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Developing favorite distribution mode of fresh food donations with grey relation analysis and TRIZ

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ABSTRACT

Taiwan currently grapples with the intricate task of balancing its food supply and demand, resulting in the emergence of critical food surplus and waste issues. To address this pressing challenge, the government has turned to food donation initiatives led by public associations and private corporations to alleviate food waste concerns. Nevertheless, a significant obstacle remains in the form of the efficient and effective distribution of these fresh food donations from the supply side to the demand side. Therefore, this study aims to pioneer an innovative and optimized distribution model for fresh food donations employing TRIZ (Theory of Inventive Problem Solving) and grey relational analysis. Through an in-depth analysis of questionnaire data gathered from the public, this research uncovers the most favored distribution model, namely, "Government-invited third-party logistics providers (3PLs) to voluntarily manage distribution services, alongside the provision of preferential subsidies or tax incentives." Building upon these findings, this study offers valuable recommendations for governmental agricultural authorities and other stakeholders within the fresh food donation supply chain, serving as a cornerstone for sustainable food management practices.

Keywords: Fresh Food Donation; Distribution Mode; Disadvantaged Groups; TRIZ; Grey Relational Analysis.

1 Introduction

Food waste is recognized as a significant global challenge, particularly as the world population is projected to reach nine billion by 2050 (Garrone et al., 2014). Annually, approximately one-third of the food intended for human consumption worldwide does not reach our tables, being either squandered or misplaced (Mokrane et al., 2023). The annual worldwide food waste and loss could theoretically feed 939 million adults, assuming a diet of 2000 kcal and 50 g of protein per person each day (Abbade, 2020). In response to the growing need for a more sustainable future, food waste management has garnered increased attention from policymakers, NGOs, practitioners, and academics across various disciplines (de Hooge et al., 2017; Secondi et al., 2015; Seminar, 2016; van Giesen & de Hooge, 2019). Schanes et al. (2018) highlight the complexity of food waste and emphasize the integration of different perspectives to identify factors that contribute to or hinder its generation. This integrated approach also aids in designing surplus food distribution strategies in the final stages of the food supply chain.

To address the challenge of reducing food waste and promoting more sustainable food management, TRIZ is employed. TRIZ facilitates the development of more suitable distribution modes for fresh food donations. Wang et al. (2024) applies the TRIZ methodology to design a strategy that aligns with the real needs of users, enabling them to become active participants in the effort to reduce household food waste.

In Taiwan, the agricultural industry faces the issue of oversupply in certain types of fresh food, while various disadvantaged groups, such as low-income families, homeless individuals, and seniors living alone, suffer from food shortages. This imbalance between supply and demand leads to food waste. Although public and corporate food donations are commonly used to address

these problems, logistical constraints make it difficult to effectively supply surplus food to the intended recipients, resulting in further food waste during the distribution process. Farmers with excess fresh food (with a focus on fresh fruits and vegetables) and the disadvantaged groups in need are scattered across different geographic locations, exacerbating the challenge of establishing an efficient distribution system that effectively connects supply and demand.

While some studies have proposed traceable supply chains for surplus food management (Aysoy et al., 2015), few have presented innovative distribution modes specifically for fresh food donations. Fortunately, the modern agriculture sector is known for its high level of innovation, which includes new production and processing practices, novel locations, and innovative supply chain designs that can serve as references. This study aligns with the perspective of Shukla and Jharkharia (2013), who argue that fresh food supply chain management should shift its focus from profit maximization to waste minimization to actively contribute to the sustainability of the global food system. Therefore, the main objective of this study is to identify a new distribution mode that can overcome the logistical barriers associated with surplus fresh food donations. This is especially crucial for fresh food, which has the highest nutritional value and taste immediately after harvesting but diminishes over time, leading to spoilage (Osvald & Stirn, 2008). Due to the perishability of these fresh foods and the need to maintain a cold chain to preserve their quality, they require particular attention in the distribution process (Pulina & Timpanaro, 2012). Ultimately, reducing food waste lies at the core of an effective food management system, necessitating the development of appropriate strategies for a sustainable food supply chain (Barlagne et al., 2015).

In contrast to many studies that utilize theoretical models such as delivery scheduling, routing, and location selection to address distribution mode issues (Gajanand & Narendran, 2013; Regazzoni et al., 2013; Ullrich, 2012; van den Heuvel et al., 2014), our research takes a different approach. We focus on understanding the behavioral preferences of key actors involved in fresh food donations, including farmers, the government, logistics service providers, and disadvantaged groups (DGs). By considering these preferences, our aim is to identify an appropriate distribution mode that minimizes overall distribution costs while ensuring the satisfaction of DGs with respect to fresh food donations. To achieve these objectives, this study employs TRIZ (Theory of Inventive Problem Solving) in conjunction with grey relational analysis. Through this approach, we develop preferred distribution modes that effectively distribute fresh food donations to DGs in a suitable manner. By integrating the insights gained from TRIZ and grey relational analysis, we can optimize the distribution process and enhance the overall effectiveness of fresh food donation initiatives.

In this article, an extensive literature review was conducted to examine the distribution modes of agricultural products, as well as TRIZ. Subsequently, TRIZ was applied to generate 11 feasible alternative distribution modes. Questionnaires were then administered to farmers, third-party logistics providers (3PLs), and disadvantaged groups (DGs) to determine the most appropriate options. Furthermore, the chosen distribution mode was tested through the presentation of relevant cases and examples. The analytical results and discussions derived from these investigations are presented, and concluding remarks are provided at the end of the article.

2 Distribution mode of agricultural products and TRIZ

2.1 Distribution performance of agricultural products

To assess the effectiveness of the agricultural distribution system, it is crucial to develop an appropriate performance measurement framework. Bowersox et al. (2000) and Gunasekaran et al. (2005) have incorporated performance metrics such as customer satisfaction, delivery speed, dependability, flexibility, and cost to evaluate distribution performance. However, with the growing emphasis on sustainable development and corporate social responsibility, there is a need to consider the social dimensions of logistics management and maximize both economic value and social expectations.

In this study, our specific goals are to achieve social welfare and address the social dimension, an aspect that has received limited attention from researchers (Beske-Janssen et al., 2015). To this end, we draw inspiration from the concept of humanitarian logistics performance, which aims to maximize the benefits of disadvantaged groups (DGs), farmers, and third-party logistics service providers (3PLs) by identifying an appropriate and cost-effective distribution approach for fresh food donations. To gain practical insights, we conducted

in-depth interviews with industry experts, resulting in the identification of core criteria for fresh food distribution. Furthermore, building on the research conducted by Lan et al. (2008), which explored the distribution mode of regional food cold chains with a focus on improving economic and social effects, we identified safety, efficiency, and flexibility as the main influencing factors. By combining the insights from the in-depth interviews and existing literature, this study identifies three performance metrics: "freshness," "speed," and "convenience."

2.2 Government's current distribution options

Based on in-depth interviews conducted with the competent authority responsible for agricultural affairs in Taiwan, namely the Council of Agriculture (COA), six existing alternatives for distributing fresh food donations to disadvantaged groups (DGs) have been identified. These alternatives are outlined below:

#1. 3PL provides home delivery.
#2. Regional Governmental welfare institutes take care of distribution.
#3. Regional retailers' storage and DGs' pickup
#4. DGs bought from markets and got refund.
#5. The regional wholesalers purchased and distributed to DGs.
#6. Farmers distributed to DGs directly.

Based on the recommendations provided by experts, a comprehensive comparison was conducted to evaluate the six distribution options. The strengths and weaknesses of each option are summarized in Table 1.

Table 1. Comparisons of six options of distribution

Options	Strengths
#1	Quick response time, keep fresh
#2	Cheaper, known the locations of DGs
#3	Convenient Accessibility
#4	DGs got rights to buy what they need
#5	Cheap and sufficient storage space
#6	Low inventory costs
Options	**Weaknesses**
#1	Higher transportation costs
#2	Long response time
#3	Sometimes lack willingness to pickup
#4	Most DGs are short of cash
#5	Long response time and quantity variety
#6	Low Accessibility and quantity variety

After a thorough review and analysis of the distribution options, we assessed them based on the three-performance metrics: "freshness," "speed," and "convenience." As a result, we identified four viable distribution options (#1, 2, 3, and 4). Nevertheless, several barriers still hinder the distribution of fresh food donations, which will serve as catalysts for the creation of new innovative distribution modes, as discussed in the next section.

2.3 TRIZ

The Theory of Inventive Problem Solving (TRIZ) is a process that stimulates breakthrough thinking patterns and problem-solving approaches. TRIZ stands as a methodology and philosophy for the innovation and enhancement of systems across various domains, including science, education, business, industry, and services. It offers a systematic approach to solving problems and generating optimal solutions to even the most challenging issues (Bukhman, 2021). While originally developed for technical fields, TRIZ has increasingly been applied in non-technical sectors, including the service sector (Chai et al., 2005; Chen et al., 2015; Cong & Tong, 2008; Regazzoni et al., 2013; Retseptor, 2003). Zhang et al. (2003) suggested that the 40 Inventive Principles of TRIZ, commonly used for resolving contradiction problems, should be adapted for service operations instead of physical product development. Among the various tool sets of TRIZ, the 40 inventive principles (IPs) are particularly popular and frequently utilized (Cong & Tong, 2008). Jeeradist et al. (2016) applied TRIZ to improve passengers' perceptions of an airline's image by enhancing service quality and safety. Chen et al. (2015) mapped service-quality parameters with TRIZ parameters in the health sector, while Su and Lin (2008) proposed a creative and systematic model using TRIZ methodology for generating innovative solutions for quality improvement. TRIZ methodology is implemented in classroom teaching to transform the educational environment—converting silence into dynamic interaction, transforming the audience into active participants, turning passivity into active learning, and encouraging individual efforts to evolve into collaborative endeavors (Shouhui et al., 2022). In TRIZ methodology, most problems are

accompanied by inherent contradictions, which can arise from conflicting requirements for the same element in the system or conflicting elements within the same system. Identifying these inherent contradictions is a crucial step in TRIZ problem analysis. Once a contradiction is formulated, more advanced TRIZ knowledge-based tools can be employed to resolve it. The resolution of the contradiction often leads to a solution for the main problem and other associated minor problems. The detailed contradiction matrix and corresponding principles can be found in Appendix I and II.

3 Develop innovative distribution options by TRIZ

Building upon the insights gathered from the in-depth interviews and existing methods of distributing fresh food donations to disadvantaged groups (DGs) in Taiwan, this study utilized TRIZ to generate innovative distribution options. By employing the TRIZ analysis process, we linked the identified strengths and weaknesses to the improving and worsening parameters in the TRIZ contradiction matrix. This enabled us to derive new innovative principles and corresponding distribution options. Based on the preliminary findings, four feasible distribution options (#1, 2, 3, and 4) were identified, and TRIZ was employed to analyze each of these options individually.

3.1 #1 3PL provides home delivery.

The identified strength of this distribution option lies in its quick response time, which helps maintain the freshness of the donations. This aligns with the TRIZ improving feature of "Adaptability or versatility (35)". Conversely, a weakness of this option is the higher transportation costs resulting from the dispersed locations of disadvantaged groups (DGs) and the need for disaggregated shipping. This corresponds to the TRIZ worsening feature of "loss of energy (22)". According to the TRIZ contradiction matrix, the inventive principles proposed to address the improving feature (35) and worsening feature (22) are "Mechanical Vibration (18)", "Dynamics (15)", and "Segmentation (1)".

3.1.1 Inventive Principles 18 “Mechanical Vibration”

Applying TRIZ inventive principle 18 to service industries, two relevant strategies are identified: "Benchmarking the best practices across different service industries to improve service quality and foster innovation in developing service offerings" and "Adapting service capacity based on the fluctuation pattern of customer demands." Building upon these principles, this study proposes a novel distribution option wherein the government collaborates with prominent convenience chain stores, specifically 7-Eleven. These stores possess inherent advantages in terms of accessibility and logistics expertise due to their extensive distribution network. Furthermore, they are committed to fulfilling their role as responsible and upright citizens by actively assisting disadvantaged groups (DGs) in need.

3.1.2 Inventive Principles 15 “Dynamics”

Applying TRIZ inventive principle 15 to service industries, two relevant strategies are identified: "Empowering frontline staff with discretionary authority in delivering services" and "Adapting service provisions to meet customer demands." Based on these principles, this study proposes that the government should establish an online exchange system to facilitate communication between farmers and DGs. Through this system, farmers can update information regarding their surplus fresh food, including type, quantity, and location. DGs, on the other hand, can place orders online and select their preferred delivery methods. By providing this platform, the government enables direct interaction between farmers and DGs, empowering them to make decisions and meet their specific needs.

3.1.3 Inventive Principles 1 “Segmentation”

Applying TRIZ inventive principle 1 to service industries, two relevant strategies are identified: "Dividing service packages into several components" and "Segmenting the customer base based on relevant information such as needs, ages, and buying behaviors." Based on these principles, this study proposes that the government should segment the areas where DGs are located based on population density. Subsequently, self-managed teams can be formed to oversee the calculation of demand information and explore suitable distribution options. By dividing the service packages into components and segmenting the customer base, the government can effectively tailor its distribution efforts to meet the specific needs of different areas and DGs.

3.2 #2 Regional Governmental welfare institutes take care of distribution.

The regional social welfare institutes possess strength in their deep understanding of DGs, leading to the corresponding TRIZ improving feature of "ease of operation (33)". However, a weakness is observed in the long response time due to the two-stage distribution process: collection from farmers, storage in warehouses, and subsequent delivery to DGs. This weakness aligns with the TRIZ worsening feature of "speed (9)". According to the TRIZ contradiction matrix, the proposed solutions for improving feature (33) and worsening feature (9) are the inventive principles of "Mechanical Vibration (18)", "The other way round (13)", and "Discarding and recovering (34)".

3.2.1 Inventive Principles 18 “Mechanical Vibration”

Applying inventive principles 18 to develop an innovative distribution option, we propose that the government should implement an appropriate incentive mechanism to reward the social workers of welfare institutes who are involved in the distribution of fresh food donations to DGs. By recognizing and rewarding their efforts, it will motivate and encourage them to perform their distribution tasks more effectively and efficiently.

3.2.2 Inventive principles 13 “The other way round”

Applying inventive principles 13 to service industries, we can consider the following approaches: "Invert the action(s) used to solve the problem, e.g. e-services," "make fixed parts movable, e.g. delivering on-site services," and "turn the object upside down, e.g. customers can serve themselves." Correspondingly, we propose that the government should reorganize the inbound and outbound logistics processes. The collection of fresh food donations can be assigned to the government to achieve economies of scale, while the small-batch last-mile delivery can be outsourced to third-party logistics providers (3PLs). By dividing the tasks, both the government and 3PLs can benefit from the division of labor, resulting in more efficient and effective distribution of fresh food donations to DGs.

3.2.3 Inventive Principles 34 “Discarding and recovering.”

Applying inventive principle 34 to service industries, which suggests removing and reusing elements directly after they have fulfilled their functions, we propose that the government should consider signing long-term outsourcing contracts with third-party logistics providers (3PLs) instead of engaging in arms-length market transactions. By establishing long-term partnerships with trusted 3PLs, the government can cultivate relational capital among themselves, the 3PLs, and the DGs. This approach aims to enhance collaboration and cooperation, ultimately increasing the overall social welfare in the distribution of fresh food donations.

3.3 #3 The Regional Retail Storage and DGs pickup

The distribution option's strength lies in its convenient accessibility due to the widespread presence of retail stores in Taiwan. This aligns with the TRIZ improving feature of "ease of operation (33)". However, a weakness of this option is the potential decrease in willingness to pick up fresh food donations when the price of the food decreases. This corresponds to the TRIZ worsening feature of "stability of the object (13)". The contradiction matrix suggests employing inventive principles such as "Color changes (32)", "Parameter changes (35)", and "Flexible shells and thin films (30)" to address these contradictions.

3.3.1 Inventive Principles 32 “Color changes”

Principles 32, when applied to service industries, encompass offering different options for delivering the service to add value to the customer and utilizing color change to enhance transparency and trust. Building upon these principles, we propose that the government should establish a dedicated and transparent communication platform. This platform will serve to disclose relevant information to all stakeholders who willingly participate in the distribution of fresh food donations to the intended beneficiaries. The application of inventive principles 35 will be further discussed in section 3.4.2.

3.3.2 Inventive Principles 30 “Flexible

shells and thin films"

Principles 30, when applied to service industries, focus on isolating functions, processes, and activities to reduce costs. Drawing from this principle, we propose the separation of two types of beneficiary groups (DGs). DGs residing near the farmers' fields should be responsible for self-pickup, while those located far away should rely on third-party logistics providers (3PLs) for delivery. By implementing this approach, the overall distribution costs can be optimized and reduced.

3.4 #4 DGs bought from markets and got refund.

The strength of this distribution option is DGs have more choices to buy what kind of fresh food they need and increase their willingness to participate, and then the corresponding TRIZ improving features is "power (21)". The weakness is the complicated and time-consuming process to get a refund, also has liquidity problem of cash flow for DGs, and the corresponding TRIZ worsening features is "difficulty of detecting and measuring (37)". The contradiction matrix shows the proposed solutions are inventive principles "periodic action (19)", "Parameter changes (35)", and "Partial or excessive actions (16)".

3.4.1 Inventive principles 19 "periodic action"

Principles 19 applied to service industries emphasizes the importance of collecting customers' feedback regularly, providing specific services periodically, and engaging in repeated promotion activities. In line with these principles, we propose that governmental authorities should regularly collect information on DGs' demand quantity and offer home delivery services to meet their specific needs.

3.4.2 Inventive principles 35 "Parameter changes"

Principles 35 applied to service industries highlights the importance of simplifying the service process and upgrading services for loyal customers. These principles emphasize the need for change. In line with these principles, we propose a change in the delivery responsibilities from the government to farmers. The government can prioritize those farmers who provide voluntary logistics services in purchasing contracts. This change aims to streamline the delivery process and provide enhanced services for loyal customers.

3.4.3 Inventive principles 16 "Partial or excessive actions"

Principles 16 applied to service industries emphasize the importance of providing beforehand notices and explanations to customers regarding the temporary unavailability of services. This helps prevent a loss of customer loyalty due to blind waiting. Additionally, satisfying customers with high service quality is crucial. In line with these principles, we propose that the government invite 3PLs that prioritize their social responsibility and aim to enhance their corporate image through offering distribution services. The government can provide preferential subsidies or tax reductions to partially cover the logistics costs incurred by these 3PLs. This approach encourages the involvement of socially responsible 3PLs and ensures the provision of high-quality distribution services.

4 Use TRIZ to develop new distribution options.

We have employed the inventive thinking approach of the TRIZ methodology to develop a systematic framework that showcases new distribution options for fresh food donations. The main innovative options are summarized as follows:

a. Utilizing demand information requested in advance by DGs to determine the timing and method of distribution.
b. Prioritizing the purchase of donations from farmers willing to undertake distribution to neighboring DGs.
c. Inviting socially responsible 3PLs that emphasize their corporate image enhancement through distribution services, while offering preferential government subsidies or tax reductions to partially cover their logistics costs.
d. Collaborating with leading convenience chain stores such as 7-ELEVEN, which possess accessibility advantages and logistics expertise due to their extensive distribution network. These stores are fully committed to serving as

responsible and upright citizens, assisting DGs.

e. Establishing an online exchange system to bridge the gap between farmers and DGs. Through this system, farmers can update information on fresh food over-supply (type, quantity, location, etc.), while DGs can place online orders and select their preferred delivery methods.

f. Segmenting DGs based on population density and forming self-managed teams responsible for managing demand information and distribution options.

g. Rewarding social workers from regional governments who distribute surplus agricultural products to DGs and receive positive feedback.

h. Undertaking inbound logistics while outsourcing the last mile delivery to 3PLs, allowing for a division of labor that benefits both governments and 3PLs.

i. Signing long-term outsourcing contracts with 3PLs to cultivate relational capital among the government, 3PLs, and DGs, thereby increasing overall social welfare.

j. Establishing a specific and transparent communication platform to disclose related information to all stakeholders voluntarily participating in the distribution of fresh food donations to DGs.

k. Implementing a separation strategy for two types of DGs: those residing near farmers' fields can pick up the donations themselves, while others living farther away rely on 3PLs for delivery, resulting in improved overall distribution costs.

In addition, three major goals have been identified for the distribution of fresh food donations: "freshness," "speed," and "convenience." We conducted questionnaires to gather opinions from relevant professionals, including logistics service providers and governmental officials responsible for fresh food donations. The results of the survey will assist in selecting the most appropriate distribution modes to achieve the specified goals.

5 Grey relational analysis

By integrating existing literature, governmental information, and interviews with industry experts, this study has identified three main distribution goals for distributing fresh food donations to DGs. Additionally, this study has developed eleven new distribution options using the TRIZ methodology. Subsequently, questionnaires were administered to gather data from governments, farmers, and DGs to align the new distribution options with the three established goals. The results of the collected questionnaires are presented below and are divided into four sections, which describe the survey results, define the research targets, outline the questionnaire design, present the analysis method, and discuss the empirical results.

5.1 Define the search targets.

The objective of this questionnaire is to identify the most suitable method for distributing fresh food donations to DGs. Therefore, the questionnaire was primarily distributed to three target groups: DGs, farmers, and 3PLs.

5.2 Questionnaire Design

The questionnaire is structured into five parts. Part 1 focuses on the weighted priority of distribution options, while parts 2 to 4 address the goals of freshness, speed, and convenience, respectively, followed by the weighted priority of distribution options for each goal. Part 5 collects demographic information from respondents.

5.3 Research Methods

For data analysis, this study employed the grey relational analysis (GRA) method. The GRA method calculates the correlation degree of each evaluation object to estimate its grade. It combines qualitative and quantitative analysis and overcomes the limitations of traditional correlation analysis methods, which are not suitable for nonlinear models. The fundamental idea of GRA is to assess the similarity level of geometric patterns of sequence curves and determine the closeness to system characteristics based on relevant factors. Assume that $X_0 = (x_0(1), x_0(2), \ldots, x_0(n))$ represents the sequence of data representing the system characteristics, and $X_i = (x_i(1), x_i(2), \ldots, x_i(n))$, $i = 1, 2, \ldots, m$ represents sequences of m relevant factors. The degree of grey incidence (or grey rational grade) for X_i with respect to X_0, $_{0i} = (X_0, X_i)$, is defined by Equations (1) and (2), where $_{0i}(k)$ is the incident coefficient of k^{th} sample

between sequences X_0 and X_i and a distinguishing coefficient which value is between 0 and 1, as a lot of contribution, this study set distinguishing coefficient (ζ) as 0.5 to enlarge the difference among final incident coefficients, and then calculated to get the grey relational coefficient.

$$\gamma_{oi} = \gamma(X_0, X_i) = \frac{1}{n}\sum_{k=1}^{n}\gamma_{oi}(k), i = 1,2,\dots,m \quad (1)$$

The procedures of GRA are, (1) list the comparative series for further investigation (2) calculate the distance between comparative and reference series (3) calculate the grey relational coefficient (4) determine the grade of grey relations (5) depict the chart based on grey relational grade (GRG).

In this study, we present the GRG in a graphical format. Each point on the lines represents a value calculated by grey relational analysis, where a higher value indicates a greater importance of the corresponding options. The points are grouped based on the tightness of each value. The critical success factors (CSFs) suggest that in any organization, certain factors (typically three to six factors) are critical to its success. This study will retain less than half of the options in the questionnaire, which is less than 11/2≒5.

5.4 Empirical results

In our study, we distributed the questionnaires to three groups: DGs, farmers, and 3PLs, and received valid samples from 198 DGs, 6 farmers, and 5 3PLs. Using grey relational analysis, and considering the four expected goals, namely "Ranks of favorite distribution options", "Freshness", "Speed", and "Convenience", we present the ranks of distribution options as follows.

5.4.1 Ranks of favorite distribution options

In this question, respondents were asked to score the listed eleven distribution options using a Likert 5-point scale. From the perspective of DGs, we identified three Critical Success Factors (CSFs): "b. (GRG=0.593)", "a. (GRG=0.576)", and "c. (GRG=0.539)", as shown in **Figure 1**.

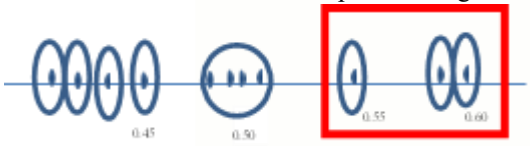


Figure 1. Ranks of favorite distribution options with GRG-the perspectives of DGs (note：Points located in red rectangle mean CSFs)

From the perspectives of farmers, we extracted four CSFs, that is "j. (GRG=1)", "c. (GRG=0.792)", "f. (GRG=0.782)", "b.(GRG=0.735)". As to the perspectives of 3PLs, we extracted three CSFs, that is "k. (GRG=1)", "b. (GRG=0.8222)", and "f. (GRG=0.7556) shown in **Figure 2** and **Figure 3**.

Figure 2. Ranks of favorite distribution options with GRG-the perspectives of farmers

Figure 3 Ranks of favorite distribution options with GRG-the perspectives of 3PLs

In summary, this study identified that "b. If the farmers are willing to undertake distribution of donations to neighboring DGs, the government will give priority to purchase from these farmers" is the only option that was considered a priority by all three groups (DGs, farmers, and 3PLs). Option "c." received support from both DGs and farmers, while option "f." was identified as preferred by farmers and 3PLs. These results indicate differences in preference among the three groups.

5.4.2 Freshness

Given the goal of keeping freshness, and from the perspectives of DGs who extracted five CSFs that is "b. (GRG=0.586)", "a. (GRG=0.547)", d. (GRG=0.51)", "f. (GRG=0.508)", "c. (GRG=0.502)".

Famers identified four CSFs that are "a. (GRG=1)", "j. (GRG=0.815)", "f. (GRG=0.759)", and "h. (GRG=0.754)." 3PLs have identified four CSFs that is "b. (GRG=0.822)", "k. (GRG=0.810)", " i. (GRG=0.698)", "h. (GRG=0.676). Shown in **Figures 4**, 5, and 6 respectively.

Figure 4. Ranks of priority distribution options with GRG given the goal of keeping freshness -the perspectives of DGs

Figure 5. Ranks of priority distribution options with GRG given the goal freshness -the perspectives of farmers.

Figure 6. Ranks of priority distribution options with GRG given the goal of keeping freshness -the perspectives of 3PLs

According to the results, both DGs and farmers reach mutual agree in "a" and "f". And b got support from both DGs and 3PLs. As to supporting by farmers and 3PLs is "j."

5.4.3 Speed

Given the goal of speed, and from the perspectives of DGs who extracted three CSFs that is "b (GRG=0.585)", "c (GRG=0.535)", and "d (GRG=0.532)". The farmers identified three CSFs that is "a (GRG=1)", "j (GRG=0.815), and "i (GRG=0.75)". The 3PLs identified four CSFs that is " a (GRG=0.440)", "b (GRG=0.350)", "h(GRG=0.263)", and "e (GRG=0.204). Shown in figure 7, 8 and 9 respectively.

Figure 7. Ranks of priority distribution options with GRG given the goal of speed-the perspectives of DGs

Figure 8. Ranks of priority distribution options with GRG given the goal of speed-the perspectives of farmers

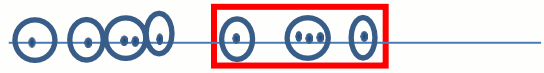
Figure 9. Ranks of priority distribution options with GRG given the goal of speed-the perspectives of 3PLs

According to the results and given the goal of speed, both DGs and 3PLs agree "b" is the priority distribution option. Farmers and 3PLs reached a mutual agreement in "a."

5.4.4 Convenience

Given the goal of convenience, and from the perspectives of DGs who extracted five CSFs that is "b (GRG=0.564)", "c (GRG=0.526)", "d (GRG=0.521)", "a (GRG=0.516)", and "i (GRG=0.503).

Farmers identified four CSFs that is "a (GRG=0.778)", "(GRG=0.815)", "i (GRG=0.754)", and "f (GRG=0.73)." The 3PLs identified four CSFs that is "a (GRG=0.613)", "d (GRG=0.421)", "g (GRG=0.297)", and "k (GRG=0.256)." Shown in Figures 10, 11, and 12 respectively.



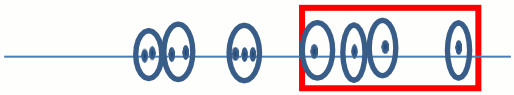


Figure 10. Ranks of priority distribution options with GRG given the goal of convenience-the perspectives of DGs

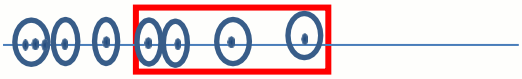


Figure 11. Ranks of priority distribution options with GRG given the goal of convenience-the perspectives of farmers

Figure 12. Ranks of priority distribution options with GRG given the goal of convenience-the perspectives of 3PLs

Based on the obtained results and with a focus on the goal of convenience, this study observed that option "a" was identified as a priority by all three groups. Additionally, both DGs and 3PLs considered option "d" as a priority. To facilitate comparisons, Table 2 presents a summary of the rankings of distribution options as perceived by DGs, farmers, and 3PLs, considering different goals.

Table 2. Summaries of ranks (DGs, farmers, and 3PLs)

Ranks of favorite distribution options		
DGs	Farmers	3PL
b.(.5932)	j. (1)	k.(1.)
a.(.5756)	c. (.792)	b.(.8222)
c.(.5386)	f. (.782)	f.(.7556)

	b. (.735)	
Freshness		
DGs	Farmers	3PL
b. (.586)	a. (1)	b.(.822)
a. (.547)	j. (.815)	k.(.810)
d. (.51)	f. (.759)	i.(.698)
f. (.508)	h. (.754)	j.(.676)
c. (0.502)		
Speed		
DGs	Farmers	3PL
b. (0.585)	a.(1)	a. (0.440)
c. (0.535)	j.(0.815)	b. (0.350)
d. (0.532)	i.(0.75)	h. (0.263)
		e. (0.204)
Convenience		
DGs	Farmers	3PL
b. (0.564)	a. (0.778)	a.(0.613)
c. (0.526)	j. (0.815)	d.(0.421)
d. (0.521)	i. (0.754)	g.(0.297)
a. (0.516)	f. (0.73)	k.(0.256)
i. (0.503)		

Note: a b, c…k stands for eleven distribution options

According to the findings presented in Table 2, DGs regarded option "b" as the preferred distribution option. Farmers, on the other hand, identified option "j" as the best, while 3PLs considered option "k" as their priority choice. When considering the goal of maintaining freshness, DGs prioritized option "b", whereas farmers favored option "a", and 3PLs also considered option "b" as their top choice. In terms of speed, DGs considered option "b" as the priority option, while both farmers and 3PLs believed option "a" to be the preferred distribution method. Similarly, for the goal of convenience, the priority options align with those for speed.

Based on these results, several common elements were identified that were highlighted by all three groups (DGs, farmers, and 3PLs). Firstly, obtaining advance demand information from DGs was deemed crucial as it allows for efficient planning of delivery routes and quantities, reducing unnecessary distribution arrangements, and taking advantage of economies of scale. Transparency in demand information contributes to increased distribution efficiency. Secondly, "home delivery" emerged as the most preferred distribution mode by all three groups. However, there were differences in perceptions regarding who should bear the transportation costs associated with home delivery. While all three groups recognized the benefits of "home delivery" in achieving freshness, speed, and convenience, the issue of cost responsibility remains controversial and unresolved.

In conclusion, this study suggests that "home delivery" is the appropriate distribution mode. However, the issue of cost sharing for home delivery remains a contentious and unresolved matter.

6 Case study

`To illustrate distribution efficiency, a case study was conducted. The study consists of three parts: investigating the numbers and demand information of DGs, presenting the contents and estimated costs of alternative distribution options, and evaluating the performance of these options.

6.1 Numbers and demand information of DGs

Government authorities investigated and identified 391 DGs in need of fresh fruit donations, with a total of 35,014 individuals. Among these DGs, 179 groups (17,472 people) purchased the fruits themselves and received refunds from the government, while the remaining 212 groups (17,542 people) relied on home delivery. The total distribution weight amounted to 18,400 kilograms (kg).

6.2 Contents and estimated costs of alternatives

In this section, we demonstrate two distribution options proposed by the Taiwan Government: option 1, where DGs purchase the fruits themselves and opt for home delivery, and option 2, where Kerry Logistics offers free distribution services. The total expenditures for option 1 and option 2 are estimated to be approximately USD 15,672 and USD 12,294, respectively. The details are as follows:

6.2.1 Option1: DGs purchased by themselves and home delivery

1. **DGs purchases**

a. To simplify implementation procedures and ensure price consistency, the Government announced a reference price range of USD 0.83 to 1 per kilogram (kg) based on surveys conducted at Taipei's fruits and vegetables markets. The subsidy standard was set at USD 1 per kg.

b. Government authorities notified DGs through official documents that they had 7 days to purchase the specified quantities of guava from the nearest supermarkets or agricultural stores. The stores would then issue invoices or receipts. DGs were required to send back these invoices/receipts along with their bank account numbers to the government authorities to obtain reimbursement for their expenditures.

Table 3 provides a detailed breakdown of the purchases made by 179 groups (17,472 people) who bought the fruits themselves and submitted their invoices to the government authorities. Each person received 0.5 kg (9,140 kg in total) of guava, with a subsidy of USD 1 per kg plus transfer fees. The total expenditures for this option amounted to approximately USD 9,319.

Table 3. Expenditures of DGs purchased by themselves

Total Demand	9,140 Kilogram (457catons, CTNs)
expenditures	Guava price USD 9,140 (457CTNs*20kg*USD 1=9,140)
	Transferring fees 179 (179 units*USD 1=179)
	Total 9,319

2. **Home delivery**

a. Kerry Logistics provided free distribution services.

b. The government set the reference price for purchasing guavas from farmers at USD 0.57. As a result, 212 DGs required a total of 9,260 kg of donated guavas. The logistics operation cost was estimated to be USD 0.067 per kg, and the labeling fee was USD 0.034 per unit. The total expenditures for this option were approximately USD 6,019, as presented in Table 4.

Table 4. Expenditures of Home delivery by Kerry Logistics

Total Demand	9,260 Kilogram (463 CTNs)
Expenditures	Guava price USD 5,279 (463 CTNs*20kg*USD 0.57=5,279)
	Operation Cost 620 (9,260kg* USD 0.066= USD 620)
	Labeling 157.4 (463CTNs* USD 0.34=USD 157)
	Total 6,056

Total expenditures of DGs purchased and home delivery is USD 15,194.

6.2.2. Option 2: Kerry Logistics offered free distribution services.

The government announced the reference price for purchasing guavas from farmers to be USD 0.57. There is a total of 391 DGs (consisting of 35,014 people) in need of donated guavas. The logistics operation cost is estimated to be USD 0.067 per kg, and the labeling fee is USD 0.034 per unit. The total expenditures for this option are approximately USD 12,034, as presented in Table 5.

Table 5. Kerry Logistics offered free distribution services.

Total Demand	18,400 Kilogram (920 CTNs)
Expenditures	Guava price USD 10,448 (920 CTNs*20kg*USD 0.57=10,488)
	Operation Cost 1,233 (18,400kg* USD 0.067= USD 1,233)
	Labeling 313 (920 CTNs* USD 0.034=USD 313)
	Total 12,034

Compared these two options, total expenditures are USD 15,194 and 12,034 for options 1 and 2 respectively, the winner is option 2, and the gap (cost saving) is USD 3,160.

7 Discussion

The findings of this study accentuate the critical role of advanced demand information in optimizing the distribution of food donations. The unanimous endorsement from DGs, farmers, and 3PLs regarding the necessity for transparency in demand data underscores its importance in streamlining delivery routes and quantities, which potentially mitigates superfluous logistics efforts and leverages economies of scale. Home delivery, favored across all parties, emerges as a significant advancement in the distribution model, addressing key performance metrics of freshness, speed, and convenience. Yet, the persisting debate over fiscal responsibilities linked to transportation costs for home delivery indicates a need for a consensus-driven model to address cost-sharing mechanisms.

The preference for home delivery further signifies a paradigm shift in distribution towards more consumer-centric approaches that value direct and rapid access to goods. However, the divergent views on cost assumption highlight the complexities inherent in implementing such systems, where the benefits of efficiency and immediacy must be balanced against the economic viability and sustainability of the distribution network. This study contributes to this discourse by suggesting that the resolution of this contention is pivotal for the successful adoption of home delivery as the preferred mode of distribution.

8 Conclusion

This investigation set out to forge an innovative distribution model capable of enhancing social welfare while concurrently minimizing food waste, aligning with the United Nations' Sustainable Development Goal 12. The rigorous process of literature review, expert interviews, and integration of governmental measures culminated in the identification of three salient performance metrics and the development of eleven distribution alternatives via TRIZ methodology. The empirical assessment, including a real-data test, established a distribution framework that notably prioritizes government incentivization of 3PL voluntary services, supported by subsidies or tax incentives.

The advocated model not only fosters economic efficiency by reducing distribution costs but also endorses a socially responsible corporate ethos among 3PLs, potentially elevating their public image. The government's pivotal role extends beyond facilitation to regulation and oversight of the logistical and financial flows of food donations, where strategic partnerships with financial institutions can streamline subsidy and payment processes. The establishment of an online platform for the real-time disclosure of donation information is proposed as an essential component of this model, ensuring that DGs can seamlessly access donation data, and 3PLs can execute logistics tasks with enhanced precision.

Encouraging 3PL participation through sufficient incentives and societal advocacy for corporate social responsibility represents a holistic approach that integrates the strengths of public, private, and social sectors. This study underscores the significance of such collaborative efforts in reinforcing the sustainable management of food surplus and the realization of distribution models that are both efficient and equitable. The successful implementation of these recommendations is anticipated to have a positive impact on the reduction of food waste, fostering a more sustainable and responsible food distribution ecosystem.

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Appendix I the contradiction matrix

Deteriorated Attributes Improved Attributes	Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	…	Productivity
Weight of moving object			15,8, 29,34		29,1, 38,34	…	35,3 24,37
Weight of stationary object				10,1 29,35		…	1,28 15,35
Length of moving object	8,15, 29,34					…	14,4 28,29
Length of stationary object		35,2 40,29				…	30,1 7,26
Area of moving object	2,17, 29,4		14,15 16,4			…	10,2 34,2
…..	…	…	…	…	…	…	…
Productivity	35,2, 24,37	28,2, 15,3	18,4, 28,38	30,7, 14,26	10,2, 34,3	…	

Appendix II the 40 inventive principles

No	Principle	No	Principle	No	Principle
1	Segmentation	15	Dynamics	28	Mechanics substitution
2	Taking out	16	Partial or excessive action	29	Pneumatics and hydraulics
3	Local quality	17	Another dimension	30	Flexible shells and thin films
4	Asymmetry	18	Mechanical vibration	31	Porous materials
5	Merge	19	Periodic action	32	Color changes
6	Universality	20	Continuity of useful action	33	Homogeneity
7	Nesting	21	Skipping	34	Discarding and recovering
8	Anti-weight	22	Blessing in disguise	35	Parameter change
9	Preliminary anti-action	23	Feedback	36	Phase transition
10	Preliminary action	24	Intermediary	37	Thermal expansion
11	Beforehand cushioning	25	Self-service	38	Boosted interactions
12	Equipotentiality	26	Copying	39	Insert atmosphere
13	Inverse	27	Cheap short-living objects	40	Composite structure
14	Spheroidality				