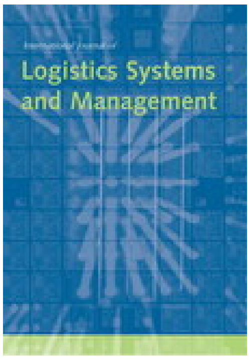

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Distribution system and logistics centres planning for agricultural products

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Abstract: This research starts from understanding the demand for agricultural logistics centres of the relevant agricultural entities to define such demand. Moreover, this study aims to employ scientific management methods to determine the appropriate number of regional agricultural logistics centres required to be established, as well as the classification of and cooperation modes for these logistics centres. We also introduce the concept of modern logistics and employ the mathematical planning result as a feasible major direction for adoption and integration into the current logistics system based on the current conditions of specific manufacturers. Furthermore, we recommend the coaching model in discussing the plan of establishing logistics centre systems in agricultural production areas from a realistic perspective.

Keywords: distribution system; logistics centres; agricultural products; modern logistics; mathematical planning.

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1 Introduction

Green fruit suppliers are farmers, farmer organisations (e.g., farmers' union and green fruit associations), traffickers, and importers, with farmers and farmers' organisations comprising over 70% of this group. Meanwhile, sellers include wholesalers, retailers, traffickers, large consumers (e.g., schools and institutions), exporters, and processing companies, with retail sales comprising 76% of this sector (AGRSTAT, 2016). Farmers, farmers' organisations, traffickers, and importers are also vegetable suppliers of vegetables. Although the total number of farmers and farmers' organisations comprises 55% of vegetable suppliers, this total is different from that of green fruit suppliers because traffickers comprise the majority of the latter. Vegetable sellers include wholesalers, traffickers, large consumers, processing companies, and a few exporters; the sale of vegetables is mainly based on the domestic market covering 64% (AGRSTAT, 2016). Moreover, the export amount is small because vegetables are difficult to preserve and transport compared with green fruits.

The Annual of Agricultural Product Wholesale Market, which is released by the Department of Agriculture (2013), reported that the top 5 regions (counties) that supply green fruits are Yilan County (13.8%), Hualien County (12%), Nantou (10.6%), Pingtung County (10.2%) and Miaoli County (9.4%). Meanwhile, the top 5 regions in terms of green fruit sales are Taipei City (25.7%), Taichung City (16.5%%), New Taipei City (13.8%), Kaohsiung City (11.1%) and Tainan City (7.4%) (Ru and Su, 1998).

The top 5 regions in terms of vegetable supply are Yinglin County (29.6%), Changhua County (18.9%), Chiayi County (9.9%), Pingtung County (9.2%) and Nantou County (8.35%). Meanwhile, the top 5 regions in terms of total vegetable sales are Taipei City (43%), Kaohsiung City (12.4%), Taichung City (8.1%), New Taipei City (6.3%) and Hsinchu City (4.4%).

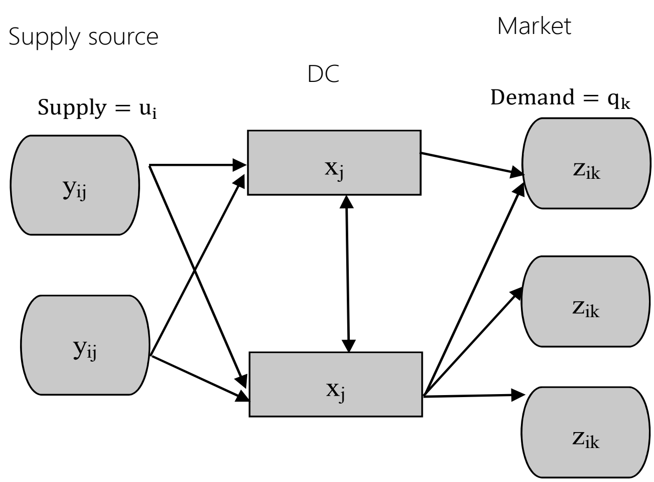
The preceding sets of statistics show that the supply and sales regions of green fruits and vegetables are significantly different from one another, and agricultural products have to be transported from the production regions to the consumer markets. Therefore, enhancing the efficiency of logistics in agriculture is crucial.

2 Model

This research considers different products (i.e., vegetables and fruits) and the total number of logistics centres in building and executing the transport models, as well as obtaining information on the appropriate number of agricultural logistics centres, their sizes, and scope of services. Initially, the ten high-speed stations are used as basis for location selection. However, the locations and number of logistics centres are eventually determined according to transportation cost.

Designing the logistics network and centres entails focusing on the functions of agricultural product circulation (Paksoy and Cavlak, 2011; Stock and Lambert, 2001). Agricultural product logistics and distribution centres bridge agricultural production and consumers, thereby enabling agricultural producers, suppliers, and distributors to integrate production, supply, and sales by sharing a platform. The seamless transition between these various aspects plays an important catalytic role in the transport of commodities. The domestic logistics system of agricultural products is modernising and has created a complete chain of production, purchase, processing, storage, handling, transport, distribution and sales. To enhance economic development and satisfy customer demand, a reasonable and highly efficient planning is necessary in increasing the flow of products that will gradually develop toward refined processing. Therefore, the logistics centres that have been established should not only satisfy the need for large quantity and variety, convenient transport, and independent operation of agricultural products but should also provide good conditions and methods for processing and value increase. Furthermore, the logistics and distribution centres of processed agricultural products should not only be characterised by distribution, connection, transport, storage, sorting, handling, transport, packing, and logistics information processing but should also have the value-added functions of payment settlement, demand forecasting, consulting in logistics system design, and logistics education and training. Therefore, conducting extensive research on the planning of logistics and distribution centres for agricultural products is necessary. Accordingly, the current study has built models for the analysis of actual problems to draw accurate conclusions.

Figure 1 The processes and symbols of fruits and vegetables being transported into and out of the logistics centres



The current model aims to minimise the total transportation cost of fruits, vegetables, and agricultural products in the province (Vernin et al., 1998). We have adopted a linear mixed integer planning to solve the problems on agricultural product distribution and sales networks. Figure 1 describes the processes and symbols of fruits and vegetables being transported into and out of the logistics centres. These processes are divided into three stages: the first stage involves the source of fruit and vegetable supplies, the second stage comprises the logistics centres in various administrative areas, and the third stage features the market demand terminal. In this model, y_{ij} refers to the amount of supply from the supply source i to the logistics centre j, z_{jk} refers to the extent of demand from the logistics centre j to the market demand terminal k, and d_{ij} refers to the distance between the various administrative regions i and logistics centres j.

Design of the model parameters

$i = 1 \ldots S$	the integration S formed by the supply sources in various administrative regions
$j = 1 \ldots D$	the integration D formed by the logistics centres
$k = 1 \ldots M$	the integration M formed by the demand points in various administrative regions
u_i	the supply of fruits and vegetables in the administrative region i (in tons)
q_k	the demand for fruits and vegetables in the administrative region k (in tons)
d_{ij}	the distance between the administrative region i and the logistics centre j (in km)
totalDC	the total number of logistics centres to be established, which can be unequal numbers from 1 to S in this model.

Design of the decision variables

x_j	to establish logistics centre j or not, where $x_j = 1$ represents the logistics centre that should be established in area j and $x_j = 0$ represents that the logistics centre will not be established
y_{ij}	the quantity supplied from the administrative region i to the logistics centre j
z_{ij}	the quantity supplied from the logistics centre j to the administrative region j.

Mathematical planning

- Target formula:

$$\sum_{i,j \in S,D} y_{ij} d_{ij} + \sum_{j,k \in D,M} z_{ij} d_{ij} \tag{1}$$

- Flow balance constraints:

$$\sum_{i \in S} y_{ij} = \sum_{k \in M} z_{jk}, \forall_j \in D \tag{2}$$

$$i_i = \sum_{j \in D} y_{ij}, \forall_i \in S \tag{3}$$

$$\text{totalDC} = \sum_{j \in D} x_j \tag{4}$$

- Supply constraints:

$$q_k \leq \sum_{j \in D} z_{jk}, \forall_k \in M \tag{5}$$

$$y_{ij} \leq x_j \times N, \forall_{ij} \in S, D \tag{6}$$

- Non-negative constraints:

$$u_i, q_k, d_{lj}, \text{totalDC}, y_{ij}, z_{ij} \geq 0 \quad (7)$$

- Binary constraints:

$$x_j \in \{0, 1\} \quad (8)$$

Formula (1) is the target formula of the mathematical planning that considers the minimised total transportation cost from the origin of production to the logistics centre, as well as from the logistics centre to the consumer markets. Constraint formulas (2) to (4) are flow conservation relational formulas. Constraint (2) is the quantity guaranteed from all supply sources to the logistics centre j = the total amount k delivered from the logistics centre j to all markets. Constraint (3) is the amount of supply from the administrative region i = the amount of supply from the supply sources i to all logistics centres j. Constraint (4) is the total number of logistics centres = the total number of logistics centres that used j.

Constraints (5) and (6) are constraints for which demand must be satisfied, thereby showing that the amount of demand q_k at the market terminal k should be satisfied by the amount from the logistics centre j to the market demand terminal k. Constraints (7) and (8) are the basic constraints of the variable range.

3 Analysis

We gathered the production statistics of agricultural products in various administrative regions from the agricultural statistics database (AGRSTAT, 2016) provided by the Council of Agriculture of the Executive Yuan. Accordingly, we obtained the production output of fruits and vegetables between 2011 and 2014. We also used the population statistics database of the Department of Population of the Interior Ministry to obtain the total population in various administrative regions.

The following factors are necessary for estimating the demand for fruits and vegetables to calculate the various values required by the model parameters:

1. Configuration of the administrative regions: The operational plan of the high-speed railway company assumed that population is dense near high-speed railway stations. Therefore, the administrative regions that should be covered by the logistics centres must be defined according to the stations along the high-speed railway. Accordingly, the administrative regions we have designated are Shuangbei, Taoyuan, Hsinchu, Miaoli, Taichung, Changhua, Yinglin, Chiayi, Tainan and Kaohsiung. Nankang, Taipei and Banqiao are in the same living circle and we have integrated them with Shuangbei.
2. Amount of fruit supply: To calculate the total fruit and vegetable productions in various administrative regions for 2014, we have obtained the specific vegetable and fruit productions in these regions from the agricultural statistics database of the Council of Agriculture.
3. Demand for vegetables and fruits: The Department of Health of the Executive Yuan recommended that every person needs three portions of vegetables and two portions of fruits (one portion is approximately 100 g) per day. Thus, the total amount of

vegetables and fruits required per year is obtained by multiplying the department's recommendation to the population of every administrative region as of the end of October 2015 (as published by the Department of Population of the Interior Ministry population statistics database).

4 Distance between various logistics centres: The logistics centres in the administrative regions are planned according to the high-speed railway stations plan in these regions. Therefore, the straight line distance that has been calculated between the railway stations is set as the distance between the logistics centres. To obtain consistent results in the analysis, this research presumes that the unit transportation cost for vegetables and fruits are the same because numerous varieties of these produce and their characteristics are different from one another.

5 Considering that the total DC number of logistics centres that may be established is undetermined, we intend to determine the most suitable number of centres to establish based on the current agricultural product logistics system of one logistics centre in every administrative region [Taipei and Banqiao (integrated) > Shuangbei].

We estimated the best locations for the logistics centres using three models according to the production of and demand for vegetables and fruits in various regions. The first model only considered vegetables, the second model only considered fruits, and the third model considered both vegetables and fruits.

The result of planning indicates that when vegetables are considered, the supply amount in Yinglin considerably exceeds those of the other counties and cities. By contrast, the demand of Shuangbei City substantially surpasses those of the other counties and cities. However, demand is distributed evenly in counties and cities with the second highest demand. The result of the optimised selection indicates that if only one vegetable logistics centre is built, then such centre should be built in Changhua. If two vegetable logistics centres are built, then they should be built in Changhua and Tainan. If three vegetable logistics centres are built, then they should be built in Shuangbei, Yinglin and Tainan. The locations of four vegetable logistics centres are considerably dense. Moreover, the locations of logistics centres should be near the production origin but also consider the shortest distance from the demand. Thus, Changhua is selected for one logistics centre, Changhua and Tainan for two centres, and Shuangbei, Yinglin and Tainan for three centres.

If only one vegetable logistics centre is built, then the vegetable supply of all counties and cities will pass through the logistics centre in Changhua; thus, its capacity should be at least 2,175,652 metric tons. If two vegetable logistics centres are built, then the vegetable supply of all counties and cities will pass through the logistics centres in Changhua and Tainan. However, the vegetables produced in the three counties in the south can supply the nearest logistics centre in Tainan and its capacity should be at least 510,645 metric tons. With regards to demand, the logistics centre in Changhua can supply most counties and cities, whereas the logistics centre in Tainan only needs to supply Tainan and Kaohsiung. The situation in Chayi is special because it connects with both regions while its productivity substantially exceeds the demand. Therefore, we recommend that the supply and demand should be through different logistics centres to achieve high efficiency. Transporting vegetables and fruits not only increases cost but also considerably damages these goods. Realistically, transporting these goods between the logistics centres is not considered. Instead, we consider the balance from the production origin, and that the goods are transported from the origin to the most appropriate logistics centres before they are distributed to the consumer markets.

If three vegetable logistics centres are built, then the vegetable supply from most counties and cities will pass through the logistics centre in Shuangbei; however, a limited amount will pass through the logistics centres in Yinglin and Tainan. Therefore, these centres' capacities should be at least 730,412, 934,594 and 510,645 metric tons, respectively (i.e., they are large, medium, and small logistics centres). Production in the north, as well as in Chiayi, is required because the demand of Shuangbei is larger than those of the other regions. A small percentage of Chiayi's entire production needs to supply the demand in the south, while the rest will enter the logistics centre in Yinglin. The production of the two counties in the south will enter the logistics centre in Tainan. Meanwhile, the logistics centre in Shuangbei supplies the demand of this region, whereas that in Yinglin supplies the demand of most counties and cities. The logistics centre in Tainan only needs to supply the two large cities in the south. If four or more logistics centres are established, then the distance between the logistics centres to be established in Tainan and Kaohsiung is substantially short; thus, establishing numerous logistics centre is no longer necessary.

In the second model, we only considered the configuration of fruit logistics system planning. With regard to the supply of fruits, the production of fruits in various counties and cities is equal to the production of vegetables except in the northern counties and cities. The amount of supply in Taichung and Tainan is more than those of in other counties and cities. The demand of Shuangbei considerably exceeds those of the other counties and cities, while that of Taichung and Tainan is also high. Although a logistics centre should be located near the production origin, the shortest distance from the demand locations is also considered. Therefore, Changhua has been selected. The result of the optimised selection indicates that if only one fruit logistics centre is built, then such centre should be built in Changhua, which is the same as the recommendation for vegetables. In selecting two logistics centres, locations near the production origin should be selected, but the shortest distance from the demand is also considered. If two fruit logistics centres are established, then they should be built in Taichung and Tainan; however, the recommendation of logistics centre in the north is different from that of vegetables. In selecting three fruit logistics centres, the distance of production and demand should be considered because this number is large. If three fruit logistics centres are established, then they should be built in Hsinchu, Yinglin and Tainan. Hsinchu is different because the production in Taichung is considerably high and the location should be further south. Under the premise of establishing three logistics centres in Taichung, these centres should not be established because Shuangbei is a major demand market. The selection of locations for four logistics centres is considerably dense; thus, the circumstance of four or more logistics centres is not considered.

If only one fruit logistics centre is built, then the fruit supply from all counties and cities will pass through the logistics centre in Changhua; thus, its capacity should be at least 1,745,541 metric tons. If only two fruit logistics centres are established, then the fruit supply of most counties and cities will pass through Taichung, whereas the production of the three southern counties and cities can supply the nearest logistics centre in Tainan. Therefore, its capacity should be at least 679,413 metric tons. With regard to demand, the logistics centre in Taichung can supply most counties and cities, whereas that in Tainan needs to supply Chiayi, Tainan and Kaohsiung. If three logistics centres are established, then the fruit supply to most counties and cities will pass through

Hsinchu, whereas a limited amount will pass through the logistics centres in Yinglin and Tainan. Therefore, the capacities of the three logistics centres should be at least 618,704, 452,288 and 674,610 metric tons, respectively (i.e., they are large, medium and small logistics centres). Production in the north is required because the demand of Shuangbei is considerably larger than those of the other regions. However, as production and demand are equal, the production origin only serves one logistics centre and does not need to acquire goods from other regions. With regard to demand, Shuangbei needs supplies from Hsinchu and Yinglin, and Chiayi needs goods from Yinglin and Tainan. When four or more logistics centres are established, the distance between the logistics centres in Tainan and Kaohsiung will considerably decrease; hence, establishing a fourth logistics centre is no longer necessary.

By considering the comprehensive supply system of fruits and vegetables, the supply of Yinglin substantially exceeds those of the other counties and cities. The demand of Shuangbei considerably exceeds those of the other cities, and the counties and cities with the second highest demand are the other two metropolis regions. The result of the optimised selection indicates that if only one comprehensive logistics centre is built, then it should be built in Changhua and the comprehensive supply of all counties and cities will pass through the logistics centre in Changhua. Thus, the capacity of this region should be at least 4,651,606 metric tons. If only two comprehensive logistics centres are built, then they should be built in Taichung and Tainan. The comprehensive supply of most counties and cities will pass through Taichung and the products of the three counties and cities in the south can be supplied by the nearest logistics centre in Tainan. Therefore, its capacity should be at least 1,255,871 metric tons. With regards to demand, the logistics centre in Taichung can provide supplies to most counties and cities, whereas that in Tainan only needs to supply Chiayi, Tainan and Kaohsiung. If three comprehensive logistics centres are built, then they should be built in Shuangbei, Yinglin and Tainan. If these three centres are built, then the comprehensive supply to most counties and cities will pass through the logistics centre in Shuangbei and a limited amount will pass through the logistics centres in Yinglin and Tainan. Therefore, their respective capacities should be at least 1,217,354, 1,587,789 and 1,116,051 metric tons, respectively, or they should be large logistics centres. Table 1 lists the comprehensive results. Production in the north is required because the demand of Shuangbei considerably exceeds those of the other regions. Most of the production of Changhua is supplied to the logistics centre in Shuangbei, whereas the rest is supplied to those in Yinglin. The logistics centre in Tainan only needs to supply the two metropolis regions in the south. With regard to administrative regions, the logistics centre in Shuangbei collects the production of both Changhua and the north, and only supplies the consumer markets in Shuangbei. The supply to the logistics centre in Yinglin is mainly based on the harvests in Yinglin and is supplemented by several products from the nearby Changhua and Chiayi regions, which are supplied to most counties and cities. Tainan and Kaohsiung are separate systems and do not collect goods from other regions because the production, supply, and demand are completed in Tainan; the two regions are separate from the other counties and cities. When four or more logistics centres are established, the distance between the logistics centres in Tainan and Kaohsiung will considerably decrease; thus, establishing a fourth logistics centre is no longer necessary.

Table 1 Results of the best transportation mode

Products	*Vegetables*	*Fruits*	*Comprehensive (vegetables and fruits)*
#DC = 1	Changhua (2,176)*	Changhua (1,746)	Changhua (4,652)
#DC = 2	Changhua (1,665), Tainan (511)	Taichung (1,067), Tainan (679)	Taichung (2,996), Tainan (1,256)
#DC = 3	Shaungbei (730), Yinglin (935), Tainan (511)	Hsinchu (619), Yinglin (452), Tainan (675)	Shuangbei (1,217), Yinglin (1,588), Tainan (1,116)

Note: Changhua (2,176)*: the best handling capacity of the Changhua logistics centre is 2,176.

4 Discussion

The increased cost and risks of agricultural products inventory has led to the emergence of scientific management as the best method for addressing the logistics system issues of modern agricultural production (Chen et al., 2018). The agricultural product flow process at various stages tends to increase the delivery efficiency and reduce inventory, thereby requiring replenishment on a timely basis (Chen and Chen, 2019). The pre-time for satisfying orders is considerably short, thereby requiring strict delivery time. The modern concept of logistics management does not merely depend on mathematical planning but also act according to local circumstances and recommend the best management mode based on the actual conditions of specific manufacturers. Therefore, we have determined a feasible major direction from the mathematical planning result. Moreover, we have adapted and integrated this information in the current logistics system to explore the planning of the logistics centre system in terms of the origin of agricultural products from a realistic perspective. This chapter aims to consider the different scales of large, medium, and small logistics centres of agricultural products and the results after the execution of the transport mode. This objective is combined with the demand of five dealers who intend to improve the logistics system to integrate it into the best agricultural logistics centre system.

Currently, the appropriate roles of the five agricultural entities that have been interviewed can be classified into large logistics centre, medium-sized regional distribution centre, and small regional goods collection centre. Therefore, Han Guang Fruit and Vegetable Production Cooperative can be classified as large logistics centre because of their comprehensive functions, numerous agricultural products processed, extensive services, and ownership of its logistics fleet. By contrast, Green Fruit Company (Hsinchu Branch) is classified as a small logistics centre because it only provides specific fruits in specific geographic areas, as well as delivers green fruits according to the orders after it has collected the goods. The other three companies, namely, Xiang He Fruits and Vegetables Production Cooperative, Xinhu Cooperation Farm, and Hualian City Farmers' Union, are classified as small logistics centres because they only provide service to specific areas, outsource logistics to other logistics companies, and own a few logistics vehicles although they have a few functions of logistics centres.

Currently, the agricultural logistics centre system in the province has problems not only with the size of factory buildings but also with functions and equipment. Under the current operational conditions, obtaining land to build the logistics centre is expensive and selecting the location is difficult as well. The integration of channels is also difficult and the attitude of the dealers should be adjusted. The combination of agricultural products must meet the market demand and the economic scale must be profitable. Moreover, the commodity flow must be standardised, the popularisation must be extended, and the communication environment must be stable. Modern management professionals must also have sufficient professional knowledge. Upstream and downstream industries must reach a common view to achieve overall optimisation as well (Ho et al., 2018). Considering the countermeasures from the macro perspective is required when facing various problems. Therefore, establishing a modern agricultural logistics centre requires the integration of homogeneous common distribution system of agricultural commodities to considerably increase the economic scale of input and output goods, promote the simplification and standardisation of processes, rapidly communicate the market information, master the sales pulse, and reduce the cost of business operation (Ghosh and Mondal, 2018).

The functions and equipment of agricultural logistics centres should be developed toward modernisation in terms of manufacturing, information, manpower saving, simplification, reasonability and automation. Thus, logistics centres should create a clean and safe working environment, as well as use computers to replace the workforce in processing large and complex data. Handling agricultural products should be combined with pallets, forklifts, and electric trailers for operation, as well as use simple management methods to achieve the management goal of first in-first out and sorting error control. This process should summarise the operation to be compiled into a standard operation, promote proposal improvement, obtain effective work proposal, and introduce automatic inventory, automatic order receiving, automatic sorting, and automatic delivery.

A modern agricultural logistics centre (whether large, medium, or small) must have an ambient or low-temperature tallying area that meets the standard. Storage needs appropriate cool warehouses for processing the products harvested during the year. In terms of cross-warehouse operation management, a conveyor belt sorting system is a necessary equipment toward modernisation. Therefore, automating agricultural product logistics necessitates three major systems, namely, electronic volume label, automatic classification and automatic warehousing systems.

1 Electronic volume label system: This system is also called computer-assisted picking or pick-by-light system, which is currently popular in the domestic market. The general uses of this system are classified as follows:

   a Picking type is mainly used for goods delivery that picks up the quantity of commodities from the storage positions.

   b Sowing type combines the same goods from different orders, collects the total amount of goods required by clients from the storage positions, loads them onto the transport vehicle, and then separate and pack them at the delivery area according to the different orders.

   In recent years, RFID-type electronic volume label is a novel technology that substitutes for pick-by-light. As different persons cannot distinguish for which goods collector the light is on, a goods collection area only allows the entry of one goods collector and the others must queue up to wait, thereby resulting in a bottleneck. If the goods collectors are equipped with RFID, then the bottleneck can be avoided.

2 Automatic classification system: This system is quite mature and stable. Combined with conveying belt automatic transport and barcode automatic identification systems, automatic goods collection and classification can be achieved, which has been used by many large distribution centres and frozen food companies for quite some time.

3 Automatic warehousing system: The process of warehousing equipment automatically completing the work of goods storage and collection is called automatic warehousing. The objective of automatic warehousing not only provides storage space for materials and products but also plays the role of integration. This system covers the functions of business, production, storage, and relevant engineering and management. Typically, an automatic warehousing system can be categorised as body structure, automatic storage and collection main unit, storage load unit, storage and collection temporary station, computerised control system and other accessory equipment. The body structure comprises the warehouse body, materials, and lighting, among others. The automatic storage and collection main unit is the centre of the storage and collection actions of the entire system; all operations depend on this main unit. The storage load unit comprises pallets and plastic containers, among others. The storage and temporary collection stations provide a buffer area for the main unit and accessory equipment. The computerised control system controls the storage and collection actions of the entire system, sequence of goods and material picking, and transmission and coordination of action signals. In addition, accessory equipment, including various conveying equipment and unmanned handling vehicles, is required.

The construction area of a large factory that processes refrigerated fresh vegetables and fruits should be larger than 1,000 square metres, which can be a multi-floor building. The first floor can be divided into the refrigeration machine room and packing and goods handling area. The machinery and equipment include a cutting machine, IQF fast freezing machine, packing conveying line and refrigeration room. The net height of the factory warehouse can be designed as 12 m and above, and the warehousing equipment can adopt the operational mode of pallet and flat rack combined with a narrow-path stacking machine. To reduce the interactive influence of ethylene and other gases on the vegetables and fruits, the low-temperature warehouse can be divided into several small closed chambers where the temperature is controlled between 0°C and 25°C. For a few small chambers, gas control can be adjusted according to the needs to extend the preservation time for numerous fresh vegetables and fruits. In addition, the delivery platform can be designed at a height of 1.3 m, and installed with a lifting platform, door seal and sliding door. The extended area on the second floor can be used as the rain shelter. The goods can be moved using the elevator and vertical lift or can be directly connected with the processing factory. The top of the goods handling area can be added with an attic used as administration office, meeting room, computer room, resting room, canteen, cloakroom, newsroom or classroom.

With regard to a fresh fruit and vegetable logistics centre with area below 1,000 m^2, a multi-floor building can be added with the construction area. Attention should be paid that the lift can be a bottleneck for operation. According to the law, a small section of the packing and goods handling area and the goods input and output buffer area can be shared. If a refrigeration equipment cannot be built, then the holding time of goods should be decreased to reduce the losses of fresh fruits and vegetables. If only green fruits are processed, then a small logistics centre could be built and the existing facilities could be used to achieve the highest efficiency.

In addition to the transition and goods collection functions, agricultural product logistics centres also include logistics processing, such as the operation of fresh fruit and vegetable cutting. This process includes cutting the fresh vegetables and fruits; refrigerating and drying them; performing the operations of pre-cooling, refrigeration, temporary storage, and material storage at the factory; and delivering them to the contractual factories for processing before they are returned to the cutting factory for final cutting, cooling, and drying processes. Having confirmed the orders, the goods are delivered to the domestic distributors or dealers, chain supermarkets, or large stores or average consumers.

The treatment technologies of fruits and vegetables in the cold chain logistics centre include pressure differential pre-cooling, which refers to an improved indoor air-cooling method. This method is commonly applied to fruits, vegetables, and cut flowers, and uses extractors to create pressure differential on both sides of the packaging carton. Cool air enters the packaging carton from one side to be in contact with the commodities and eliminates the hot air directly, thereby immediately reducing the temperature of the goods within a short period of time. Vacuum pre-cooling refers to placing fresh vegetables in a sealed container and the air and vapours are rapidly extracted. With the decrease of pressure, the vegetables are cooled because of the rapid moisture evaporation. The fruit and vegetable air-regulated warehouse refers to a building that preserves goods through the manned regulation of air, temperature and moisture.

The operational procedures of fruit and vegetable cold chain logistics centres have defined that every packaging should clearly list (i.e., the markings should be clear, complete and correct) the following information on the commodities: commodity name, standard number, trademark, name, address, and phone number of the manufacturer, specifications (grade), weight (net volume), preservation conditions and expiration date.

The warehouse for fruits and vegetables should be equipped with temperature measurement and monitoring systems, among others. Maintenance and calibration should be conducted at least once a year. The warehouse should also be installed with temperature alarm, emergency alarm, escape, and emergency power supply systems. Furthermore, the warehouse should be free from frost, wetness, mess, and ardours; and should be cleaned and maintained orderly every day. The warehouse should also be disinfected and the air be ventilated often and in real time. Prior to entry, the temperature of the warehouse should be pre-adjusted to the temperature of goods storage or lower than the goods storage requirement. When the goods are stored in an air-regulated warehouse, the warehouse door should be closed. All lamps used should adopt the explosion-proof safe lighting system to prevent breaking. The warehousing area should have a power generator in case of power failure. The other rules of the warehouse should comply with the requirements of operational procedures. Agricultural products should be pre-treated prior to entry into the warehouse, and the fruits and vegetables that require preservation for a long time should be pre-cooled.

Various fresh vegetables can be pre-cooled with water, indoor, vacuum, and pressure differential pre-cooling methods, among others, depending on the types of vegetables. Fresh fruits should not undergo water and vacuum pre-cooling techniques to prevent rotting or loss of moisture for the fruits. The pre-cooling temperature should be selected according to the types of fruits and vegetables; most products, including several chilling-sensitive products, can be pre-cooled to appropriate storage temperature. The pre-cooling point should be set above the chilling temperature. Pre-cooled fruits and vegetables should be immediately placed inside the warehouse to prevent temperature increase. The temperature and moisture parameters of the warehouse should comply with the fruit and vegetable storage requirements.

Attention should also be given to air ventilation during the storage and placement of goods in the warehouse. Goods should be stored separately according to products, specifications, production origin, maturity and processing status. Moreover, goods should not be mixed with hazardous, toxic, corroding and polluting substances. Fruits that can easily cause cross-contamination should be stored separately and labelled properly. During storage, appropriate air ventilation is required to eliminate ethylene and hazardous gases. Space is also required between pallets for cool air circulation to maintain the required temperature. Goods should not be stored in close contact with walls, roof, or floor, and they should be at least 10 cm off the floor. Moreover, the conditions of the fruits and vegetables stored in the warehouse should be checked twice per week, and unqualified goods should be immediately removed to prevent cross-contamination. During storage, frequent opening or moving of the packaging should be avoided. After the goods have been placed inside the warehouse, the position labels and plane maps of these goods should be used for convenient tracking and management. Gangways should be saved for the sample checking of goods.

Complete records for the goods stored in the warehouse are required. Temperature and moisture control methods and standards should be designed, and the records should be checked at all times and when necessary. The warehouse should have a stock record and the goods shipped out of the factory should be recorded, including but not limited to batch numbers, delivery time, location, objects, and quantity, for convenient product recall in case of problems. Every batch of goods should have inspection records, and all records should be preserved for a period of one year until the expiration date.

When the goods issued from the warehouse are loaded into the transport vehicles, the process should follow the first in–first out rule and records should be made immediately. Any operations at the loading operation area should comply with the temperature of the goods preservation or should be conducted in an area where the temperature is below 15°C to prevent temperature increase and the generation of condensed water. During handling, the transport and distribution of fruits and vegetables, as well as their temperature, should comply with control standards.

During transport, the cabin of the transport vehicles should be equipped with temperature sensors and automatic temperature recorder. The transport vehicles should be equipped with rainproof and dust-proof equipment, as well as temperature, moisture, and freshness-preservation equipment according to the characteristics and hygiene requirements of different fruits and vegetables. The transport vehicles should have good insulation effect and can be tightly closed. Its interior structure should enable the even distribution of cool air temperature and the external structure should be able to reflect solar radiation heat. When the vehicle door is open, the loss of cool air and heat penetration should be reduced to the minimum. Moreover, the transport vehicle should be installed with appropriate leakage prevention facilities to prevent leakage of cool air and entry of heat. The inner walls of the vehicle cabin should have cool air circulation channels to ensure air circulation. Maintenance and inspection system for the transport vehicles and vehicle cabins should be set once every six months at the transition of seasons to ensure the good operation of equipment. The other transport vehicles should also comply with the technical requirements of transport vehicles.

With regard to process at the fruit and vegetable cold chain logistics centre, CAS has designed a standard for the production process of fresh cut fruits and vegetables. These goods refer to various types of vegetables and fruits that are packaged after collection, sorting, cleaning, cutting and centrifugal dehydration. Fresh cut fruits and vegetables are supplied for further processing or for direct consumption. According to the characteristics of products, the peeled vegetables and fruits that have not been cut will only be removed with the base. The CAS fresh cut vegetables and fruits have the following features:

1. High quality: High quality produce considerably preserves freshness. Cut fruits and vegetables are those harvested from the farmland, which have been vacuum pre-cooled and treated to preserve the high quality of these produce. These goods are temporarily stored in a refrigerated storeroom to preserve and maintain their freshness.
2. Food health concept: During the initial processing, fresh cut vegetables and fruits will be pre-cooled after harvest after insects and back materials have been removed. These goods are cleaned using cold water (i.e., below 4°C) to preserve their nutrition and vitamins, as well as the life cycle of their freshness.
3. Hygiene and safety: The fresh cut vegetables and fruits selected for processing are qualified agricultural products harvested from certified farmlands and free from pesticides. The production origin requires documents regarding the use of pesticides and chemical fertilisers to meet safe harvest standards.
4. No problem of waste treatment: Wastes have been removed from fresh cut vegetables and fruits during the initial processing. The products provided can be directly supplied for further processing, while the agricultural wastes are left at the production origin, thereby saving treatment time and adhering to the concept of environmental protection.
5. Rich in dietary content and quality: Fresh cut vegetables and fruits are tasty and of high quality. However, they are also seasonal vegetables and fruits harvested from farmlands and have been provided through the cooperation of farms and cooperatives. Accordingly, the variety of agricultural products is extensive, nutrient content is varied, and the quality can be upgraded because they have been harvested from different farmlands.

The physiological and metabolic mechanisms of the produce still continue after harvesting, thereby accelerating the aging process of these goods, particularly after the completion of the cutting process. Accordingly, the quality deteriorates rapidly, thereby shortening the preservation period for the cut products. Therefore, the production of cut vegetables and fruits is different from the normal manufacturing industry that only guarantees a lack of raw materials shortage. The processing of fresh cut products should consider the raw materials and freshness. This process typically adopts the mode of production after receiving orders to prevent the loss of materials and finished products caused by excessive materials or overstock.

Table 2 Execution results and cases of the best transportation models

	DC number	*Counties and cities*	*Processing amount*	*DC large, medium and small*	*Cases*
Vegetables	n = 1	Changhua	2,176	Large	Han Guang Fruit and Vegetable Production Cooperative
	n = 2	Changhua	1,665	Large	Han Guang Fruit and Vegetable Production Cooperative
		Tainan	511	Medium	Xinhu Cooperation Farm
	n = 3	Shuangbei	730	Medium	Xiang He Fruit and Vegetable Production Cooperative
		Yinglin	935	Medium	Xinhu Cooperation Farm
		Tainan	511	Medium	Xinhu Cooperation Farm
Fruits	n = 1	Changhua	1,746	Large	Han Guang Fruit and Vegetable Production Cooperative
	n = 2	Taichung	1,067	Large	Nil*
		Tainan	679	Medium	Xinhu Cooperation Farm
	n = 3	Hsinchu	619	Medium	Xiang He Fruit and Vegetable Production Cooperative
		Yinglin	452	Medium	Xinhu Cooperation Farm
		Tainan	675	Medium	Xinhu Cooperation Farm
Comprehensive (fruits and vegetables)	n = 1	Changhua	4,652	Large	Han Guang Fruit and Vegetable Production Cooperative
	n = 2	Taichung	2,996	Large	Nil
		Tainan	1,256	Large	Han Guang Fruit and Vegetable Production Cooperative
	n = 3	Shuangbei	1,217	Large	Nil
		Yinglin	1,588	Large	Han Guang Fruit and Vegetable Production Cooperative
		Tainan	1,116	Large	Han Guang Fruit and Vegetable Production Cooperative

Note: Nil*, * shows that no dealer currently intends to invest in building a large agricultural logistics centre.

We integrated the mathematical planning results in implementing the logistics system according to the supply and demand of vegetables and fruits in various administrative regions. The result of the optimised selection indicates that two of the three logistics centres should be established in Yinglin and Tainan. The positions of vegetables and fruits for the third logistics centre are different. The demand of Shuangbei for vegetables considerably exceeds those of the other counties and cities; thus, the vegetable logistics centre should be established in Shuangbei. The fruit logistics centre should be established in Hsinchu because the production of Taichung is considerably high and the demand of Shuangbei is still the highest. Therefore, the location should be further south and a fruit logistics distribution centre should be established in Hsinchu to achieve the minimum cost. If the two logistics centres in Yinglin comprehensively process both vegetables and fruits, then these two logistics centres should be large to process all flows. If they process separately, then Yinglin and Tainan need to establish large and small logistics centres for vegetables. Yinglin and Tainan needs to establish medium and small logistics centres for fruits. If they process separately, then the vegetable and fruit logistics centres in Shuangbei and Hsinchu, respectively, should be medium-sized logistics centres. Table 2 lists the transportation model results and cases.

5 Conclusions

Through data collection and interviews, this research has further understood the demand for agricultural logistics centres by agricultural entities. Accordingly, Han Guang Fruit and Vegetable Production Cooperative need to establish the operational mode of cross-warehouse logistics centre. Xinhu Cooperation Farm needs to improve the platform equipment of the shipping dock. Xiang He Fruit and Vegetable Production Cooperative are optimistic in building a vegetable cool storage centre. Fruit distribution branch hopes to improve the processes of goods collection yard. The Farmers' Union of Hualian City is optimistic in introducing modern operational coaching. The optimised selection results indicate that we have determined that the suitable number of agricultural logistics centres to establish is 3, and 2 of them should be established in Yinglin and Tainan whether for vegetables or fruits. Shuangbei and Hsinchu should establish medium and small logistics centres, respectively, to process vegetables and fruits.

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