation (EOO) is 0.182 consecutively.

Refer to Table 5, it found that priority score of primary factor: Green efficiency (GE) includes secondary factors that are Self-Piercing Rivets (SPR) at 0.237, Clinch Joints (CJ) at 0.216, Rivets (R) at 0.193, Bolt & Nut (BN) at 0.189, and Spot Welding (SW) at 0.165 in order.

So, analysis result of primary and secondary factor loadings to assess Analytic Hierarchy Process (AHP) for Green Production in Thailand's automotive industry found that the highest average of primary factor loading is Green Efficiency (GE) (0.235), following by Production Cost (PDC) (0.208), Factor of safety (FOS) (0.192), Product Recovery (PR) (0.184), and Ease of Operation (EOO) (0.182) in order. For secondary factor of Green Efficiency (GE), the highest loading is Self-Piercing Rivets (SPR) (0.237), second is Clinch Joints (CJ) (0.216), and the least is Spot Welding (SW) (0.165). For secondary factors of Factor of safety (FOS), the highest loading is Bolt & Nut (BN) (0.250), second is Clinch Joints (CJ) (0.216), and the least is Spot Welding (SW) (0.169). For secondary factors of Ease of Operation (EOO), the highest loading is Clinch Joints (CJ) (0.246), second is Bolt & Nut (BN) (0.219), and the least is Self-Piercing Rivets (SPR) (0.158). For secondary factors of Production Cost (PDC), the highest loading is Clinch Joints (CJ) (0.256), second is Bolt & Nut (BN) (0.225), and the least is Spot Welding (SW) (0.166). For secondary factors of Product Recovery (PR), the highest loading is Bolt & Nut (BN) (0.236), second is Clinch Joints (CJ) (0.216), and the least is Spot Welding (SW) (0.134) according to analytic result as presented in in Table 6. Moreover, the inspection of Consistency Ratio (C.R.) found that it is between 0.03 and 0.09 which is less than 0.10. That meant experts had compared the Pairwise of different factors, and scored the significance of each factor accordingly.

4.6 Discussion

The world population is still increasingly growing and the natural resource and energy demands are also increased, resulting in a continuous growth of production industry (Li et al., 2023). However, the rapid growth by using resource and energy also causes very bad environmental impacts, leading to higher level of pollution, greenhouse gas release, and waste production. So, it leads to Green Production method that places importance on environment and society, as well as business concern, environmental regulations, and customer demand. Environmentally friendly practice in automotive industry is dramatically growing (Chhabra, Garg, & Singh, 2017; Ha, 2024). The main method on reduction of dangerous environmental impacts, along with to increase the production efficiency is Green Production management.

In this study, researcher has selected the environmentally friendly auto-part assembling process according to experts' opinions to select the best possible method by using Analytic Hierarchy Process. The primary factors include Green Efficiency (GE), Factor of safety (FOS), Ease of Operation (EOO), Production Cost (PDC), and Product Recovery (PR). The secondary factors consist of Bolt & Nut (BN), Clinch Joints (CJ), Rivets (R), Self-Piercing Rivets (SPR), and Spot Welding (SW). According to study results, the best alternative to improve Green Production of automotive assembly for ABC company as a case study, is Green Efficiency (GE). For assembling process, the average significance of factor loading, arranged in descending order, are Self-Piercing Rivets (SPR), Clinch Joints (CJ), Rivets (R), Bolt & Nut (BN), and Spot Welding (SW). This study is conformed to the research of Chhabra et al. (2017).

The alternatives suggested by experts can be used in company's auto-part assembling department to improve green production process. Moreover, the research results can also be the method of Green Production process improvement for automotive industry and other industries in relevant to production process. Also, it makes people see an important role regarding the best appropriate alternative of green production. So, the company determination is altering from conventional production to environmentally friendly production for sustainable efficiency which can be used for development of operational method of your company.

Therefore, for the assessment of Analytic Hierarchy Process (AHP) for Green Production of Thailand's Automotive Industry in the production company, factor of automatic production technology is considered as non-significance for this study. So, this factor should be added in the future study because change of recently ongoing technological environment is the company's limitation which may affect the success of green production operation. Furthermore, Analytic Hierarchy Process (AHP) might be applied with other analytic and decision-making tools such as Sensitivity Analysis, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Multi-objective Pre-emptive Goal programming (PGP) etc.

Table 4.1 Scoring Rank to prepare for the main factors' comparison

Criterion	Empirical value
Equally important	1
Moderately more important	3
Strongly more important	5
Very strongly more important	7
Extremely more important	9
Immediate values	2,4,6,8

Table 4.2 RI value depending on number of factors

N	1	2	3	4	5	6	7	8	9	10	11	12
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54

Table 4.3 Experience of the experts.

SN	Profession and position	Organization	Qualification	Experience (Years)	Age (Years)
1	Academician	University	PhD	20	41
2	Academician	University	M.Eng	24	45
3	Manager	Automobile parts manufacturer	M.Eng	19	40
4	Production manager	Car manufacturer unit	MBA	28	48
5	Quality manager	Automobile parts manufacturer	M.Eng	25	45
6	Senior Production manager	Automobile parts manufacturer	MBA	18	37

Table 4.3 Experience of the experts. (Continue)

SN	Profession and position	Organization	Qualification	Experience (Years)	Age (Years)
7	Entrepreneur	Automobile parts manufacturer	PhD	20	40
8	Entrepreneur	Automobile parts manufacturer	MBA	19	38
9	Production manager	Car manufacturer unit	M.Eng	29	48

Table 4.4 Analysis of primary factor loading

Factor	EG	FOS	EOO	PDC	RR	Total	Score
GE	0.23	0.25	0.28	0.25	0.16	1.17	0.235
FOS	0.17	0.19	0.18	0.19	0.22	0.96	0.192
EOO	0.15	0.19	0.18	0.18	0.21	0.91	0.182
PDC	0.19	0.21	0.21	0.21	0.23	1.04	0.208
PR	0.26	0.16	0.15	0.17	0.18	0.92	0.184
Total	1.00	1.00	1.00	1.00	1.00	5.00	1.000

Table 4.5 Analysis of secondary factor loading

Factor	SPR	BN	SW	R	CJ	Total	Score
SPR	0.24	0.25	0.25	0.21	0.24	1.19	0.237
BN	0.17	0.19	0.20	0.23	0.15	0.95	0.189
SW	0.16	0.15	0.17	0.19	0.16	0.83	0.165
R	0.21	0.15	0.17	0.19	0.23	0.96	0.193
CJ	0.22	0.26	0.22	0.18	0.21	1.08	0.216
Total	1.00	1.00	1.00	1.00	1.00	5.00	1.000

Table 4.6 Summary of analysis result of primary and secondary criteria

Factors	Main	Secondary
Green efficiency (GE)	0.235	
Self-Piercing Rivets (SPR)		0.237
Clinch Joints (CJ)		0.216
Rivets (R)		0.193
Bolt & Nut (BN)		0.189
Spot Welding (SW)		0.165
Production cost (PDC)	0.208	
Clinch Joints (CJ)		0.256
Bolt & Nut (BN)		0.225
Rivets (R)		0.182
Self-Piercing Rivets (SPR)		0.170
Spot Welding (SW)		0.166
Factor of safety (FOS)	0.192	
Bolt & Nut (BN)		0.250
Clinch Joints (CJ)		0.216
Self-Piercing Rivets (SPR)		0.189
Rivets (R)		0.177
Spot Welding (SW)		0.169
Product Recovery (PR)	0.184	
Bolt & Nut (BN)		0.236
Clinch Joints (CJ)		0.216
Rivets (R)		0.210
Self-Piercing Rivets (SPR)		0.205
Spot Welding (SW)		0.134
Ease of Operation (EOO)	0.182	
Clinch Joints (CJ)		0.246
Bolt & Nut (BN)		0.219
Rivets (R)		0.201
Self-Piercing Rivets (SPR)		0.176
Spot Welding (SW)		0.158

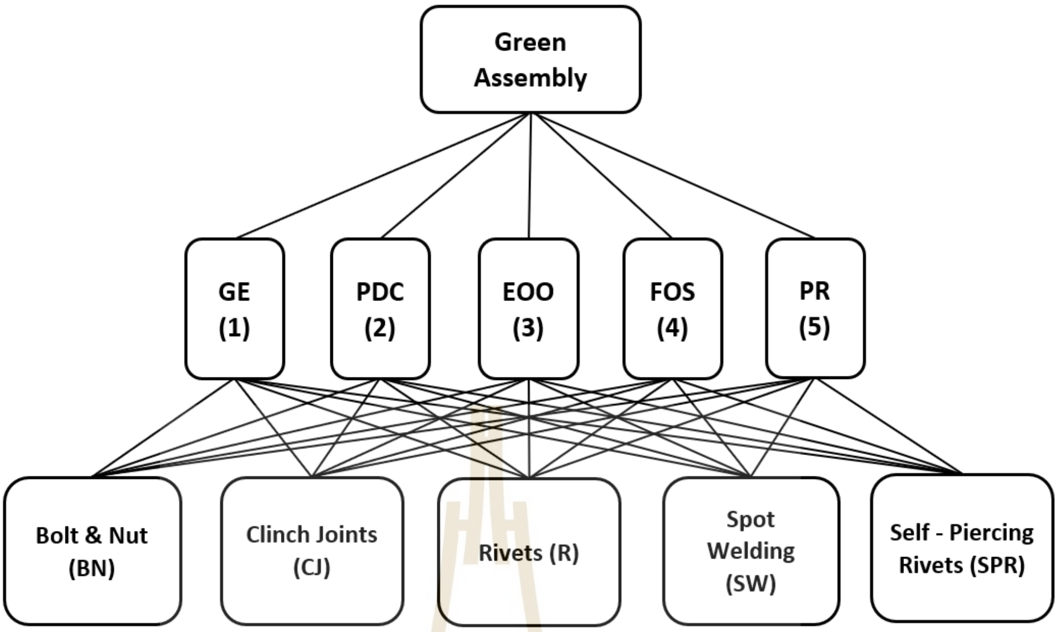

Figure 4.1 The search for appropriate types of assembly (Green Assembly)

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CHAPTER V
CONCLUSION AND RECOMMENATIONS

Thailand is the world's important automotive manufacturing and exporting bases, and the auto-part manufacturing business is also part of supply chain which plays a key role. In year 2023, products of vehicle, tools, and parts are Thailand's number one export value. However, when there is the demand of economic growth, it often relates to the increase of consumption and service, transportation, storage, and increasing number of product consumption such as exploitation, excessive natural resource use, and use of non-recycling materials, recycling and Greenhouse Gas release. These are the main causes of Climate Change and Global Warming etc. which directly affect the environment. Entrepreneurs and government sector have to handle and cooperate for problem solving. So, they seek for suitable strategies in context of sustainability management of Thailand's automotive industry which is highly necessary at the moment. Therefore, we have studied about factors affecting the efficiency of Green Logistics Policy, and prioritized the automotive industry factors, in order to examine relation, and identify factors affecting the Green Logistics Management, aiming to recommend the methods to help entrepreneurs and government sector to be able to determine supporting policy of organization's Green Logistics Management, to sustainably reduce environmental impacts caused by automotive industry. Study results are as below.

5.1 Green Logistics Measurement Model in Motor Vehicle Industry of Thailand

Study No. 1: Development of Green Logistics Measurement Model for Thailand's automotive industry. According to the continuous growth of automotive industry, including higher level of resource use, what follows is environmental pollution problem. However, there is still a research gap regarding the systematic assessment of Green Logistics in different dimensions in automotive manufacturing industry. This measurement model is surveyed on the perception of 1,638 samples who are operators of automotive industrial sector from 570 companies in Thailand. By using questionnaire survey, the data is analyzed with Exploratory Factor Analysis and Secondary-order Confirmatory Analysis. Research result found that Green Logistics Measurement Model of Thailand's automotive industry consists of 8 factors, including Green Product Design, Green Purchasing, Green Manufacturing, Green Transportation, Green Reverse Logistics, Green Marketing, Green Consumption, and Green Communication. Research results indicate the concerns of operators of automotive industrial sector that there should be a development of organization's Green Logistics Management to sustainably reduce environmental impacts caused by industrial sector. Moreover, entrepreneurs should place importance on the Green Reverse Logistics which is prioritized by questionnaire respondents. Entrepreneurs or organization leaders should be aware of environment and give priority to the reuse of products and leftover materials, from production process to the end when a product is used, to make benefit from the improperly leftover resources, and to worthily use materials as another way to reduce waste amount. For Green Communication, Entrepreneurs should pay attention to Green Communication regarding product recommendation through the websites and social media to let consumers know, in order to motivate consumers to pay attention to the Green Product and Green Purchasing which can stimulate overall behavior, and encourage the group-to-group impact among buyers and suppliers by having several agreed measures e.g. following environmentally friendly purchasing standard, improving the operation, and developing operational flexibility which lead to the environmental efficiency improvement.

The research result will benefit to government sector and automotive industrial entrepreneurs who can take the mentioned factors to create assessment criteria to measure capacity of Green Logistics Management, and make the competitive advantage, along with reduce the environmental impacts.

5.2 Key Factors Shaping Green Logistics in Thailand's Auto Industry: An Application of Structural Equation Modeling

Study No. 2: Structural Equation Model of factors influencing Green Logistics Management of Thailand's automotive industry caused by competition in the industry. Recently, environmental responsibility is also a main issue which partners from several countries have demanded the Thai entrepreneurs to follow international standard of environmental and social responsibilities. Green Logistics system management is a key factor which helps to reduce cost, well-increase competitive efficiency for industrial sector, and save the environment. Refer to a survey on 1,638 samples of operators of automotive industrial sector, study methods are Secondary-order Confirmatory Analysis (CFA), and creation of Structural Equation Model of Relation. Research result can summarize that the results indicate that the analysis on factors of government environmental policies, organizational environmental policies, an organization's financial capacity to embrace green transformations, willingness to invest in environmentally responsible consumption, and societal perceptions related to environmental concerns affect factor of Logistics Management in automotive industry. In addition, our study partakes in expansion of: Firstly, to know the main factors related to environmentally friendly Logistics Management of staff, engineers, and managers of automotive industry. Secondly, to promote the development of environmentally friendly Logistics guideline in developing countries. Thirdly, to know the key mechanism which supports Green Logistics Management of Thailand's automotive industry. Additionally, your study helps to continue existing body of knowledge, regarding role and attempt of Government's Environmental Policy, Organization's Environmental Policy, Organization's Financial Ability during Green Change, Financial Willingness toward Green Consumption, and Social Reputation regarding Environmental Care. These factors affect the environmentally friendly Logistics Management in different dimensions, including Purchasing, Production, Marketing, Consumption, Reverse Logistics, Transportation, and Communications. Most of such factors are very involved in Logistics activities of the environmentally friendly industrial sector.

This study result will benefit to entrepreneurs and government sector by taking it to determine Organization's Environmental Policy. Also, the auto-part assembling industrial sector can use it to improve, solve, and gain their efficiency of Green Logistics Management.

5.3 Analytic Hierarchy Process (AHP) Assessment of Green Production in Thailand's Automotive Industry.

Study No. 3: Assessment of Analytic Hierarchy Process (AHP) for Green Production in Thailand's automotive industry: Due to increasing pressure from government sector, business partners, consumers, and environmental activists, it also makes entrepreneurs of production sector aware of environment impacts, aa well as the increasing social concerns regarding an assurance of sustainable environment. Green Production Assessment is a key method to obtain environmentally friendly auto-part assembly, and to gain a competitive efficiency of automotive industry. For assessment, we have over 15 years of experience experts in automotive industry who are manager, business owner, and scholar, total of 9 experts comparing alternatives, primary and secondary factors, as well as different criteria as specified in the AHP questionnaire. For relevant factors, the obtained primary factors are Green Efficiency (GE), Factor of Safety (FOS), Ease of Operation (EOO), Production Cost (PDC), and Product Recovery (PR). Also, secondary factors consist of Bolt & Nut (BN), Clinch Joints

(CJ), Rivets (R), Self-Piercing Rivets (SPR), and Spot Welding (SW). For research result, the best alternative of Green Production improvement of auto-part assembling for case study: ABC company is Green Efficiency (EG) which has assembling method alternatives (มีทางเลือกวิธีการประกอบ), and average factor loadings (มีค่าเฉลี่ยน้ำหนักของปัจจัย) ranked in ascending order as follow: Self-Piercing Rivets (SPR), Clinch Joints (CJ), Rivets (R), Bolt & Nut (BN), and Spot Welding (SW). Alternatives suggested by the experts can be used for company's auto-part assembling department to improve the Green Production Process.

The study result will benefit to entrepreneurs by using it as improvement method of Green Production Process in automotive industry, and other production industries which are related to production process. Also, it shows a key role regarding the proper alternative of Green Production. So, company's determination to transform a conventional production into the environmentally friendly production for sustainable efficiency can take it to develop working method of your company.

5.4 Recommendations.

Study on factors affecting effectiveness of Green Logistics focuses on the search for indicators related to Green Logistics Management, and relative factors affecting Green Logistics Management. Moreover, there is a study on priority assessment of Green Production factor in Thailand's automotive industry, leading to determination of key strategy for the environmentally friendly production management. Researcher can summarize the recommendations as below.

1. Creation of Green Logistics Measurement Model for Thailand's automotive industry: Entrepreneurs and government sector should give priority to different dimensions of Green Logistics, along with environmental care, in order to decrease environmental impacts. Research result will consider significance of each latent variable and observed variable.

2. Development on the form of factors affecting Green Logistics for Thailand's automotive industry: Entrepreneurs and government sector should focus on importance of factors affecting Green Logistics, including Government's Environmental Policy, Organization's Environmental Policy, Organization's Financial Ability regarding Green Change, Willingness to Pay for Green Consumption, Social Reputation regarding Environment as they are propellants to create Organization's Green Logistics Management for sustainable development regarding environment in Thailand.

3. Assessment of Analytic Hierarchy Process (AHP) for Green Logistics of Thailand's automotive industry: Entrepreneurs should focus on improvement of Green

Production and other production industries which have the assembling process, to see a key role of the best alternative of Green Production. So, company's determination to transform a conventional production into the environmentally friendly production for sustainable efficiency can take it to develop working method of automobile assembling industry for the sustainable development in terms of environment in Thailand.

4. A limitation of this study is that the sample group used in the study included three groups: Automotive manufacturer, Automotive parts manufacturers (Tier-1), and Automotive parts manufacturers (Tier-2-3). The analysis should be examined. Is model invariance similar or different across groups?

5.5 References

Youngswaing W, Jomnonkwao S, Cheunkamon E, Ratanavaraha V. Key Factors Shaping Green Logistics in Thailand's Auto Industry: An Application of Structural Equation Modeling. Logistics. 2024; 8(1):17.

APPENDIX I
LIST OF PUBLICATIONS

List of Publications

Youngswaing W, Jomnonkwao S, Cheunkamon E, Ratanavaraha V. Key Factors Shaping Green Logistics in Thailand’s Auto Industry: An Application of Structural Equation Modeling. Logistics. 2024; 8(1):17. https://doi.org/10.3390/logi

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Article

Key Factors Shaping Green Logistics in Thailand's Auto Industry: An Application of Structural Equation Modeling

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Abstract: *Background*: Environmental responsibility is a critical focus in business and production. International partners have urged Thai businesses to adhere to global standards in environmental and social accountability. Green logistics management focuses on minimizing costs and boosting competitive efficiency in the industrial sector, while also promoting environmental protection. This study investigates the factors influencing green logistics in the motor vehicle industry. *Methods*: A self-administered questionnaire was used for data collection from 1638 participants. Confirmatory factor analysis and structural equation modeling were employed to identify causal links impacting green logistics effectiveness. *Results*: Findings indicate that government and organizational environmental policies, a company's financial ability to implement green initiatives, commitment to eco-friendly investment, and public environmental attitudes significantly and directly affect the efficiency of green logistics. *Conclusions*: This research provides valuable insights for car manufacturers into key factors in green logistics management. These insights can help in developing strategic plans to achieve environmental sustainability in the context of future market competition.

Keywords: green logistics management; environmental policy; willingness to pay; financial ability; social reputation; structural equation model

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1. Introduction

The motor vehicle industry in Thailand holds a pivotal position within the national economy, contributing approximately 5.4% of the country's gross domestic product (GDP) and constituting around 12.3% of the GDP of the industrial sector. In the year 2023, Thailand's automobile production reached 1.4 million vehicles, securing the 10th global ranking in terms of production volume. Impressively, almost 52% of these manufactured vehicles were exported to a total of 172 countries, with the export value reaching THB 1,300,000, making automobiles Thailand's foremost export commodity [1]. The swift expansion of the manufacturing sector, closely intertwined with increased consumption of products and services such as transportation, storage, and distribution, has given rise to environmental concerns. Mass consumption patterns have led to issues like inefficient energy utilization, collective sources of pollution, and resource depletion, all of which have adverse repercussions for the environment [2].

The escalating concerns encompassing environmental, social, and economic dimensions have exerted mounting pressure on the automobile industry from governmental bodies, partners, consumers, and environmental advocacy groups. This pressure has prompted policymakers in the production sector to acknowledge the escalating environmental impacts and the necessity for a more sustainable approach. Consequently, the adoption of green logistics management strategies has emerged as a response to redirect the industrial sector's focus towards environmental sustainability [3,4]. The role and responsibility of green logistics involve assisting the industrial sector in enhancing its environmental performance and social responsibility. Embracing green logistics not only fosters customer loyalty and brand trust but also enhances profitability [5]. Green logistics practices are indispensable, as they facilitate pollution reduction throughout the production process, product delivery, and customer service, minimize resource shortages, reduce the consumption of resources and renewable energy, and mitigate climate change [5,6]. Furthermore, green logistics management can positively impact various ecosystems beyond customer expectations and prompt entrepreneurs to recognize the environmental consequences of production, as well as the environmental footprint of suppliers and customers.

Sustainable development involves supportive interaction among different dimensions, including economic, social and environmental aspects. Also, it is the only way to return to environmentally friendly activities such as natural resources conservation, waste management, and reduction of air pollution [7]. Government sector regulation, cooperation of supply chain alliance, and various green practices, for example, green production, green design, green purchase, environmentally friendly logistics, etc., are all pushing forward to generate green production in the industrial sector. These elements also decrease dangerous impacts to the environment [8,9], as well as responding to sustainable consumption and environmentally friendly trading. All of those support the Sustainable Development Goals (SDGs). Moreover, the utilization of green logistics practice and green supply chains are the keys to pursuing SDG number 12: "To ensure sustainable consumption and production patterns" since this goal focuses on supporting the technological capability of developing countries that leads to better sustainable production and consumption patterns of products, such as decreasing waste generated by reusing and recycling processes, decreasing chemicals and toxic waste being released to nature, as well as sustainable purchasing, and efficient use of natural resources, etc. One key to sustainable development that has not received much attention in previous studies is green logistics using technology [10].

Prior research on green logistics has explored various industries, including logistics services (such as transportation, warehousing, freight forwarding, and packaging) [2,5,11], the mining industry [12], production industries (such as agriculture, beverages, textiles, and pharmaceuticals) [13], service and production industries (entertainment, logistics, and manufacturing) [3], and distribution companies (food and beverage, textiles, electronics, pharmaceuticals, and agricultural chemicals) [14]. However, in reference to the previously mentioned literature review, it found that there are fewer studies into green logistics in the automobile industry. Green logistics in the automobile industry has a similar pattern to green logistics activities in other manufacturing industries. The research of Agyabeng-Mensah and Tang [14] has emphasized the management of stakeholder cooperation to solve problems in green logistics (in terms of operation, learning, transportation, and policy control), which is different from our research, which has emphasized logistics management in reducing the environmental impacts caused by logistics activities throughout the supply chain, from the origin and raw material sourcing process, product design and service, production process, transportation process, reverse logistics, consumption, and communication, to the marketing.

Recently, a growing number of scholars have begun to focus on green logistics. Nevertheless, a review of the literature reveals that studies analyzing the factors involved in green logistics management, encompassing its various dimensions, remain fragmented and incomplete. Furthermore, recent research has examined the relationships between green logistics practices and other factors, such as production sustainability and the circular economy in China and Bangladesh [15,16], the efficiency of social sustainability and environmental sustainability among production companies in Ghana [13], and circular economy practices within the manufacturing industry in India [6]. The study of Khatib [17] indicated that sustainable efficiency was developed through the sustainable aspects and performance of stock repurchase. The research results have indicated that environments and societal considerations have influenced stockholders' decisions regarding their investment. However, the main purpose of the stockholders' investment is to focus on the financial pursuit of gain. These studies represent an initial exploration of the impacts of green logistics management on other factors, thereby highlighting a gap in the literature concerning the relationships between several factors that partially influence green logistics management within the motor vehicle industry in developing countries.

The inspiration of this study is the environmental problems caused by the industrial sector. As Thailand is in the top rank of automobile and automobile parts manufacturing exporters, the automobile manufacturers play a key role in pushing forward the economy of Thailand. To reduce the environmental problems in the automobile industry it is important to have a good management system, which recognizes the importance of green logistics in the automobile industry of Thailand, which is a developing country. However, according to the studies identified in the literature review, previous research has not covered logistics management in every dimension. Also, there has been no study of the main sustainable pillars of SDGs, in terms of the environment, which precisely affect logistics management. Therefore, we have conducted this study.

Our study involves three parts: (1) to learn about the main factors relevant to environmentally friendly logistics management from the points of view of staff, engineers, and managers in an automobile industry group; (2) to promote the development of a code of conduct for environmentally friendly logistics in developing countries; and (3) to learn about the key mechanisms that support green logistics management in the automobile industry of Thailand. Furthermore, the study contributes to expanding the existing body of knowledge regarding the roles of the government and organizations and their attempts to implement environmental policy, the financial ability of an organization to implement green change, the financial willingness to pay for green consumption, and the social reputation of organizations regarding their attitudes to the environment. These factors affect environmentally friendly logistics management in different dimensions, including purchasing, production, marketing, consumption, reverse logistics, transportation, and communication. These factors are highly relevant to logistics activities in an environmentally friendly industrial sector.

Data were collected from experienced professionals employed in the motor vehicle industry through a five-point Likert scale questionnaire, employing a convenience-based random sampling method. Data analysis involved descriptive statistical analysis, confirmatory factor analysis, and structural equation modeling (SEM). The findings of this study offer novel insights and emphasize the need for a comprehensive understanding of the factors affecting green logistics management in order to address emerging environmental challenges with broader scope and definition. Thus, this research has the potential to garner support from government bodies, entrepreneurs, and stakeholders, and identify the factors influencing logistics management within the motor vehicle industry in Thailand.

2. Theoretical Background and Hypotheses

2.1. Green Logistics Management

Logistics in business operations is part of supply chain management, and its roles are to plan, control, and store data and products from their origin to consumption, and to respond to consumers' needs. Most logistics activities focus on procurement, distribution, maintenance, and inventory management, but do not involve marketing activities, new product development, or finance [2]. Green logistics relates to production and product distribution, packaging, product search, and product distribution management by focusing on material and waste management, energy saving, and fuel-reducing transportation, in terms of environmental and social responsibility [18,19]. The main objectives of green logistics are to reduce the environmental impacts of logistics activity, reduce energy and waste, improve product brand value, gain operational efficiency, and reduce costs by using energy at maximum efficiency [20–22]. Furthermore, green logistics also focuses on reducing carbon production, reducing waste, producing environmentally friendly containers and packaging, promoting environmentally friendly transport, and reducing environmental impacts in the production supply chain [3].

Environmentally friendly logistics is a key factor in the green supply chain [2]. It is a practical method for achieving sustainable development since it also helps different businesses in the supply chain to become efficient by indicating and selecting environmentally friendly material suppliers, suggesting environmentally friendly solutions, and using green transport for customer delivery. In addition, implementing environmentally friendly logistics makes logistics companies more competitive regarding worldwide provision. Regarding the research on green logistics, there are studies of different green logistics factors in numerous forms, e.g., green design [23,24], green procurement [25–27], green manufacturing [24,26], green marketing [26], green consumption [28], green reverse logistics [23,29], green transportation [23,25,30,31], and green communication [32], etc. However, most factors are used in the manufacturing industry and are widely tested. Thus, they are highly reliable and can create eco-production management efficiency that goes beyond customer expectations, including by impacting the supply chain [33]. Researchers have hypothesized that green logistics factors in the Thai motor vehicle industry comprise green design, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication.

2.2. Government Environmental Policy

The government influences and leads organizational behavior, raises awareness in the public sector of the importance of eco-industry development, and implements strict legalization regarding environmental policy to create effective environmental protection controls by the domestic industry sector [34]. Many people believe that the government should protect the environment, which is preferable to handing authority to the private sector, because the private sector will only focus on maximizing profits as their goal. Thus, the government often intervenes in the business operations of the private sector through environmental regulations and different forms of business incentives, e.g., promotional policies for cost reduction, low-interest rate loans for clean technology procurement, support for research grants for green industry promotion [35], etc. The government is responsible for enforcing environmental laws and rules, which impact environmental monitoring efficiency and people's security and well-being [36]. The government places importance on environmental conservation and recovery for sustainable development by enacting strict regulations regarding the environmental standards of products. These regulations help towards the government's environmental policy, environmental quality management, protecting and treating the environment, and helping it to recover, as well as promoting sustainable efficiency. Examples of research on government green project policies in other countries include the government's environmental policy that played a key role in controlling problems in logistics for the environment in southeast Europe [37]. Studies on government policy changes in many countries have found that environmental policy influenced goal-setting in activities in the manufacturing industry [38]. In a study on government promotion of an environmentally friendly logistics policy for the industrial sector, the results found that the government had to work with experienced logistics organizations, especially those in transport and storage, to respond to this policy at maximum efficiency [5]. Moreover, there are studies on the causal relationships of the Chinese government's policy systems, which positively affected green logistics operations in the coal industry [12], and a study on the effect of the Chinese government's environmental regulations, which caused positive green changes in the production industry related to implementing operations in accordance with the methods arranged by government for environmental technology innovation [39]. Thus, we expect that the Thai government's environmental policy will positively affect the green logistics management of the Thai Motor Vehicle Industry Group.

Hypothesis 1 (H1). *The Government's environmental policy influences green logistics management of the Thai Motor Vehicle Industry Group.*

2.3. Environmental Policy in the Organization

Changes to the natural environment have a significant influence on business relationships. However, there are different ideas about why companies must use environmental management practices [40]. Thus, we conducted a review of previous literature on organizational social responsibility or sustainable development policy. The review found that there are studies on employee perceptions of organizational internal environmental policy [41], innovation and sustainable development [42], top executives' intentions to encourage organizational ability to comply with of the environmental practice standards [43], employees' intentions toward green innovation management and human resource practices [9], stimulation of voluntary compliance with organizations' green policies [44], stimulation for companies to adopt the ISO 14001 is an international certifiable environmental management [45] and ISO 9000 framework was created as a quality management system standard, service and process performance measurement and improvement promotional policy in practice [46,47]. According to an examination of the relationship between organizational internal environmental policy and green logistical management, there is a study of an organization's top executive related to the company response to green logistics and the green supply chain [39]. The top executive's support is a main factor in environmentally friendly procurement practices [48]. Referring to the literature reviews, we can conclude that organizational internal environmental policy led by top executives plays a key role in driving the organization's environmental caretaking forward. Thus, this study develops a better understanding of the mechanisms influencing organizational internal environmental policy in terms of how the regulations arranged by the executives affect green logistics management in the Thai motor vehicle industry. Thus, we established the next hypothesis as follows:

Hypothesis 2 (H2). *Environmental policy in an organization influences green logistics management of the Thai Motor Vehicle Industry Group.*

2.4. Financial Ability of an Organization to Implement Green Change

Environmental value is mostly considered a national resource obtained from two areas: the people sector (residential wastewater and garbage) and the industrial sector, e.g., pollution emissions, waste from production processes, and wastewater that requires a share of environmental treatment costs, since they are a source of environmental problems [49]. In many countries, governments or local agencies support investment in pollution control and allocate budgets for environmental problem-solving. However, funds to help solve environmental problems are required from industrial sector organizations, since they are the greatest source of the pollution problem [50]. A study on organizational financial ability can help strengthen value and add marketing value to organizations [51]. The literature review on the relationship between organizational financial ability and green change found that financial ability, technological innovation, and government policy positively affect the green change efficiency of the manufacturing industry in China [52]. However, there are few studies on how organizational financial ability to implement green change impacts green logistics management in the Thai motor vehicle industry. Thus, the researchers set the following hypothesis:

Hypothesis 3 (H3). *Financial ability in an organization for green change influences the green logistics management of the Thai Motor Vehicle Industry Group.*

2.5. Financial Willingness to Pay for Green Consumption

There are many studies on customer willingness to pay for environmentally friendly products [53]. Environmentally friendly product manufacturing affects the green supply chain and leads to higher retail prices. Furthermore, customer willingness to pay for environmentally friendly products motivates retailers and producers to invest in environmentally friendly technology and reduce product manufacturing costs [54]. Friendly cooperation toward green logistics operations between suppliers and customers of several companies positively impacts sustainable consumption behavior, while expensive transactions negatively affect such a relationship [55]. According to an examination of the impact of financial willingness to pay for green consumption, it was found that willingness to pay positively impacts environmentally friendly transport. This result also indicates that governments must be in control of marketing and educate consumers regarding environmentally friendly transport and energy-saving fuel [56]. Based on the results of the literature review regarding the impact of willingness to pay Thai motor vehicle entrepreneurs for green logistics management, the researchers established the following hypothesis:

Hypothesis 4 (H4). *Financial willingness to pay for green consumption influences the green logistics management of the Thai Motor Vehicle Industry Group.*

2.6. Social Reputation for Environmental Concern

A low level of trust causes a risk to a business's reputation. It also causes the government to pay more attention to monitoring and examination of the business, which might affect the business's profits in the long term. Organizational social responsibility promotes a good reputation and might benefit future business operations [57]. Corporate reputation is affected by various factors, e.g., transparency, human value, employee welfare, the organization's leader's reputations, ability to handle change, and social and environmental standpoint [58]. An organizations' environmentally friendly reputation is a valuable property that can drive the success of organizational environmental management. Moreover, activities which promote a positive environmental reputation also support creating organizational green innovation. This requires using eco-design principles and using fewer and environmentally friendly materials to develop several products and processes [59]. However, our review found that there are limitations on how social reputation affects green logistics management. Thus, the researchers established the following hypothesis:

Hypothesis 5 (H5). *Social reputation about the environment influences the green logistics management of the Thai Motor Vehicle Industry Group.*

Table 1 presents the findings of the literature review, which are mostly related to factors responding to the main sustainable pillars of SDGs in regard to the environment. The relevant study results revealed the limitations of those studies in terms of the different samples' scales, geological areas, and analytical methods. For example, a study on the problems of global warming and climate change was conducted in developing countries where the problems were caused by inefficient government environmental policies. Therefore, the concept of green logistics will help policy makers and researchers to understand the importance of green logistics, to improve society and the economy of the countries, as well as their environmental efficiency [60]. A study on environmental regulations and laws encouraged several companies to look for new methods of reducing expenditure and costs, and brought positive results for green innovation [61]. Another study on green innovation for environmental operations led to improvements in the organization's operation, while the result also indicated that the executives would work towards environmental innovation, encouraging changes at an organizational level which led to utilizing environmentally friendly practices [9]. The researchers identified the knowledge gap in the study of the factors responding to the main sustainable pillars that affected green logistics management. We summarize the research from the literature review. The factors affecting green logistics management of the motor vehicle industry consist of government environmental policy, organizations' internal environmental policy, attitudes towards environmental comprehension, organizational financial ability to implement green change, willingness to pay for green consumption, and social reputation regarding the environment. To evaluate the impact of each factor, the five hypotheses are tested according to the research objectives.

Table 1. Summary of the factors responding to the main sustainable pillars of SDGs in terms of the environment.

Authors	Location	Types	Method	Samples	SDGs	Government Environmental Policy	Environmental Policy in the Organization	Financial Ability of an Organization for Green Change	Financial Willingness to Pay for Green Consumption	Social Reputation Regarding the Environment
Jazairy and von Haartman [39]	Sweden	Interviews	Delphi approach	17	Environment	✓				
Fan, Abbas, Zhong, Pawar, Adam and Alarif [42]	Pakistan	Survey	SEM-PLS	276	Environment		✓			
Maji, Mohd Saudi and Yusuf [5]	Nigeria	Survey	chi-square and regression	197	Environment		✓			
Beškovnik and Twrdy [37]	European	Article	-	-	Environment	✓				
Ahmed, Akbar, Aijaz, Channar, Ahmed and Parmar [9]	Pakistan	Survey	SEM-PLS	320	Environment		✓			
Iqbal, Nadeem, Gull and Kayani [51]	USA	Database	Empirical models	46,000	Environment			✓		
Zhai and An [52]	China	Survey	SEM	500	Environment	✓		✓		
Akhtar, et al. [62]	Malaysia	Survey	SEM-PLS	308	Environment				✓	
Agyabeng-Mensah, Afum and Baah [59]	China	Survey	SEM	208	Environment	✓				✓
Khan, Sharif, Golpîra and Kumar [60]	Malaysia	Database	FMOLS and DOLS	-	Environment social and economic	✓				
Javeed, Teh, Ong, Lan, Muthaiyah and Latief [61]	China	Database	Appropriate econometric	-	Environment	✓	✓			
This study	Thailand	Survey	SEM	1638	Environment	✓	✓	✓	✓	✓

SEM—structural equation modeling; PLS—partial least squares; FMOLS—fully modified ordinary least squares; DOLS—dynamic modified ordinary least squares; ✓ means that variables were used in the studies.

3. Methodology

Measurement and Data Collection

The survey instrument for this study was designed based on an extensive literature review and relevant research findings. The questions were selected from previous studies that had passed accuracy and trust testing through the IOC method. The survey is divided into three sections: The first section captures the demographic details of the respondents, including job title, organization size, nationality, details about the organization's shareholders, business nature, duration of involvement in the green project policy practices, among others. The second section delves into activities related to green project policy practices specific to the Thai Motor Vehicle Industry Group. The third section assesses the factors that influence activities concerning green project policy practices within the Thai Motor Vehicle Industry Group, as presented in Table A1. Responses were recorded using a 5-point Likert scale, where 1 signifies 'Do not agree', and 5 stands for 'Totally agree'. Before this survey, the questionnaire was used in a pilot test, which was conducted using 35 samples distributed to companies in the motor vehicle industry. The number of pilot surveys in the sample was similar to the study of Mettathamrong, et al. [63]. Based on feedback, minor modifications to the questionnaire were implemented.

The respondents must be at least 20 years old, have more than one year of work experience in the motor vehicle industry, and work as an engineer, employee, or manager. The complete samples necessary for model analysis are 1:15, which is equal to observable variables recommended by Golob [64]. There are 82 observable variables in this study; thus, samples must be greater than 1230 to be suitable. We obtained 1638 samples from this survey, which are sufficient for SEM requirements [65].

We chose our operating method of simple random sampling in central and eastern regions of Thailand because there are many automobile and automobile parts manufacturers located here, with 570 companies in total. We contacted the companies by email and received responses from 300 companies, accounting for 52.6%. Then our team went to the manufactures to conduct the face-to-face surveys and collected data between April and July 2022. Once we collected and checked the accuracy of the questionnaires, we analyzed the data from 1638 samples.

The population data showed that years of work experience are as follows: 5–10 years—513 (31.3%) and 1–3 years—411 (25.1%). Company sizes are 200–1000 employees—828 (50.5%) and more than 1000 employees—441 (50.5%). For company shareholders' nationality, Thais hold more shares than foreigners—798 (48.7%), and there were 450 Thai 100% shareholders (27.5%). For type of business, automotive parts manufacturers represent (Tier-1) 963 (58.8%), and automotive manufacturers represent 447 (27.3%). In terms of job position, there are 1071 employees (65.4%) and 369 engineers (22.5%), as presented in Table 2 and Figure 1.

Table 2. The profiles of survey respondents (n = 1638).

Company Characteristics	The Number of Respondents	Percentage
Operating period		
<1 year	207	12.6
1–3 years	411	25.1
4–6 years	513	31.3
7–9 years	342	20.9
>10 years	165	10.1

Table 2. *Cont.*

Company Characteristics	The Number of Respondents	Percentage
Company size		
<200 employees	369	22.5
200–1000 employees	828	50.5
>1000 employees	441	26.9
Shareholders' nationality		
100% Thai	450	27.5
Thai > Foreigners	798	48.7
Foreigners > Thais	258	15.8
100% Foreigners	132	8.1
Business type		
Automotive manufacturer	447	27.3
Automotive parts manufacturers (Tier-1)	963	58.8
Automotive parts manufacturers (Tiers-2–3)	228	13.9
Job position		
Officer	1071	65.4
Engineer	369	22.5
Manager	198	11.6

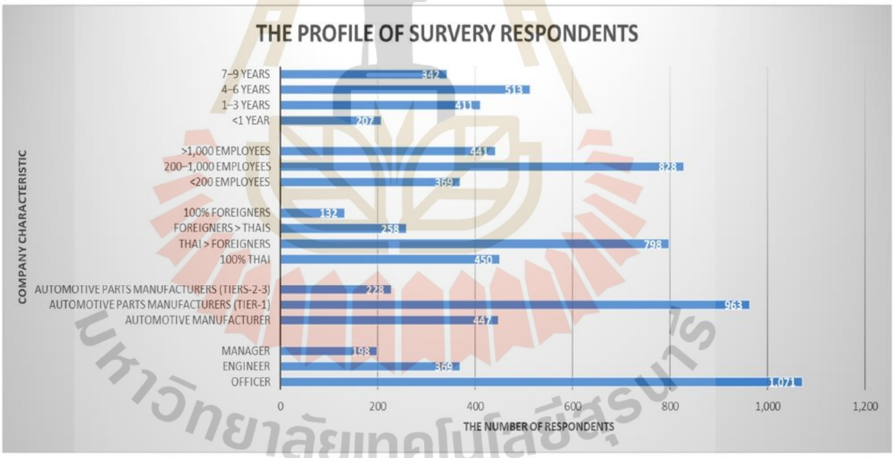

Figure 1. The profiles of survey respondents.

4. Data Analysis and Results

4.1. Descriptive Data

According analysis of the results from the preliminary statistical test, the mean is 3.595–4.396, and the standard deviation is 0.743–0.976. Cronbach's alpha is more than 0.7. green design, green procurement, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication are

0.86, 0.873, 0.800, 0.827, 0.782, 0.918, 0.855, and 8.150, respectively. While the government's environmental policy, organizations' internal environmental policy, organizational financial ability for green change, financial willingness to pay for green consumption, and social reputation for the environment were 9.15, 0.852, 0.852, 0.895, 0.858, and 0.865, respectively. In summary, Cronbach's alpha is 0.7–0.8, which is internally consistent. The measurement model analysis using the Kaiser–Meyer–Olkin statistic is 0.876, indicating that there is a type of observable variable that can be used to derive reliable factors.

4.2. Measurement Model Assessment

In the context of this study, confirmatory factor analysis (CFA) was carried out using the M-plus program, a suitable tool for comprehensive results analysis [66]. To ensure the reliability and precision of the measurement model, the research team employed a multipronged approach. First, the average variable extracted (AVE) analysis revealed values spanning from 0.619 to 0.818 for the observable variables, all of which exceeded the widely accepted threshold of 0.50 [65]. Second, construct reliability (CR) analysis indicated values ranging from 0.785 to 0.910, surpassing the recommended minimum of 0.70, in accordance with the guidance of Hair and colleagues [65]. Additionally, the confirmatory factor analysis (CFA) encompassed both first-order and second-order CFA. In the first-order CFA, the standardized factor loadings of the observable variables ranged from 0.612 to 0.849, and in the second-order CFA, these loadings ranged from 0.692 to 0.895, all of which exceeded the threshold of 0.50 recommended by Hair [65]. These meticulous analyses collectively confirm the statistical significance of the measurement model, as evidenced by p-values < 0.001, as presented in Table 3.

Table 3. Results of descriptive statistics and confirmatory factor analysis.

Latent Variables/ Factor Code	Code of Observed Variables	Mean	SD	Standardized Loadings		CR	AVE	Cronbach's α
				1st-Ordered	2nd-Ordered			
(a) Endogenous Latent Variables								
Green design/(GRDE)	GD1	4.361	0.728	0.732 **	0.721 **	0.825	0.661	0.86
	GD2	4.115	0.711	0.755 **				
	GD3	4.112	0.697	0.747 **				
	GD4	4.212	0.734	0.590 **				
	GD5	3.946	0.772	0.574 **				
	GD6	3.995	0.845	0.569 **				
Green procurement /(GRPR)	GP1	3.875	0.839	0.627 **	0.797 **	0.868	0.671	0.873
	GP2	3.964	0.838	0.704 **				
	GP3	3.988	0.803	0.685 **				
	GP4	4.009	0.789	0.664 **				
	GP5	3.973	0.803	0.630 **				
	GP6	3.952	0.785	0.661 **				
	GP7	4.029	0.746	0.712 **				
	GP8	4.074	0.777	0.687 **				

Table 3. *Cont.*

Latent Variables/ Factor Code	Code of Observed Variables	Mean	SD	Standardized Loadings 1st-Ordered	Standardized Loadings 2nd-Ordered	CR	AVE	Cronbach's α
Green Manufacturing /(GRMA)	GM1	4.197	0.696	0.717 **	0.716 **	0.789	0.619	0.800
	GM2	4.154	0.757	0.619 **				
	GM3	4.183	0.775	0.612 **				
	GM4	4.330	0.768	0.589 **				
	GM5	4.178	0.821	0.549 **				
	GM6	4.167	0.819	0.630 **				
Green marketing /(GRKE)	GMA1	3.851	0.819	0.618 **	0.883 **	0.814	0.683	0.827
	GMA2	3.789	0.836	0.667 **				
	GMA3	3.769	0.820	0.718 **				
	GMA4	3.879	0.853	0.723 **				
	GMA5	4.030	0.842	0.690 **				
Green consumption /(GRCO)	GC1	4.149	0.844	0.610 **	0.895 **	0.785	0.635	0.782
	GC2	4.158	0.842	0.642 **				
	GC3	4.212	0.767	0.669 **				
	GC4	4.396	0.718	0.618 **				
Green reverse logistics /(GREL)	GR1	3.774	0.877	0.725 **	0.692 **	0.910	0.747	0.918
	GR2	3.934	0.834	0.758 **				
	GR3	3.777	0.915	0.775 **				
	GR4	3.804	0.888	0.754 **				
	GR5	4.033	0.947	0.724 **				
	GR6	3.907	0.839	0.731 **				
	GR7	3.667	0.917	0.766 **				
	GR8	3.678	0.977	0.746 **				
Green Transportation/ (GRTR)	GT1	4.008	0.814	0.632 **	0.870 **	0.852	0.646	0.855
	GT2	3.816	0.799	0.632 **				
	GT3	3.856	0.800	0.614 **				
	GT4	3.874	0.844	0.617 **				
	GT5	3.913	0.843	0.665 **				
	GT6	3.896	0.849	0.658 **				
	GT7	4.055	0.819	0.726 **				
	GT8	3.953	0.896	0.626 **				
Green communication/(GCOM)	GCO1	3.793	0.922	0.739 **	0.728 **	0.808	0.715	8.15
	GCO2	3.760	0.904	0.761 **				
	GCO3	3.747	0.927	0.712 **				
	GCO4	3.595	1.092	0.649 **				

Table 3. *Cont.*

Latent Variables/ Factor Code	Code of Observed Variables	Mean	SD	Standardized Loadings		CR	AVE	Cronbach's α
				1st-Ordered	2nd-Ordered			
(b) Exogenous Latent Variables								
Government environmental policy/(GOVE)	GE1	4.117	0.973	0.709 **	-	0.903	0.780	9.15
	GE2	4.027	0.931	0.792 **				
	GE3	4.073	0.919	0.797 **				
	GE4	3.923	0.933	0.776 **				
	GE5	3.940	0.949	0.829 **				
	GE6	3.874	0.954	0.775 **				
Environmental policy in the organization/(ENPO)	EO1	4.081	0.771	0.615 **	-	0.808	0.613	0.852
	EO2	4.055	0.757	0.676 **				
	EO3	4.101	0.798	0.612 **				
	EO4	4.139	0.832	0.596 **				
	EO5	4.125	0.836	0.586 **				
	EO6	4.288	0.812	0.540 **				
	EO7	4.033	0.800	0.664 **				
Financial ability in an organization in the green change/(FAOG)	FG1	3.903	0.898	0.849 **	-	0.910	0.818	0.895
	FG2	3.863	0.833	0.801 **				
	FG3	3.877	0.822	0.838 **				
	FG4	3.929	0.850	0.814 **				
	FG5	3.963	0.866	0.786 **				
Financial willingness to pay in green Consumption/(FWPG)	FWP1	3.943	0.750	0.646 **	-	0.874	0.705	0.858
	FWP2	4.018	0.758	0.710 **				
	FWP3	4.027	0.754	0.792 **				
	FWP4	3.960	0.788	0.711 **				
	FWP5	4.046	0.792	0.700 **				
	FWP6	3.907	0.856	0.705 **				
	FWP7	3.859	0.854	0.669 **				
Social reputation about the environment/(SRAE)	SE1	3.608	0.924	0.724 **	-	0.870	0.699	0.865
	SE2	3.794	0.881	0.709 **				
	SE3	3.890	0.851	0.677 **				
	SE4	3.863	0.956	0.633 **				
	SE5	4.038	0.817	0.718 **				
	SE6	3.901	0.785	0.710 **				
	SE7	3.738	0.877	0.723 **				

** significant at = 0.001.

The standardized loading values of each variable are as follows.

- Green design: There are six observed variables. For the highest value of standardized loading, the statistical value is GD2 (γ = 0.755), second is GD3 (γ = 0.747), and the least is GD6 (γ = 0.569).

- Green procurement: There are eight observed variables. For the highest value of standardized loading, the statistical value is GP7 (γ = 0.712), second is GP2 (γ = 0.704) and the least is GP5 (γ = 0.630).
- Green manufacturing: There are six observed variables. For the highest value of standardized loading, the statistical value is GM1 (γ = 0.717), second is GM2 (γ = 0.619), and the least is GM5 (γ = 0.549).
- Green marketing: There are five observed variables. For the highest value of standardized loading, the statistical value is GMA4 (γ = 0.723), second is GMA3 (γ = 0.718), and the least is GMA1 (γ = 0.618).
- Green consumption: There are four observed variables. For the highest value of standardized loading, the statistical value is GC3 (γ = 0.699), second is GC2 (γ = 0.642), and the least is GC1 (γ = 0.610).
- Green reverse logistics: There are seven observed variables. For the highest value of standardized loading, the statistical value is GR3 (γ = 0.775), second is GR7 (γ = 0.766), and the least is GR5 (γ = 0.724).
- Green transportation: There are eight observed variables. For the highest list of standardized loading, the statistical value is GT7 (γ = 0.726), second is GT5 (γ = 0.665), and the least is GT3 (γ = 0.614).
- Green communication: There are four observed variables. For the highest value of standardized loading, the statistic value is GCO2 (γ = 0.761), second is GCO1 (γ = 0.739), and the least is GCO4 (γ = 0.649).
- Government environmental policy: There are six observed variables. For the highest value of standardized loading, the statistical value is GE5 (γ = 0.829), second is GE3 (γ = 0.797), and the least is GE1 (γ = 0.709).
- Environmental policy in the organization: There are seven observed variables. For the highest value of standardized loading, the statistical value is EO2 (γ = 0.676), second is EO7 (γ = 0.664), and the least is EO6 (γ = 0.540).
- Financial ability in an organization for green change: There are five observed variables. For the highest value of standardized loading, the statistical value is FG1 (γ = 0.849), second is FG3 (γ = 0.838), and the least is FG5 (γ = 0.786).
- Financial willingness to pay for green consumption: There are six observed variables. For the highest value of standardized loading, the statistical value is FWP3 (γ = 0.792), second is FWP4 (γ = 0.711), and the least is FWP1 (γ = 0.646).
- Social reputation for the environment: There are seven observed variables. For the highest value of standardized loading, the statistical value is SE1 (γ = 0.724), second is SE7 (γ = 0.723), and the least is SE4 (γ = 0.633).

The secondary results of the CFA are as outlined below:

- Green logistics: There are eight observed variables. The highest value of standardized loading is green consumption, (γ = 0.895), second is green marketing; (γ = 0.883), and the least is green reverse logistics (γ = 0.692).

Furthermore, the investigation was extended to assess the relationships between different factors in the study. Pearson's correlation analysis was employed, revealing correlation coefficients that ranged from 0.289 to 0.980. These results underscore the positive and statistically significant interrelationships between the study's factors, demonstrating their meaningful associations according to the 0.05 significance level, as illustrated in Table 4. These rigorous analyses contribute to the robustness and validity of the research findings, enhancing the overall quality of the study.

Table 4. Pearson correlation coefficients.

Constructs	1	2	3	4	5	6	7	8	9	10	11	12
2. GRPR	0.545 **											
3. GRMA	0.412 **	0.526 **										
4. GRKE	0.473 **	0.537 **	0.507 **									
5. GRCO	0.536 **	0.587 **	0.503 **	0.449 **								
6. GREL	0.467 **	0.514 **	0.349 **	0.573 **	0.388 **							
7. GRTR	0.497 **	0.564 **	0.545 **	0.617 **	0.566 **	0.542 **						
8. GCOM	0.497 **	0.564 **	0.545 **	0.617 **	0.566 **	0.542 **	0.980 **					
9. GOVE	0.433 **	0.452 **	0.489 **	0.558 **	0.567 **	0.402 **	0.617 **	0.617 **				
10. ENPO	0.431 **	0.492 **	0.559 **	0.504 **	0.464 **	0.391 **	0.597 **	0.597 **	0.523 **			
11. FAOG	0.464 **	0.529 **	0.289 **	0.377 **	0.620 **	0.373 **	0.451 **	0.451 **	0.457 **	0.403 **		
12. FWPG	0.433 **	0.474 **	0.442 **	0.538 **	0.499 **	0.433 **	0.605 **	0.605 **	0.547 **	0.544 **	0.471 **	
13. SRAE	0.512 **	0.515 **	0.409 **	0.616 **	0.479 **	0.565 **	0.625 **	0.625 **	0.644 **	0.535 **	0.491 **	0.619 **

** significant at = 0.001.

4.3. Structural Model and Hypotheses Testing

The present study employed structural equation modeling (SEM) with the highest probability method to scrutinize the relationships between the variables within the context of the Thai Motor Vehicle Industry Group's green logistics management. The results of the goodness of fit analysis demonstrated a commendable fit, with an χ^2 value of 10,574.997 and 2686 degrees of freedom (df), yielding a highly significant *p*-value of less than 0.001. Furthermore, the χ^2/df ratio of 3.937, which is below the conventional threshold of five and signifies a robust fit of the model to the data [67]. The fit indices also provided corroborative evidence, as the root mean square error of approximation (RMSEA) exhibited a value of 0.042, well below the recommended cutoff of 0.07 [68]. Additionally, the comparative fit index (CFI) was 0.909, surpassing the minimum acceptance threshold of 0.90 [67], and the Tucker–Lewis index (TLI) achieved a value of 0.891, exceeding the 0.80 benchmark [69]. Moreover, the standardized root mean square residual (SRMR) was 0.050, within the acceptable range of 0.08 or less [67]. Taken together, these findings affirm the congruence of the SEM model with the empirical data, providing a strong foundation for the subsequent hypothesis evaluations. The hypotheses presented in Table 5 and Figure 2 are assessed as follows.

Table 5. Summary of hypothesis testing.

Hypothesis	Standardized Coefficient	Remark
H1: Government environmental policy →Green logistics	0.187 **	Supported
H2: Environmental policy in the organization →Green logistics	0.386 **	Supported
H3: Financial ability in an organization in the green change→Green logistics	0.084 **	Supported
H4: Financial willingness to pay in green consumption→Green logistics	0.179 **	Supported
H5: Social reputation about the environment→Green logistics	0.218 **	Supported

** significant at = 0.001.

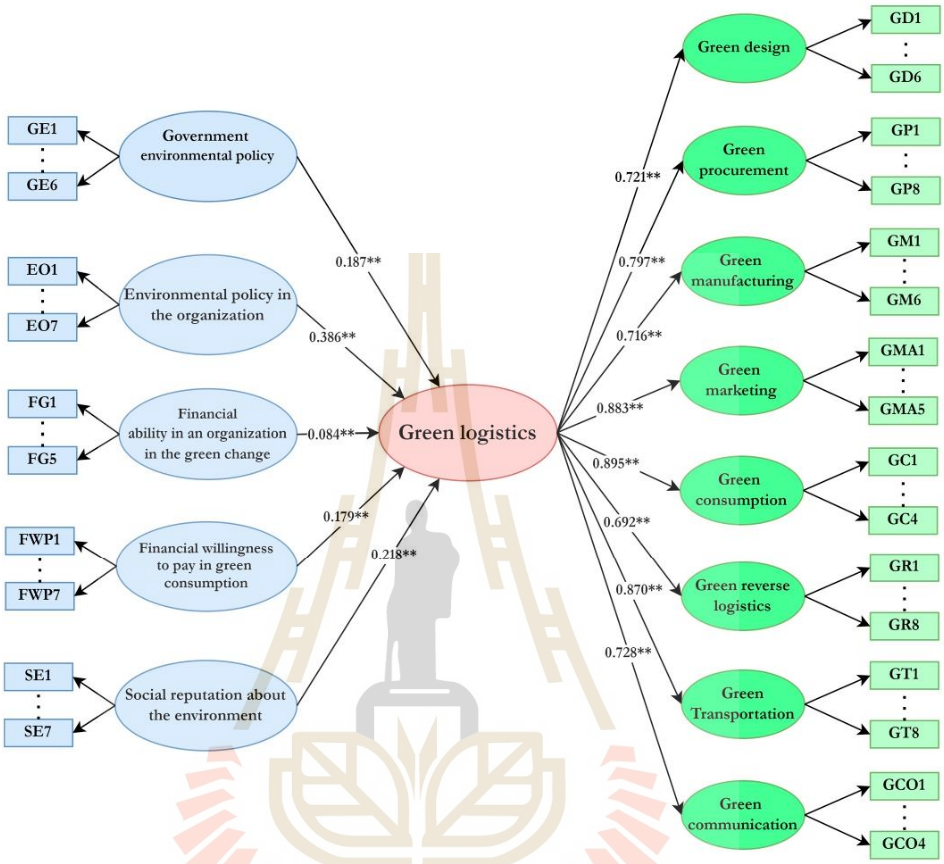

Figure 2. SEM of green logistics in Thailand's auto industry for entrepreneurs to use as a guideline for planning logistics management. strategies. ** Significant at 0.01 level.

Turning to the assessment of the formulated hypotheses, the empirical results reinforce the theoretical constructs under investigation. Firstly, the government's environmental policy, acting as an influential factor in the green logistics management of the Thai Motor Vehicle Industry Group, exhibited a significant standardized path coefficient of 0.187 at a level of $p < 0.01$, providing robust support for Hypothesis 1 (H1). Similarly, Hypothesis 2 (H2) is substantiated because the internal environmental policy within the organization, affecting green logistics management, is associated with a substantial standardized path coefficient of 0.386, accompanied by a significance level of $p < 0.01$. Furthermore, Hypothesis 3 (H3) finds empirical validation, as the organization's financial efficiency for green change, influencing green logistics management, is underscored by a standardized path coefficient of 0.084 at $p < 0.01$ significance. Likewise, Hypothesis 4 (H4) is reinforced, with the financial willingness to pay for green consumption, impacting green logistics management, characterized by a noteworthy standardized path coefficient of 0.179 and a significance level of $p < 0.01$. Finally, Hypothesis 5 (H5) gains empirical support because the social reputation for environmental endeavors, influencing green logistics management, is marked by a substantial standardized path coefficient of 0.218 at $p < 0.01$ significance. These collective findings provide valuable insights into the intricate relationships governing the green logistics management within the Thai Motor Vehicle Industry Group.

5. Discussion

The principal objective of this study is to investigate the influence of various factors shaping policies affecting green logistics projects within the Thai Motor Vehicle Industry Group, employing Structural Equation Modeling (SEM). The analysis revealed a consistent index of item objective congruence within the research model. All the studied factors are significantly relevant to the hypotheses, which can be explained as follows.

According to the structural equation model, for the result of Hypothesis 1—government's environmental policy positively affects green logistics, we found that the standardized path coefficient value is $\gamma = 0.187$. This research finding underscores the substantial impact of governmental environmental policies on green logistics initiatives, a result consistent with prior studies that emphasize the role of stringent environmental law enforcement and the implementation of punitive measures to incentivize and bolster environmentally responsible logistics operations. Such policies not only serve to protect the environment but also facilitate industrial growth and development [12,37]. For Hypothesis 2—environmental policy in the organization positively affects green logistics, we found that the standardized path coefficient value is $\gamma = 0.386$. The influence of an organization's internal environmental policies on green logistics management resonates with earlier research highlighting the pivotal role of executive intent in promoting and charting the direction of green logistics activities that align with government regulations. This corroborates the findings of [30,47]. For Hypothesis 3—financial ability in an organization to implement green change positively affects green logistics, we found that the standardized path coefficient value is $\gamma = 0.084$. This shows that the factor related to an organization's financial capacity to drive green transformation, thus affecting green logistics management, which aligns with the findings of Azapagic and Perdan [50].

For Hypothesis 4—financial willingness to pay for green consumption positively affects green logistics, we found that the standardized path coefficient value is $\gamma = 0.179$. This shows the necessity for organizations to formulate precise policy plans for internal pollution control investments, recognizing organizations as sources of environmental pollution. Furthermore, the finding pertaining to the financial commitment to support environmentally responsible consumption, which in turn influences green logistics management, corresponds with earlier research highlighting the significance of intentions to cooperate in funding energy and environmental conservation initiatives, thereby influencing sustainable green logistics management. It corroborates the findings of [55,56].

Lastly, for Hypothesis 5—financial willingness to pay for green consumption positively affects green logistics, we found that the standardized path coefficient value is $\gamma = 0.179$. The observed influence of the social reputation for environmental concerns regarding green logistics management is in harmony with previous studies underscoring the impact of participation in environmental public relations, engagement in government-led educational initiatives, contributions to environmental conservation, and the conduct of organizational environmental assessments as contributors to green logistics operations in accordance with organizational social responsibilities. These findings are similar to those of [58,59].

Furthermore, the outcomes of the measurement model with regards to green logistics management within the Thai Motor Vehicle Industry Group encompass dimensions such as green design, green procurement, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication. This comprehensive model aligns with earlier research that has elucidated various factors contributing to the enhancement of green logistics management efficiency, including principles such as the 3Rs (Recycle, Reproduce, and Reuse), the promotion of clean technology usage, and the improvement of production processes to minimize waste generation, all of which are integral components of green manufacturing [24]. Additionally, product design strategies aimed at reducing environmental impact, such as product design for recycling and the reduction of unnecessary materials, align with the green design dimension, consistent with previous research findings [23,24,70]. Collaborative efforts with suppliers for environmentally friendly procurement practices and the establishment of environmentally conscious procurement systems are integral to the green procurement dimension, a concept consistent with prior research [27,71]. These findings are in harmony with earlier studies that underscore the importance of green logistics activities in enhancing environmentally friendly production efficiency, reducing pollution, and conserving natural resources [72]. Moreover, the study reinforces the notion that green logistics activities should prioritize green procurement as a means to introduce environmentally friendly materials into the production process, thereby promoting sustainability and environmentally responsible practices within the industry [16].

In summary, the results indicated that the analysis of factors of government environmental policies, organizational environmental policies, an organization's financial capacity to embrace green transformations, willingness to invest in environmentally responsible consumption, and societal perceptions related to environmental concerns, affect logistics management in the automobile industry. These factors play important roles for entrepreneurs and government sectors in determining the environmental policies of the automobile parts manufacturing industry and evaluating the consistency between development pattern and empirical pattern.

5.1. Theoretical Implications

In the context of Thailand, the domain of green logistics management has been relatively underexplored in previous research [73]. Furthermore, there have been shortcomings identified in the existing literature when it comes to comprehensively examining the concepts of green procurement and reverse logistics [74]. The majority of prior studies have often focused on specific aspects within this field. Consequently, our research endeavors to address this gap by systematically collating and categorizing the key factors relevant to green logistics management, taking into account the perspectives of employees, engineers, and managers within the Thai Motor Vehicle Industry Group. Utilizing a measurement model, we have sought to unravel the intricate relationships among these factors that influence green logistics. Our findings have identified several pivotal factors that exert a substantial influence on green logistics management:

Firstly, we used agency theory in this study. Agency theory means that agents or organizational management will manage the organization to give it the highest returns and avoid damage to shareholders. These are relevant to the studied factors of environmental policy in organizations, financial ability in an organization for green change, financial willingness to pay for green consumption, and social reputation for caring about the environment. This theory helps to explain the follow-up roles and monitoring mechanisms of green logistics management that are in accordance with the research of Khatib, et al. [75], Agency theory is a key aspect of the study and of monitoring. However, organizational monitoring involves understanding the roles of cultural difference, business, and environmental dimensions, which are important to study further in the future. Therefore, this study partly helps to fill the gaps left by previous research.

Secondly, this study contributes significantly to the extant body of knowledge by shedding light on the factors that impact green logistics within the motor vehicle industry in Thailand. Given the nation's highly competitive auto parts production sector, the findings of this research hold particular significance in terms of encouraging the development of green logistics practices in developing economies.

Third, our study provides empirical evidence that government environmental policies, internal environmental policies within organizations, an organization's financial capacity for enacting green initiatives, willingness to invest in environmentally conscious consumption, and the societal reputation related to environmental stewardship, collectively serve as pivotal mechanisms that underpin organizational green logistics management. This outcome resonates with research conducted in other nations, thus indicating that the factors influencing green logistics management are not constrained by geographic boundaries or the nature of manufacturing industries. It further underscores the importance of both government and private sector emphasis on these influencing factors to promote sustainable environmental development within Thailand's motor vehicle industry. In essence, this research extends the realm of factors affecting green logistics management.

Lastly, our research advances our understanding of the direct relationships between government environmental policies, internal organizational environmental policies, attitudes towards environmental consciousness, an organization's financial capability for instigating green transformation, willingness to invest in environmentally responsible consumption, and the societal perception of environmental concerns in alignment with green logistics management. The results signify the pivotal roles played by these influencing factors in enhancing the efficiency of green logistics management within Thailand's motor vehicle industry. This finding aligns with prior research efforts that seek to establish the impact of green logistics management and other factors on sustainable production and the circular economy [15,16]. It underscores the multifaceted influence of green logistics management on environmental, business, and societal aspects [13]. In summary, this research framework enriches the discourse on the roles and endeavors associated with government environmental policies, organizational environmental policies, financial capabilities within organizations undergoing green transformations, financial commitments to green consumption, and the societal reputation surrounding environmental stewardship. These factors collectively bolster green logistics management across various dimensions, including green design, green procurement, green manufacturing, green marketing, green consumption, green reverse logistics, green transportation, and green communication. Most of these factors are highly pertinent to logistics activities within the environmentally friendly industrial sector.

In essence, our study enhances the existing literature by offering a comprehensive understanding of the core factors that facilitate sustainable green logistics management, particularly within the context of the production industry in developing nations. Our empirical evidence substantiates the direct influence of government environmental policies, internal organizational environmental policies, an organization's financial capability for green transformations, willingness to invest in environmentally conscious consumption, and the societal perception of environmental concerns on the promotion of green logistics practices within Thailand's motor vehicle industry.

5.2. Practical Implications

This study serves as a valuable resource for stakeholders by illuminating the intricate complexities of green logistics in manufacturing. It provides a detailed examination of each influencing factor across various dimensions, offering a level of granularity not previously provided by the existing research. Entrepreneurs within the motor vehicle industry can leverage the insights gained from this study to tailor indicators that align with their respective organizations. They can then prioritize the enhancement of green logistics management practices to promote sustainable production and environmental stewardship. The study's findings can prove to be instrumental in assisting motor vehicle industry stakeholders in comprehending the multifaceted nature of green logistics [76].

Furthermore, this research holds significance for policy makers, both in the governmental sector and within organizations. It empowers them with a deeper understanding of the primary factors that drive green logistics management. Practical changes and the transformation of green logistics management often hinge on government policies [39]. Similarly, organizational policies play a crucial role in fostering an environment conducive to enhanced environmental care and sustainability practices [47]. Additionally, an organization's financial capacity, willingness to invest in environmentally responsible consumption, and its reputation within the industry can significantly influence its ability to effectively implement green logistics management practices. Therefore, collaboration between the government sector and industry entrepreneurs becomes imperative. A coordinated effort and a coherent plan, coupled with rigorous monitoring, are essential for advancing the cause of organizational logistics management. Such cooperation not only addresses resource scarcity issues but also enables businesses to create value, reduce environmental contamination, and contribute to the preservation of the environment by facilitating the circular usage of products.

6. Conclusions

Responsibility for the environment is a leading issue in business and the automotive manufacturing industry. Partners from various countries have requested that Thai entrepreneurs follow international standards regarding their environmental and social responsibilities. Green logistics system management aims at reducing costs and increasing competitive efficiency in the industrial sector, as well as contributing to protecting the environment. However, there is still a lack of empirical research into the factors that influence responding to the main sustainable pillar(s) of SDGs, which affect the logistics management of the motor vehicle industry, from the points if view of the staff, engineers, and managers. We operated simple random sampling at industrial factories in central and eastern regions of Thailand. There are 1638 samples in our survey. We have used structural equation model analysis.

These study results are informative for entrepreneurs and government sectors, indicating see key factors that push forward the development of green logistics management in the motor vehicle industry. The results are as follows.

First, we found that government environmental policy, according to the staff, engineers, and manager's expectations, begins when the government announces regulations and rules, promotes operational development, determines the standard, and determines tax structure in order to support green logistics operations. So, government policy makers have to place importance on these practices in order to drive the implementation of green logistics management.

Second, we found that organizations' environmental policy, according to the staff, engineers', and managers' expectations, begins with executives' intentions (high, middle, and low levels) supported by the practice of organizational green logistics management. Moreover, there are also the requirements of issuing operations, policy and objectives, requesting an ISO 14001 certificate, and coplanning with suppliers with regard to the organizational environment. So, entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

Third, we found that an organization's financial ability to adopt green change according to the staffs', engineers', and manager's expectation begins with the organization's green investment, and compensation (of shareholders, sales, investment, returned profit and net profit ratios). All of these do not affect green change, so entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

Fourth, we found that financial willingness to pay for green consumption, according to the staffs', engineers', and managers' expectations, begins with willingness to pay more for different objectives, such as environmentally friendly products, long term product usage, purchase of energy saving and environmental products etc. So, entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

Lastly, we found that social reputation regarding care for the environment, according to the staffs', engineers', and managers' expectations, begins with management or participation in environmental activities, e.g., donation for environmental conservation, responding seriously to complaints and requests to solve environmental problems, public relations of educational and environmental activities organized by government sectors or other organizations, and joining environmental protection activities, etc. So, entrepreneurs have to place importance on these practices in order to drive the implementation of green logistics management.

In addition, we also conducted factor analysis of green logistics management. For this study, the main factors consisted of green design (six factors), green procurement (eight factors), green manufacturing (six factors), green marketing (five factors), green consumption (four factors), green reverse logistics (eight factors), green transportation (eight factors), and green communication (four factors). These factors are affected by government environmental policies, organizational environmental policies, an organization's financial capacity to embrace green transformations, willingness to invest in environmentally responsible consumption, and societal perceptions related to environmental concerns.

Limitations and Future Research Directions

This research, while contributing valuable insights into the realm of green logistics management, has certain limitations that warrant acknowledgment. Firstly, the study's findings are based on the perceptions of stakeholders within a specific motor vehicle industry context in Thailand. Consequently, the generalizability of these findings to other production industries or across various countries may be constrained. Future research endeavors should aim to expand the scope by conducting surveys on green logistics management in different countries and within diverse production sectors to provide a more comprehensive understanding.

Secondly, this research adopts a cross-sectional study design, collecting data at a single point in time. Such an approach has inherent limitations in capturing dynamic and evolving phenomena. To obtain a more accurate and nuanced depiction of the subject matter, future research should consider longitudinal studies that track the evolution of green logistics management practices over time.

Thirdly, a further study may use decision tools with multiple criteria as one future research method, such as analytic network process (ANP), analytic hierarchy process (AHP), multiple-criteria decision analysis, or fuzzy analytic hierarchy process (FAHP), etc.

Lastly, the perspectives solicited in this study primarily represent the viewpoints of engineers, employees, and managers directly associated with the production sector. Other stakeholder groups, such as company owners, governmental authorities, and local agencies, may possess distinct perspectives and roles in shaping green logistics management practices. Future research endeavors could aim to incorporate a broader spectrum of viewpoints to enrich the understanding of green logistics management from a more comprehensive and holistic standpoint.

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Institutional Review Board Statement: This research has been approved by the Human Research Ethics Committee at Suranaree University of Technology, Code COA No87/2563.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Questionnaires.

Code	Items
	Green Design
GD1	Product design to reduce materials that affect the environment
GD2	Product design for reuse, recycling, and others
GD3	Product design to reduce quantity and type of material used
GD4	Product design to reduce use of dangerous/toxic materials
GD5	Product design for storage area during transportation
GD6	Building/factory design by using nontoxic material
	Green Procurement
GP1	Determining environmentally friendly procurement as part of the environmental management system
GP2	Developing basic knowledge of environmental purposing procurement to raise awareness of environmental problems
GP3	Developing person(s) in charge of procurement to buy energy-conserving product
GP4	Determining cooperate working structure between environmental agency and procurement sector
GP5	Preparing E-Catalog of environmentally friendly products (with ISO 9000 or ISO 14001 certified)
GP6	Training suppliers to reduce non-recycling package
GP7	Cooperating with suppliers for environmental objectives
GP8	Promoting ISO 14000 certification of supplier
	Green Manufacturing
GM1	Using environmental (saving) packaging
GM2	Reusing packaging
GM3	Reducing and altering materials to support green manufacturing
GM4	Controlling dangerous substances in production process
GM5	Following the practice of 3Rs (recycle, reproduce, and reuse)
GM6	Recycling the production resource as much as possible
	Green Marketing
GMA1	Advertising and Public Relations on environmentally friendly product qualification
GMA2	Product's logo design that indicates environmental friendliness
GMA3	Package design that clearly identifies as a green product
GMA4	Organizing social service activities regarding energy and environmental conservation
GMA5	Organizing educational activities regarding green products and the environment
	Green Consumption
GC1	Support the recycling product
GC2	Support the least-pollution generating product
GC3	Support an energy and environmental conserving product
GC4	Support the product with an energy-saving label
	Green Reverse Logistics
GR1	There is the sorting out for defected, expired, and unused products from production process to return them into quality improvement process
GR2	There is the sorting out for defected, expired, and unused products from production process for reproduction
GR3	There is the return of defected, expired, and unused products from customers to return them into quality improvement process
GR4	There is the return of defected, expired, and unused products from customers for reproduction
GR5	There is sorting out for defected, expired, and unused products from production process to raw material suppliers, to return them into quality improvement process
GR6	There is sorting out for defected, expired, and unused products from production process to raw material suppliers for reproduction
GR7	There is the return of defected, expired, and unused products from customers to raw material suppliers to return them into quality improvement process
GR8	There is the return of defected, expired, and unused products from customers to raw material suppliers for reproduction

Table A1. *Cont.*

Code	Items
	Green Transportation
GT1	Using vehicles in energy-saving mode
GT2	Using alternative energy
GT3	Determining energy-saving transport route
GT4	Selecting types of transportation with the least use of energy such as backhauling
GT5	Adjusting transportation schedule to avoid traffic problem
GT6	Maintaining vehicle by using preventive system
GT7	Selecting suitable vehicle's size and fuel
GT8	Using raw material from a close-distance of factory or domestic material to save transportation energy
	Green Communication
GCO1	Communication by focusing on environmentally friendly practices and product recommendations through magazine publication
GCO2	Communication by focusing on environmentally friendly practices and product recommendations through radio broadcast
GCO3	Communication by focusing on environmentally friendly practices and product recommendations through Public Relations sign
GCO4	Communication by focusing on environmentally friendly practices and product recommendations through newspaper
	Government environmental policy
GE1	Government enacts the strict law and regulation regarding the environment
GE2	Government enforces environmental regulation at the regional level
GE3	Government promotes the development and promotion of green logistics operations
GE4	Government funds on research and application of green logistics operation technology
GE5	Government determines industrial logistics standard as the main factor of green logistics operation
GE6	Government determines taxation structure to promote green logistics operation
	Environmental policy in the organization
EO1	Intention of the Top Executive for green supply chain management
EO2	Intention of the Middle Executive for green supply chain management
EO3	Intention of a Low-level Executive green supply chain management
EO4	Statement of environmental policy in writing
EO5	Environmental objectives in writing
EO6	Organization has the ISO 14001 certification
EO7	Supplier's environmental planning
	Financial ability in an organization in the green change
FG1	Organization has an actual Green Investment
FG2	Shareholder's return does not affect the green change
FG3	Sales return does not affect the green change
FG4	Investment return does not affect the green change
FG5	Returned profit ratio and net profit do not affect the green change
	Financial willingness to pay in green consumption
FWP1	Willing to pay more for environmentally friendly products
FWP2	Willing to pay more for long-term use products
FWP3	Willing to pay more for the least-pollution generating products
FWP4	Willing to pay more for a product that has the recycling package
FWP5	Willing to pay more for a product that saves energy and environment
FWP6	Willing to pay more for a product with an energy-saving label
FWP7	Willing to pay more for a product with the green product label
	Social reputation about the environment
SE1	There is the donation for environmental conservation
SE2	Participating in complaints and appealing to seriously solve environmental problems
SE3	Participating in the public relations of environmental and educational activities held by government or different organizations
SE4	Participating in environmental protection activities held by civil environmental groups
SE5	Agree to have an environmental inspection at the organization
SE6	Research projects and exposure of environmental problems
SE7	Activities held for social responsibility, regarding energy and environmental conservation in the targeted community

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