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The influence of reverse logistics and product value recovery on sustainable industries through circular economy practices

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Abstract

This research aimed to: 1) investigate the operational levels of reverse logistics, used-product value recovery, circular economy practices, and sustainable industry in Thailand's food manufacturing industry; and 2) examine the validity and reliability of the study constructs. This study employed a quantitative research approach. Data were collected from 400 personnel working in the food and beverage manufacturing industry in Thailand. The data were analyzed using descriptive statistics and Confirmatory Factor Analysis (CFA). The results revealed that: 1) the operational levels of reverse logistics, used-product value recovery, circular economy practices, and sustainable industry in Thailand's food manufacturing industry were at a high level in all aspects. This indicates that food manufacturers place importance on resource management, waste reduction, and the continuous implementation of sustainable operational practices. 2) The first-order Confirmatory Factor Analysis (CFA) model of the study constructs was consistent with the empirical data after model modification. By correlating 10 pairs of error terms, all goodness-of-fit indices satisfied the recommended evaluation criteria and were within acceptable levels. Therefore, food manufacturers should integrate reverse logistics, used-product value recovery, and circular economy practices into their operational processes to improve resource utilization, reduce waste, and support sustainable industrial development.

คำสำคัญ: Reverse logistics, Used-Product value recovery, Circular economy practices, Sustainable industry; Food industry

ประเภทบทความ: Research Article

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ผ่านการรับรองคุณภาพจากศูนย์ดัชนีการอ้างอิงวารสารไทย (TCI.) อยู่ในกลุ่ม 2 สาขามนุษยศาสตร์และสังคมศาสตร์

อิทธิพลของโลจิสติกส์ย้อนกลับและการฟื้นฟูมูลค่าผลิตภัณฑ์ที่มีต่ออุตสาหกรรมที่ยั่งยืน ผ่านแนวปฏิบัติของเศรษฐกิจหมุนเวียน

ทรงธรรม เจริญจันทร์^{1*}, โมฮัมหมัด ริไซมี ซาฮารุดิน² และ กฤษดา เสือเอี่ยม³

บทคัดย่อ

การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อ 1) ศึกษาระดับของโลจิสติกส์ย้อนกลับ การฟื้นฟูมูลค่าผลิตภัณฑ์ที่ใช้แล้ว แนวปฏิบัติเศรษฐกิจหมุนเวียน และการพัฒนาอุตสาหกรรมที่ยั่งยืน ในอุตสาหกรรมการผลิตอาหารของประเทศไทย และ 2) ตรวจสอบมาตรฐานและความน่าเชื่อถือของตัวแปรที่ศึกษา ใช้วิธีวิจัยเชิงปริมาณ เก็บรวบรวมข้อมูลจากผู้ปฏิบัติงานในอุตสาหกรรมการผลิตอาหารและเครื่องดื่มของประเทศไทย จำนวน 400 คน วิเคราะห์ข้อมูลด้วยสถิติเชิงพรรณนา และการวิเคราะห์องค์ประกอบเชิงยืนยัน ผลการวิจัยพบว่า 1) ระดับการดำเนินงานด้านโลจิสติกส์ย้อนกลับ การฟื้นฟูมูลค่าผลิตภัณฑ์ที่ใช้แล้ว แนวปฏิบัติเศรษฐกิจหมุนเวียน และอุตสาหกรรมที่ยั่งยืนในอุตสาหกรรมการผลิตอาหารของประเทศไทย อยู่ในระดับสูงทุกด้าน สะท้อนให้เห็นว่า ผู้ประกอบการให้ความสำคัญกับการบริหารจัดการทรัพยากร การลดของเสีย และการดำเนินงานที่มุ่งสู่ความยั่งยืนอย่างต่อเนื่อง 2) โมเดลองค์ประกอบเชิงยืนยันอันดับที่ 1 ของตัวแปรที่ศึกษา มีความสอดคล้องกับข้อมูลเชิงประจักษ์หลังการปรับโมเดล โดยการเชื่อมโยงค่าความคลาดเคลื่อนจำนวน 10 คู่ ส่งผลให้ค่าดัชนีความสอดคล้องของโมเดลผ่านเกณฑ์การประเมินทุกตัวชี้วัด ซึ่งอยู่ในเกณฑ์ที่ยอมรับได้ทั้งหมด ดังนั้น ผู้ประกอบการควรบูรณาการโลจิสติกส์ย้อนกลับ การฟื้นฟูมูลค่าผลิตภัณฑ์ที่ใช้แล้ว และแนวปฏิบัติเศรษฐกิจหมุนเวียนเข้ากับกระบวนการดำเนินงาน เพื่อเพิ่มประสิทธิภาพการใช้ทรัพยากร ลดของเสีย และสนับสนุนการพัฒนาอุตสาหกรรมที่ยั่งยืน

คำสำคัญ: โลจิสติกส์ย้อนกลับ, การฟื้นฟูมูลค่าผลิตภัณฑ์ที่ใช้แล้ว, แนวปฏิบัติเศรษฐกิจหมุนเวียน, อุตสาหกรรมที่ยั่งยืน, อุตสาหกรรมอาหาร

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1. Introduction

Reverse logistics has been recognized as a critical mechanism for supporting circular resource flows within industrial systems. Through activities such as product collection, inspection, sorting, acquisition, and reverse transportation, organizations can recover valuable materials and products that would otherwise become waste. Effective reverse logistics practices not only reduce environmental burdens but also improve operational efficiency and resource utilization (Frei et al., 2020; Berlin et al., 2022). In addition, used-product value recovery has emerged as an important strategy for extending product life cycles and maximizing resource value. Practices such as reuse, remanufacturing, and recycling enable organizations to recover economic value from used products while reducing the consumption of virgin materials and minimizing waste generation. These activities contribute to both resource conservation and cost reduction, thereby supporting long-term sustainability objectives (Vlajic et al., 2018; Xavier et al., 2023). Circular economy practices provide organizations with a practical approach to improving the efficiency of resource utilization by extending the value of products and materials throughout their life cycles. Rather than focusing solely on waste management, these practices encourage the recovery, reuse, and regeneration of resources as part of routine business operations. Such an approach enables organizations to reduce environmental

impacts while simultaneously strengthening operational efficiency and long-term competitiveness (Carissimi et al., 2023; Mora-Contreras et al., 2023).

From a sustainability perspective, industrial development is no longer evaluated solely on economic outcomes. Sustainable industry requires a balanced consideration of economic sustainability, environmental sustainability, and social sustainability. Organizations that successfully integrate circular resource management into their operations are more likely to achieve long-term competitiveness while simultaneously reducing environmental impacts and creating value for society (Dossou et al., 2022; Duarte et al., 2023). Although previous studies have extensively discussed reverse logistics, used-product value recovery, circular economy practices, and sustainable industry, limited empirical evidence is available regarding their operational implementation within Thailand's food manufacturing industry. In addition, studies examining the construct validity and reliability of these concepts in the Thai industrial context remain scarce. Therefore, this study focuses on investigating the operational levels of the study variables and validating the measurement model to provide reliable evidence for future research and industrial applications.

Previous studies have largely examined these concepts independently, resulting in insufficient understanding of how reverse logistics and value recovery activities

contribute to circular economy implementation and ultimately support sustainable industry development. Therefore, further investigation is needed to provide empirical evidence and practical guidance for food manufacturers seeking to improve sustainability performance through circular operational practices.

Therefore, this study contributes to the literature by providing empirical evidence on the operational implementation of reverse logistics, used-product value recovery, circular economy practices, and sustainable industry in Thailand's food manufacturing industry. In addition, the study validates the measurement model through Confirmatory Factor Analysis (CFA), providing a reliable foundation for future empirical research and practical applications.

2. Research objectives

1. To investigate the operational levels of reverse logistics, used-product value recovery, circular economy practices, and sustainable industry in Thailand's food manufacturing industry.

2. To examine the validity and reliability of the study constructs.

3. Conceptual framework

The conceptual framework was synthesized from the theoretical and empirical contributions of Frei et al. (2020), Fernando et al. (2021), Xavier et al. (2023), and Zhou et al. (2023), which provided the foundation for examining the relationships among reverse logistics, used-product value recovery, circular economy practices, and sustainable industry.

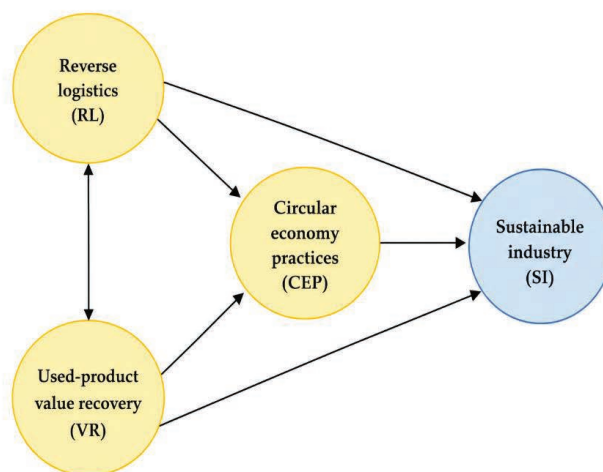


Figure 1 Conceptual framework

4. Literature review

4.1 Reverse logistics

Reverse logistics (RL) refers to the process of managing the reverse flow of products, materials, packaging, and waste from consumers or downstream supply chain destinations back into business operations for inspection, reuse, recycling, remanufacturing, or appropriate disposal. This concept has become increasingly important in the food industry, where production, transportation, consumption, and packaging activities generate substantial amounts of waste. Without a well-defined reverse logistics system, valuable resources may be discarded without being recovered or reused. From a circular economy perspective, reverse logistics is not merely a product return activity but a strategic mechanism for closing resource loops within the supply chain. It facilitates the reintegration of used materials and products into value-creating processes, thereby extending resource utilization and reducing environmental impacts. Fernando et al. (2021) explained that reverse logistics plays a critical role in supporting circular economy implementation by recovering resources and minimizing environmental burdens. Similarly, Richnák and Gubová (2021) emphasized that green logistics and reverse logistics are important operational tools for organizations seeking to achieve sustainable development objectives. Within the context of Thailand's food industry, reverse logistics can be categorized into four major activities:

used-product collection, inspection and sorting, reverse transportation, and used-product acquisition planning. These activities enable organizations to systematically recover raw materials, packaging materials, and certain types of waste for further utilization. These activities enable organizations to systematically recover raw materials, packaging materials, and production residues for further utilization, thereby improving resource efficiency and reducing waste generation. Therefore, in this study, reverse logistics refers to the systematic management of products, materials, and waste through reverse-flow activities that facilitate resource recovery, waste reduction, and efficient resource utilization, thereby supporting circular economy practices within Thailand's food industry.

Therefore, in this study, reverse logistics refers to the systematic management of products, materials, and waste through reverse-flow activities that facilitate resource recovery, waste reduction, and efficient resource utilization, thereby supporting circular economy practices within Thailand's food industry.

4.2 Used-Product value recovery

Used-Product Value Recovery (VR) is a key component of the circular economy that aims to preserve the value and utility of products, materials, and resources after use by returning them to the economic system rather than disposing of them as waste. This concept emphasizes efficient resource

utilization, reduction of virgin material consumption, and extension of product life cycles, thereby generating economic, environmental, and social benefits (Xavier et al., 2023). Value recovery plays an important role in sustainable industrial development because it helps reduce raw material costs, minimize production waste, and improve organizational resource efficiency (Sellitto & Almeida, 2019). Furthermore, it supports the effective management of end-of-life products by maximizing their remaining value instead of relying on conventional disposal methods such as landfilling or incineration (Dwivedi et al., 2022). As a result, organizations can generate additional value from existing resources while simultaneously reducing environmental impacts and greenhouse gas emissions. In the context of the food industry, used-product value recovery can be implemented through three major approaches: reuse, remanufacturing, and recycling. Reuse refers to the repeated use of products or materials for the same or similar purposes, thereby reducing the consumption of new resources and minimizing waste generation. Remanufacturing involves repairing, refurbishing, or replacing components of used products to restore their functionality and quality to a condition comparable to that of new products. This process extends product life cycles and reduces dependence on virgin raw materials (Vlajic et al., 2018; Xavier et al., 2023). Recycling, on the other hand, refers to the process of converting used materials

or products into secondary raw materials for further production. Recycling helps reduce the consumption of natural resources, lower energy usage, and shorten production cycles. It also supports the creation of new products for secondary markets or alternative applications, thereby contributing to resource conservation and environmental sustainability (Sangwan, 2017; Cao et al., 2023). Therefore, used-product value recovery serves as a critical mechanism that enables organizations to generate additional value from existing resources while reducing waste and environmental impacts. It represents a fundamental element of circular economy implementation and provides an important pathway for advancing sustainability within Thailand's food industry.

4.3 Sustainable industry

Sustainable Industry (SI) refers to an industrial development approach that seeks to achieve a balance among economic growth, environmental conservation, and social responsibility. This approach emphasizes efficient resource utilization, the reduction of negative impacts arising from production activities, and the improvement of quality of life for stakeholders throughout the supply chain (Dossou et al., 2022; Duarte et al., 2023).

In the context of the food industry, sustainability extends beyond financial performance and profitability. It also encompasses the effective management of resources, raw materials, energy, and waste throughout the product life cycle. Guided by circular economy

principles, sustainable industrial development focuses on minimizing resource losses, maximizing value recovery, and extending the utilization of existing resources. Such practices contribute to greater resource efficiency and long-term environmental protection (Leppänen et al., 2020).

Sustainable industry can be evaluated through three major dimensions: economic sustainability, environmental sustainability, and social sustainability. Economic sustainability refers to an organization's ability to generate business growth and financial returns while utilizing resources and energy efficiently within environmental and resource constraints (Wang & Jia, 2022). Sustainable growth is not solely concerned with maximizing profits; rather, it emphasizes maintaining an appropriate balance among economic, social, and environmental systems (Nenavath & Mishra, 2023). Environmental sustainability involves industrial practices that reduce resource consumption, minimize pollution emissions, and decrease waste generation throughout production processes. It focuses on preserving the quality of natural resources, energy, water, air, and ecosystems to support long-term development (Mustafaoğlu et al., 2023). This perspective is closely aligned with circular economy principles, which emphasize resource efficiency and the recovery of value from waste materials. Social sustainability refers to business operations that prioritize the quality of life, safety, health, and well-being of employees, communities, and

consumers. Organizations are expected to implement management systems that minimize pollution-related impacts and reduce risks associated with industrial activities (Gil-Garcia et al., 2023). Furthermore, social sustainability is consistent with the Sustainable Development Goals (SDGs), particularly those related to decent work, improved quality of life, technological advancement, and inclusive social development (Duarte et al., 2023). Therefore, sustainable industry represents the outcome of balanced management across resources, production processes, and stakeholder interests in economic, environmental, and social dimensions. Such an approach enables organizations to maintain long-term competitiveness while continuously contributing to environmental stewardship and social well-being.

5. Methodology

5.1 Research method

This research adopted a quantitative research design. Data were gathered using questionnaires administered to food industry operators in Thailand. Data analysis consisted of descriptive statistics for explaining respondent characteristics and variable levels, confirmatory factor analysis (CFA).

5.2 Population and sample

The study population comprised food and beverage manufacturing companies in Thailand registered with the Department of Business Development (DBD) in 2022. The minimum required sample size of 394

respondents was determined using Yamane (1973) formula. To enhance the adequacy of the data for statistical analysis, questionnaires were collected from 400 personnel working in food and beverage manufacturing organizations, and these 400 respondents constituted the study sample.

5.3 Research instruments

The research instrument was a structured questionnaire. The content validity of the questionnaire was evaluated by five experts using the Index of Item-Objective Congruence (IOC), yielding an IOC value of 1.00. The reliability of the instrument was assessed using Cronbach's alpha coefficient based on a pilot test with 30 respondents, resulting in a reliability coefficient of 0.85. The validated questionnaire was subsequently used for data collection.

5.4 Data collection

Data were collected using a structured questionnaire comprising 93 measurement items based on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was administered to personnel involved in logistics, supply chain management, production, and sustainability-

related activities within food manufacturing organizations. The data collection process was carried out over a six-month period using a flexible mixed-mode approach that combined offline and online survey administration to improve response rates and facilitate participation. The questionnaire measured four principal constructs: reverse logistics, used-product value recovery, circular economy practices, and sustainable industry.

5.5 Data analysis

Data were analyzed in two stages. First, descriptive statistics, including frequency, percentage, mean, and standard deviation, were employed to describe the demographic characteristics of the respondents and examine the operational levels of reverse logistics, used-product value recovery, circular economy practices, and sustainable industry. Second, Confirmatory Factor Analysis (CFA) was performed to assess the construct validity and reliability of the study constructs.

6. Results

6.1 Results of the Analysis of General Characteristics of Respondents in the Food Industry

Table 1 A total of 400 completed questionnaires were collected and analyzed. The results are presented as follows.

No.	Job Position	Frequency	Percentage
1	Business Owner	0	0.00
2	Supply Chain Manager	44	11.00
3	Supply Chain Officer	102	25.50

Table 1 A total of 400 completed questionnaires were collected and analyzed. The results are presented as follows. (Cont.)

No.	Job Position	Frequency	Percentage
4	Logistics Manager	77	19.25
5	Logistics Officer	161	40.25
6	Environmental Manager	9	2.25
7	Environmental Officer	7	1.75
	Total	400	100.00

Table 1 shows that the majority of respondents were logistics officers, accounting for 161 respondents (40.86%). This was followed by supply chain officers with 102 respondents (25.89%) and logistics managers with 77 respondents (19.54%). These findings

indicate that most respondents were directly involved in logistics and supply chain management activities and therefore possessed relevant knowledge and experience related to the research topic.

Table 2 General Characteristics of Respondents Classified by Industry Type

No	Industry Type	Frequency	Percentage
1	Food Industry	370	92.50
2	Food and Beverage Industry	30	7.50
	Total	400	100.00

Table 2 shows that the majority of respondents were from the food industry, accounting for 370 respondents (93.91%). This was followed by the food and beverage industry with 24 respondents (6.09%). These findings indicate that most respondents were directly engaged in the food industry, which is consistent with the scope and objectives of this study.

6.2 Operational Levels of Reverse Logistics, Used-Product Value Recovery, Circular Economy Practices, and Sustainable Industry in Thailand's Food Manufacturing Industry: A Descriptive Statistical Analysis

The highest-rated item in each dimension is presented below:

Table 3 Mean, Standard Deviation, and Opinion Levels

Component Item	Mean	S.D.	Interpretation	Rank
Reverse Logistics				
Used-Product Collection Activity				
Food sustainability is associated with the collection of used products in food businesses.	4.25	0.72	High	1
Inspection and Sorting Activity of Used Products				
The inspection and sorting of used products in food businesses enables firms to generate greater economic value.	4.13	0.76	High	1
Reverse Transport Activity				
Reverse transport enables food businesses to create a sustainable resource circulation system.	4.25	0.72	High	1
Used-Product Acquisition Activity				
Used-product acquisition helps reduce waste generated by food businesses in the environment in a sustainable manner.	4.01	0.75	High	1
Used-Product Value Recovery				
Value Recovery through Reuse				
Product reuse is associated with resource management in food business operations.	4.01	0.78	High	1
Value Recovery through Remanufacturing				
Remanufacturing products or materials in food businesses helps reduce resource-related costs.	4.11	0.75	High	1
Value Recovery through Recycling				
Recycling helps create greater value from resources in food businesses.	4.05	0.76	High	1
Circular Economy Practices				
R-Strategy Practices				
Production resources can be reduced through the application of R-strategies to create circularity in food businesses.	4.05	0.73	High	1

Table 3 Mean, Standard Deviation, and Opinion Levels (Cont.)

Component Item	Mean	S.D.	Interpretation	Rank
Resource Efficiency Practices				
The sustainability of food businesses is associated with efficient natural resource management.	4.06	0.75	High	1
Waste Management Practices				
Resource management in food production for sustainability is related to waste management.	4.11	0.73	High	1
Sustainable Industry				
Environmental Sustainability				
Circular food business operations reduce excessive consumption of natural resources.	4.09	0.79	High	1
Social Sustainability				
Food businesses that reuse products such as packaging or equipment can improve the distribution of resources to society.	4.05	0.77	High	1
Economic Sustainability				
The use of returned products in food production processes reduces resource-related expenses in food businesses.	3.98	0.75	High	1

The findings show that all highest-rated items were assessed at a high level. Used-product collection and reverse transport received the highest mean scores under reverse logistics (Mean = 4.25), while remanufacturing (Mean = 4.11), waste management (Mean = 4.11), and environmental sustainability

(Mean = 4.09) were the highest-rated items under used-product value recovery, circular economy practices, and sustainable industry, respectively.

6.3 Results of Construct Validity and Reliability Assessment Using Confirmatory Factor Analysis (CFA)

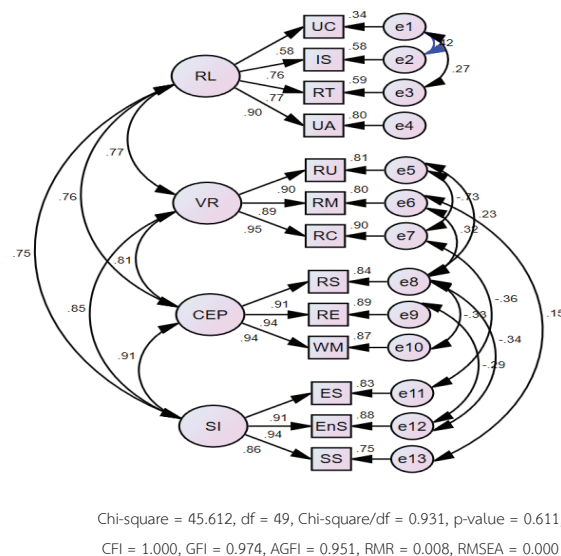


Figure 2 First-Order Confirmatory Factor Analysis (CFA) Model of the Relationships Among the Study Constructs After Model Modification

The results of the first-order Confirmatory Factor Analysis (CFA) after model modification demonstrated that the measurement model achieved a satisfactory fit with the empirical data, as illustrated in Figure 2. Model modification was performed by correlating 10 pairs of error terms, resulting in acceptable goodness-of-fit indices across all evaluation criteria.

As presented in Table 4, the goodness-of-fit statistics improved substantially after model modification. The Chi-square/df decreased from 2.771 to 0.931, which was below the recommended threshold of 2.00. The p-value

increased from 0.000 to 0.611, exceeding the recommended level of 0.05. The goodness-of-fit indices also met the acceptable criteria, with GFI = 0.974, AGFI = 0.951, and CFI = 1.000, all greater than the recommended value of 0.95. Furthermore, the residual indices satisfied the required thresholds, with RMR = 0.008 and RMSEA = 0.000, both lower than the recommended value of 0.05. These results indicate that the modified first-order CFA model was well fitted to the empirical data and that the measurement model demonstrated satisfactory construct validity and reliability for subsequent analysis.

Table 4 Goodness-of-Fit Statistics of the First-Order Confirmatory Factor Analysis (CFA) Model Before and After Model Modification

Fit Index	Acceptance Criterion	Before Model Modification	After Model Modification
	< 2.00	2.771	0.931
p-value	> 0.05	0.000	0.611
GFI	> 0.95	0.914	0.974
AGFI	> 0.95	0.868	0.951
CFI	> 0.95	0.969	1.000
RMR	< 0.05	0.014	0.008
RMSEA	< 0.05	0.083	0.000

7. Discussion and conclusions

7.1 Discussion

1. Reverse logistics

The findings revealed that reverse logistics was implemented at a high level in Thailand's food manufacturing industry. Used-product collection and reverse transportation received the highest mean scores, followed by inspection and sorting and used-product acquisition planning. These findings indicate that food manufacturers have increasingly adopted reverse logistics activities to recover products, packaging materials, and production residues for further utilization, reflecting a greater emphasis on resource management and waste reduction throughout the production process. These findings are consistent with Fernando et al. (2021), who explained that reverse logistics supports circular economy implementation through resource recovery and the reduction of environmental burdens. Similarly, Richnák and Gubová (2021) emphasized that reverse

logistics serves as an important operational tool for achieving sustainable development. The present findings also support the study of Phongthong and Vararattanachai (2024), which reported that logistics capability contributes to improved operational performance. The high level of reverse logistics implementation observed in this study therefore suggests that food manufacturers in Thailand have increasingly integrated reverse-flow activities into their operations to improve resource utilization and support sustainable industrial development.

2. Used-Product value recovery

The findings revealed that used-product value recovery was implemented at a high level in Thailand's food manufacturing industry. Among the value recovery activities, remanufacturing received the highest mean score, followed by recycling and reuse. These findings indicate that food manufacturers have increasingly recognized the importance of recovering value from used products and

materials through systematic resource utilization rather than conventional disposal. Such practices contribute to reducing production waste while maximizing the utilization of existing resources. These findings are consistent with Xavier et al. (2023), who identified used-product value recovery as a key component of circular economy implementation that enhances resource efficiency and extends product life cycles. Likewise, Sellitto and Almeida (2019) reported that value recovery improves organizational resource efficiency while reducing raw material costs. The findings also agree with Dwivedi et al. (2022), who emphasized that effective management of end-of-life products enables organizations to maximize the remaining value of products instead of relying solely on disposal methods. In addition, Cao et al. (2023) suggested that recycling contributes to resource conservation and environmental sustainability through the recovery of secondary raw materials. Therefore, the high level of used-product value recovery observed in this study reflects the increasing adoption of resource recovery practices that support more efficient resource utilization and sustainable development within Thailand's food manufacturing industry.

3. Circular economy practices

The findings revealed that circular economy practices were implemented at a high level in Thailand's food manufacturing industry. Among the three dimensions examined, waste management practices

received the highest mean score, followed by resource efficiency and R-strategy. These findings indicate that food manufacturers have increasingly incorporated circular economy principles into their operations by emphasizing efficient resource utilization, systematic waste management, and the recovery of valuable resources throughout the production process. These findings are consistent with Singh et al. (2023) and Carissimi et al. (2023), who explained that circular economy practices promote efficient resource utilization, reduce waste generation, and create balanced economic, environmental, and social value. The findings also support Le et al. (2022), who reported that the application of circular economy principles enables organizations to transform waste into valuable resources while reducing operational costs. Furthermore, the present findings are consistent with Javed et al. (2021) and Xavier et al. (2023), who emphasized that the successful implementation of circular economy practices requires the integration of production systems, resource management, and reverse logistics activities. The high operational level observed in this study therefore reflects the increasing adoption of circular economy practices as an important approach for improving resource efficiency and supporting the long-term sustainability of Thailand's food manufacturing industry.

4. Sustainable industry

The findings revealed that sustainable industry was implemented at a high level in Thailand's food manufacturing industry. Among

the three dimensions examined, environmental sustainability received the highest mean score, followed by economic sustainability and social sustainability. These findings indicate that food manufacturers have increasingly emphasized environmental protection while maintaining efficient resource utilization and sustainable business operations. The high level of implementation also reflects the growing recognition that long-term industrial development requires balancing economic performance, environmental responsibility, and social well-being. These findings are consistent with Dossou et al. (2022) and Duarte et al. (2023), who described sustainable industry as an approach that integrates economic, environmental, and social dimensions into industrial development. The findings also support Leppänen et al. (2020), who emphasized that efficient resource utilization and value recovery contribute to long-term sustainability. Furthermore, Wang and Jia (2022) highlighted the importance of balancing economic performance with efficient resource management, while Mustafaoğlu et al. (2023) and Gil-Garcia et al. (2023) emphasized the significance of environmental stewardship and social responsibility as fundamental components of sustainable industrial development. Therefore, the high operational level of sustainable industry observed in this study reflects the increasing commitment of Thailand's food manufacturers to balancing economic growth, environmental protection, and social responsibility in pursuit of long-term sustainability.

7.2 Conclusion

The conclusions of this study corresponding to the research objectives are as follows:

1. The operational levels of reverse logistics, used-product value recovery, circular economy practices, and sustainable industry in Thailand's food manufacturing industry were all found to be at a high level. This indicates that food manufacturers place considerable emphasis on resource management, waste reduction, and the continuous implementation of sustainable business practices. Considering each construct, used-product collection activity and reverse transportation activity under reverse logistics received the highest mean scores (Mean = 4.25). For used-product value recovery, remanufacturing recorded the highest mean score (Mean = 4.11). Under circular economy practices, waste management practices received the highest mean score (Mean = 4.11), while environmental sustainability achieved the highest mean score (Mean = 4.09) under sustainable industry.

In conclusion, the findings indicate that food manufacturers in Thailand have placed considerable importance on reverse logistics, used-product value recovery, and circular economy practices, which contribute to sustainable industrial development through more efficient resource utilization, waste reduction, and the recovery of valuable resources for further use.

2. The first-order Confirmatory Factor

Analysis (CFA) model of the study constructs demonstrated a satisfactory fit with the empirical data after model modification through the correlation of 10 pairs of error terms. All goodness-of-fit indices satisfied the recommended evaluation criteria, including $\chi^2/df = 0.931$, $p\text{-value} = 0.611$, $GFI = 0.974$, $AGFI = 0.951$, $CFI = 1.000$, $RMR = 0.008$, and $RMSEA = 0.000$, indicating an acceptable model fit.

These findings confirm that the latent constructs and measurement indicators possessed satisfactory construct validity and construct reliability. Consequently, the measurement model was appropriate for representing the study constructs and can be reliably used to explain the relationships among the variables examined in this study.

8. Recommendation

8.1 Recommendations for implementing

The findings indicate that food manufacturers should continue strengthening reverse logistics, used-product value recovery, and circular economy practices as integral components of their operational processes.

Emphasis should be placed on improving resource utilization, reducing waste generation, and increasing the value of recovered products and materials to support sustainable industrial development. Government agencies and industry stakeholders should also encourage the adoption of circular economy practices by promoting resource efficiency, waste management, and value recovery initiatives that enhance the long-term sustainability of Thailand's food manufacturing industry.

8.2 Future research direction

Future studies should extend this research to other manufacturing industries to compare the operational levels of reverse logistics, used-product value recovery, circular economy practices, and sustainable industry across different industrial contexts. Further research may also incorporate additional variables related to sustainable industrial development, such as digital transformation, green innovation, environmental management capability, and supply chain collaboration, to broaden the understanding of sustainability practices in manufacturing industries.

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