Choosing a Distribution Center to Improve the Vietnamese Fruit and Vegetable Supply Chain by the Hybrid Applied Mathematical Optimization and SAW

Kieu Phan (phanthuykieu2006@yahoo.com.vn)
HCMC International University https://orcid.org/0000-0001-9008-097X
Phong Ho
Hong Bang University International

Research article

Keywords: Distribution center, Mixed integer programming, Simple Additive Weighting - SAW, Supply chain, Vietnam

Posted Date: December 28th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-129795/v1

Choosing a distribution center to improve the Vietnamese fruit and vegetable supply chain by the hybrid applied Mathematical optimization and SAW

Kieu Phan[1], Phong Ho[2]

Abstract

In the current market economic conditions, the distribution center plays an important role in the the supply chain's operation, especially when the fruit and vegetable supply chains in Vietnam still do not have a suitable distribution center, leading to high arrival costs and slow shipping times. Therefore, researching and proposing a model to locate distribution centers, contributing to cost reduction of the fruit and vegetable supply chain is a crucial issue in Vietnam today. Therefore, using many survey methods such as in-depth interview, focus groups, face-to-face to collect a total of 439 samples in Vinh Long province, as well as secondary data from new articles, studies, research articles, other authentic sources directing the administration of provincial statistical management and yearbooks for analyzing the sweet potato supply chain in Vinh Long province of the Mekong Delta region. First, this study used mixed-integer linear programming and compromised programming based on IBM CPLEX Optimizer to choose a distribution center when trading-off between cost and transport time. Secondly, Simple Additive Weighting (SAW) for decision support based on excel software from the results of experts' answering to increase the objectivity for determining the location of the Distribution Center as well as in accordance with both the actual situation and the comprehensive development of local socio-economy. The contribution of proposing the mathematical model is to choose a suitable place for saving costs and reducing transport times. In additon, this approach method could be applied to other Vietnamese agri-fresh products for upgrading the competitiveness, compared with other countries' agricultural products in terms of price and quality so far.

Key words: Distribution center, Mixed integer programming, Simple Additive Weighting - SAW, Supply chain, Vietnam

1. Introduction

Vietnamese vegetables and fruits are agri-fresh produce [1], with the advantages of natural conditions, are having great opportunities when many Vietnamese vegetables and fruits, together with the advantages of natural conditions, are having great opportunities when many signed free trade agreements (FTAs), especially both the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), the European-Vietnam Free Trade Agreement (EVFTA), and Regional Comprehensive Economic Partnership (RCEP) come into effect, helping Vietnam vegetables and fruits to expand their way into markets with large scale and strong consumption. However, Vietnamese fruits and vegetables are also facing significant challenges from trading competition among producing countries, technical barriers from importing countries, especially

[1] Corresponde: phanthuykieu2006@gmail.com. PhD. Candidate - School of Business, International University, Vietnam National University, HCMC.

[2] Assoc. Prof Ho Thanh Phong, my Advisor, President– Hong Bang International University, HCMC, email: phonght@gmail.com

requirements of quarantine, safety, and prices, due to the influence of time, environmental conditions, seasonality [2]. To the extend of the authors' knowledge, up to now few studies have been published in regards to the huge wasted agri-fresh produce in various operational stages of agri-fresh supply chain management (AFSCM) caused by inefficiencies in storage, handling and transportation [3], which also has inspired us to work on it to help solve issues.

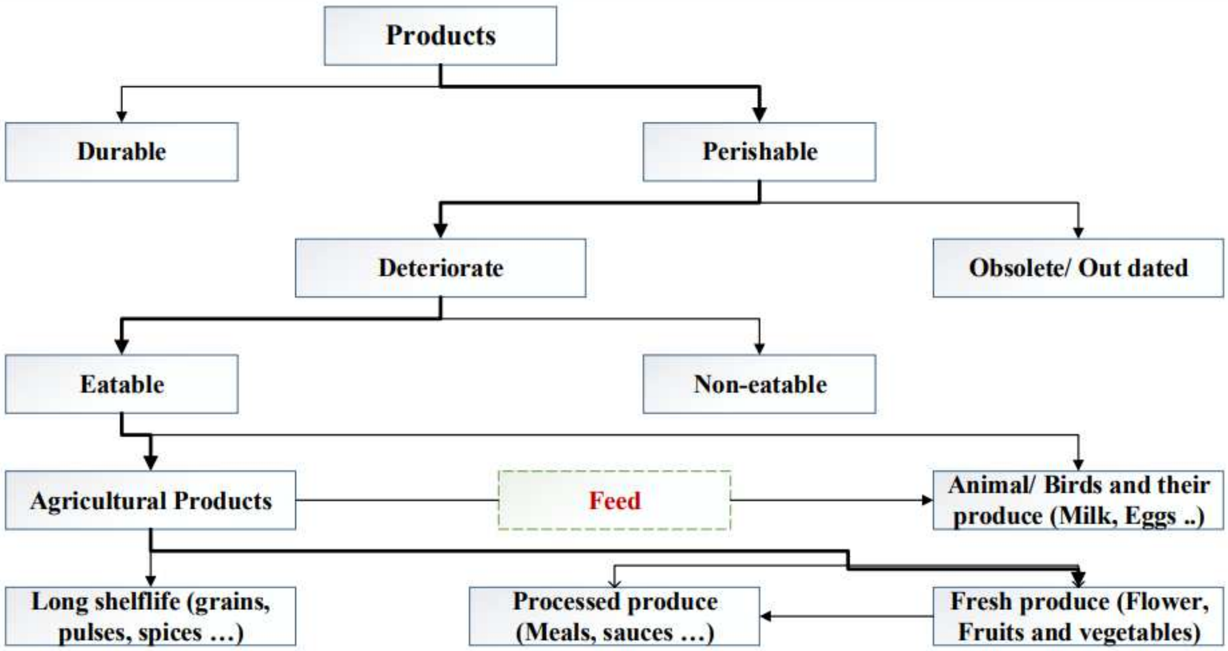

Figure 1. Product differentiation, adapted from Shukla and Jharkharia (2013)

In the world, the supply chain is not a new concept, but in Vietnam, it is still quite new, unfamiliar, especially the supply chain of agricultural products due to the hierarchy of distinguished decision-making process in strategic, tactical, and operational, which directly defines insight supply chain [4]. The supply chain is an integrated network of production and distribution options that perform the functions of purchasing raw materials, converting materials into selling products, finished products and distributing them to customers [5], [6] or a complex network of facilities, with associated decision-makers, engaged in such essential operations as production/manufacturing, storage, and the distribution of products to demand markets [6], [7]. Beisde, Chopra and Meindl define supply chains including all stages related, directly or indirectly, to meet customer needs. They argue that the supply chain includes not only manufacturers and suppliers, but also shipping providers, warehousing, retailers and customers themselves [8]. To be specific, choosing the right distribution center location can reduce logistics costs, thereby improving delivery efficiency and improving customer satisfaction. Site selection using both qualitative and quantitative methods due to site decision making is in fact a very complex issue including the determination of the number of sites, the size of the site and the appropriateness of the local overall social- economic development direction [9]. That is why borned the field of supply chain management (SCM) to control the flow of information, products, and services across a network of customers, enterprises, and supply chain partners. Moreover, SCM encompasses three decision levels: strategic, tactical and operational [10]. According to Simchi-Levi et al, SCM is the efficient integration of suppliers, factories, warehouses, and stores, so that merchandise is produced in the right quantities and distributed to the right location at the right time, so as to minimize total system cost while satisfying service requirements whereas value chains focus more on value creation, innovation, product development, and marketing [11].

In Vietnam, both enterprises and and policy makers do not fully understand the special importance of the supply chain in today's globally competitive environment. Establishing an appropriate supply chain is a vital issue for every business and industry, it is necessary to identify and promote the role of each stage to maintain sustainability, improve competitiveness, expand market share, and reduce costs, take initiative in production and trading. Any agricultural supply chain needs a distribution center. Therefore, this article focuses on choosing a distribution center for agricultural product supply chain in Vietnam, to reduce costs and improve transporting times, benefit partners, especially farmers' income. It also provides operational flexibility to cope with high levels of uncertainty in demand and achieve sustainable development goals.

The purpose of this paper is to choose the best solution for determining a distribution center when trading-off between total cost and transportation time by applying mathematical optimization technique, simulation model in the strategic planning, and multi-criteria decision-making technique. The rest of the paper is organized as follows. The related literature is reviewed in Part two. The third section is the methodology approach. Next to present the typical case study from the structure of the current sweet potato supply chain and the proposed modern one to describe a new distribution network design by application of optimization technique and simulation and SAW. The paper ends with some conclusions. The contribution of proposing the mathematical model is to choose a suitable place for saving costs and reducing transport times. In additon, this approach method could be applied to other Vietnamese agri-fresh products for upgrading the competitiveness, compared with other countries' agricultural products in terms of price and quality so far.

2. Literature review related agri-fresh produce supply chain

While *producing perishable goods* is vital to satisfying the growing global demand for food, Amorim et al. declare SCM of agri-fresh produce is equally crucial from delivering goods to the market at the right time with the minimum loss of food quantities and qualities, i.e. perishability may occur in one or more stages across the chain from the extremely short process to transportation times [12], [13]. Particularly, paid attention to the consumer satisfaction and revenue maximization with post- harvest waste reduction as a secondary objective. The product- problem- methodology mapping may serve as a framework for the managers addressing issues in FSCM [4], [14], [15].

Other characteristics, such as seasonality of agriculture production [16], [17], long supply lead times [18], [19], uncertainty in harvest time due to unpredictable weather conditions [16], [20], and relating to preserving freshness and product quality, it requires more limited delivery deadlines, more controlled storage conditions, better quality of end-products and minimum losses due to deterioration [21], [22], all of these features make more complex and harder to manage than other supply chains [23]. As a result, the operational research approaches to balancing agri-fresh produce supply chain (APSC) attract considerable interest of researchers as a mechanism to generate management efficiency through the use of modern decision technology tools, especiallly on designing and managing agri-fresh produce supply chains, although there is a significant level of inconsistency and confusion in segmenting fruits, flowers, and vegetables [22]–[26].

In perpective of supply chain management, spanning all movements and storage of raw materials, work-in-process inventory, and finished goods from the point-of-origin to the point-of-consumption [14], including coordination and collaboration with channel partners who may be suppliers, intermediaries, third-party service providers, or customers [15], integrating supply and demand management within and across companies [16]. Lowe and Prackel review the literature on applications of decision technology tools for a selected set of agribusiness problems in crop planning, which calls for more research into solving these problems. When engaging in a pioneering review of planning models relating to the production and distribution of the agri-food supply chains [19]. Additionally, Akkerman et al. declare food distribution networks management is receiving more and more attention, reviewed quantitative operations management in terms of food quality, food safety, and sustainability. The authors also discuss on three decision levels: strategic network design, tactical network planning, and operational transportation planning [27]. More recently, Zhang and Wilhelm provide growers and distribution managers' insights into the variety of possible decision support and benchmarks for improvements in the specialty crops industry, including vegetables, fruits, grapes and wine, ornamentals, tree nuts, berries and dried fruits [28]. Meanwhile, Lehmann et al. present three cases covering agriculture, logistics and food awareness to overview on technology, information content, information organization, and communication and assure the successful utilization of the potential of the future developments of Internet [29]. Furthermore, Tsolakis et al. offer an integrated hierarchical decision-making framework for the design and planning of agri-food supply chain management [30], while Paam et al. look into the optimization of agri-fresh food supply chains, with focussing on the loss minimization in the F&V supply chains [30]. Lastly, in terms of food waste, Raak et al point out causes of processing and product-related food waste, especially new insights from expert interviews [31] whereas Balaji and Arshinder identify 16 causes of food wastage in the Indian fruits and vegetables supply chain [32].

Focused on design the distribution center and supply chain network design, introducing strategies and supply chain models of food, fresh agricultural products, managing risks in the chain, defining innovation models of information, engineering and business process [9], [10]; determining the location of facilities in supply chain design network effectively is a crucial decision, be connected in detail logistics activities such as vehicle routing, inventory management, robustness and reliability [33]; using bullwhip effect in the supply chain network on demand in a treamlined theory [12]; analyzing workloads, providing recommendations on how to plan for productivity, planning the investment capital by applying simulation model [13]. Besides, Beamon reviews the literature in the area of multi-stage supply chain design and analysis with a view to developing a research agenda that may serve as a basis for future supply chain research [34] while Shen summarizes recent developments in the area of integrated supply chain design in which the decision maker needs to take inventory costs and distribution costs into consideration when determining the locations of the facilities [35]. Mentioned specifically to design agri-food supply chains under uncertainty by mathematical programming models, Esteso et al. build conceptual framework in the literature as a guide tool for both developing and analysing models based on mathematical programming to design agri-food supply chain [36], whereas Patidar et al. develop novel strategies for designing sustainable Indian agri-fresh food supply chain by incorporating SWOT into TOWS matrix [37].

3. Mathematical Formulation as a multi-objective model: Model description

3.1. Characteristics

Characteristics should be considered in supply chain network design problems by using mathematical model, particularly for agriculture products:

(1) Product: the model is designed to be able to find solutions for the system to solve the supply chain problem of many kinds of different types of agricultural products that can create a space to expand scale, development of the supply chain and logistics system later.

(2) Transportation: the model can find solutions in multimodal transport conditions, focusing on roadway and waterway transport.

(3) **Time**: most of activities including cultivation, harvesting, transportation, and trading agricultural products are affected by seasonal factors and cyclical changes in market demand, especially in China. So, the mathematical model should take the parameters, the decision variable to carry the function of the time element.

(4) Flexibility: the optimal model uses compromise programming method in helping to support multi-objective decision making that is more flexible based on a set of changes in priority between optimal goals.

3.2. The indices, input parameters, cost function components, and decision variables

Indices to formulate the concerned supply chain network design problem:

Table 1. Notation of the mathematical model

No.	Notation	Set Name
1	P	Set of products
2	R	Set of market
3	H	Set of potential distribution center
4	S	Set of plant
5	L	Set of periods
6	T	Set if transportation mode
7	(i, j)	Set of arcs
8	Z	Set of routes

Parameters to formulate the concerned supply chain network design problem:

Table 2. Parameters of the mathematical model

No.	Notation	Description
1	CAP_{sp}	Supply capacity of plant s^{th} for products p^{th}
2	$CAPC_p$	Production cost of product p^{th}
3	FC_h	Fixed cost for building warehouse h^{th}
4	cs	Inventory cost of product p^{th}
5	D_{rpl}	Demand of market r^{th} for product p^{th}
6	QRP_p	“Quality reduction point” of product p^{th}
7	sl_p	“Shelf life” product p^{th}
8	tc_z	Transportation cost of route z^{th}
9	ts	Average inventory time of product p^{th}
10	tt_z	Transportation time of route z^{th}
11	DI_{tij}	Distance from i^{th} to j^{th} when using transporter t^{th}

12	φ_{zp}	Function of diminished quality of product p[th] for route z[th]
13	$\alpha(DI_{tij})$	Function of transportation cost with respect to distance
14	$\beta(DI_{tij})$	Function of transportation time with respect to distance
15	$G1$	Optimal value of objective 1: transportation cost
16	$G2$	Optimal value of objective 2: transportation time

Decision variables to formulate the concerned supply chain network design problem:

Table 3. Decision variables of the mathematical model

No.	Notation	Description
1	X_{zpl}	Quantity of product p[th] is transported by route z[th] at period l[th]
2	Y_{spl}	Quantity of product p[th] is harvested in plant s[th] at period l[th]
3	Q_h	1, if the DC is located at potential DC h[th], otherwise 0

As mentioned above, some parameters have the direct values from the collected data, while others are special parameters that need to be processed and pre-computed as the quality loss function of the product (φ_{zp}). According to the research of Osval and Stirn [38], this parameter is calculated based on:

$$\varphi_{zp} = min\left(\frac{1}{QRP_p} * \left(\frac{sl_p - tt_{zp}}{sl_p}\right), 1\right)$$

The cost of transport by inland waterways is approximately 10 times lower than that of road [22]. Since then, the above functions are presented in table below:

Table 4. Function of transportation cost unit

Notation	Unit	Transportation mode	
		Roadway	Waterway
$\alpha(DI_{tjk})$	VND/ton	1023 * DI_{tij}	102,3 * DI_{tij}
$\gamma(DI_{tij})$	Hours	$\frac{DI_{tij}}{Average\ velocity\ in\ roadway}$	$\frac{DI_{tij}}{Average\ velocity\ in\ waterway}$

3.3. Mathematical model

3.3.1. Objective 1: Minimize total cost

Economic efficiency is one of the most consideration in supply chain network design. In this case, the logistics cost includes cultivation costs, fixed investment costs. So, the total cost is shown in equation (1).

$$Minimize \sum_z \sum_p \sum_l \left(\left(tc_{zp} X_{zpl} \right) + CAPC_p X_{zpl} (1 - \varphi_{zp}) \right) + \sum_h (Q_h FC_h) \qquad \textbf{(1)}$$

3.3.2. Objective 2: Minimize transportation time

For agriculture products, particularly sweet potato, previous studies also aim to minimize the total transportation time from the planting area to the warehouse, fixed storage time at the warehouse and transported to the market as equation (2):

$$Minimize\ \frac{\sum_z \sum_p \sum_l \left(tt_z X_{zpl}\right)}{\sum_r \sum_p \sum_l D_{rpl}} \quad \textbf{(2)}$$

Constraints

$$\sum_{z \epsilon U_s} X_{zpl} \leq Y_{spl} \qquad \forall\ s, p, l\ and\ U_s = \{z: a_z = s\} \quad \textbf{(3)}$$

$$\sum_{l \in L} Y_{spl} \leq CAP_{sp} \qquad \forall s, p \quad \textbf{(4)}$$

$$\sum_{z \in O_r} X_{zpl} \varphi_{zp} = D_{rpl} \qquad \forall\ r, p, l\ and\ O_r = \{z: b_z = r\} \quad \textbf{(5)}$$

$$\sum_{p \in P,\ z \in K_h} X_{zpl} \leq Q_h \qquad \forall\ h, z\ and\ K_h = \{z: c_z = h\} \quad \textbf{(6)}$$

$$X_{zpl}, Y_{spl} \geq 0 \qquad \forall\ s, z, p, l \quad \textbf{(7)}$$

Equation (3) aims to ensure that the amount of product is shipped from each plant does not exceed the amount of harvesting in this plant during a certain period. Equation (4) ensures that the quantity of harvested product in a plant at a certain period does not exceed the supply capacity of that plant. Equation (5) ensures that the demand in markets is adapted. Equation (6) ensures that the products only are incurred on the routes used supply chain network.

3.4. Simple Additive Weighting (SAW) For Decision Support

There are several identified Multi-criteria decision-making methods, such as Analytic Hierarchy Process; Fuzzy Set Theory; Data Envelopment Analysis; Goal Programming; Simple Additive Weighting and so on. This reseach use SAW for decision support, where SAW is known as the weighted sum method, which means finding total weights of the performance on each alternative on each attribute. SAW method proposes to complete the resolution in the decision-making system of multi-process, widely used in making decisions that have a lot of attributes. Obviously, SAW help to ease on decision support systems [39].

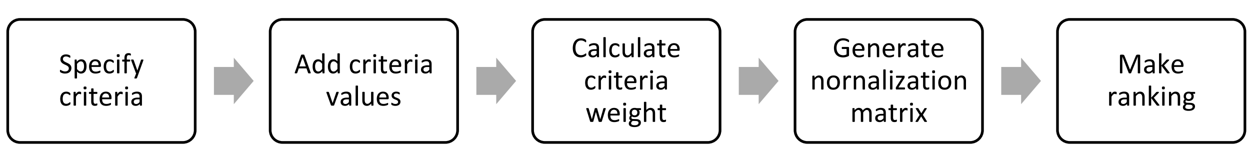

Figure 2: Simple additive weighting diagram

Source: [39]

SAW method requires a process of normalizing the decision matrix (A) to a scale that can be compared with all the ratings of existing alternatives.

$$r_{ij} = \frac{a_{ij}}{Max(a_{ij})} \quad \mathbf{(1)} \quad if \text{ j are benefit attribute}$$

$$r_{ij} = \frac{Min(a_{ij})}{a_{ij}} \quad \mathbf{(2)} \quad \text{if j is cost attribute}$$

Information:

r_{ij} = normalized performance rating value

a_{ij} = attribute value owned by each criterion

$Max(a_{ij})$ = the largest value of each criterion

$Min(a_{ij})$ = the smallest value of each criterion

$Benefit$ = if the greatest value is best

$Cost$ = if the smallest value is best

Where:

$\mathbf{r_{ij}}$ as the normalized performance rating of alternative $\boldsymbol{C_i}$ *on attribute* $\boldsymbol{D_j}$;

$\mathbf{i}$ = 1,2, … , m

$\mathbf{j}$ = 1,2, … , n

Preference value for each alternative (V_i), the funtion as equation below:

$$V_i = \sum_{j=1}^{n} W_j r_{ij} \qquad \mathbf{(3)}$$

Information:

V_i = ranking for each alternative

W_j = weighted value of each criterion

r_{ij} = normalized performance rating value

C larger value of V_i indicates that $\mathbf{C_i'}$s alternatives are preferred

4. Case study

4.1. Background sweet potato in Vinh Long Province

This paper focus on yams, planted in Vinh Long Province, Mekong Delta of Vietnam in which remains the most rural areas with highly fertile land and an abundance of freshwater as the typical case to study. To be specific, there are five main challenges, including: (1) Most small-scale growers who have fragmented land ownership while larger farms are becoming more common, leading to a comparatively low output per household or hectare; (2) The low quality of sweet potato, experiencing difficulties into penetrates demanding markets, especially fastidious markets such as the United State, Japan, and EU. As a consequence, the yield of standard export sweet potatoes is too low and unreliable to ensure the adequate quantities to meet the needs of importers, and even almost depend on Chinese traders, led to the lack of knowledge about demand market along the current chain; (3) The lack of investment, state-of-the-art techniques, technologies, and modern facilities that are required for preservation, such as cold storage, specialized washing/ sorting/ handling equipment/ ripening chambers and so forth; (4) Other challenges are costs and price due to lacking specialized farming areas, middlemen throughout its chain, and high transportation costs; and (5) Brand development and product promotion are still barriers to yams, although "Binh Tan Sweet potato" already named trademark. The strategy of effective product consumption and marketing programs in terms of quantity and quality domestically and internationally is unlikely now. This study is considered as the first time, testing a hybrid of mathematical optimization, namely production - distribution decisions and supply chain coordination to improve supply chain management of Vinh Long sweet potato.

Table 5: *Average sweet potato price during the period 2017-2018 in Binh Tan district, Vinh Long province, Vietnam.*

Months	1	2	3	4	5	6	7	8	9	10	11	Average per Quintal	Avearage per Kilogram
Price in 2017 (VND)	600,000	650,000	800,000	750,000	720,000	620,000	590,000	470,000	480,000	680,000	800,000	667,500	11.125
Price in 2018 (VND)	1,100,000	1,300,000	900,000	550,000	580,000	660,000	580,000	440,000	380,000	400,000	300,000	653,636	10.894

Note: Data was collected by authors.

Source: Created by the authors.

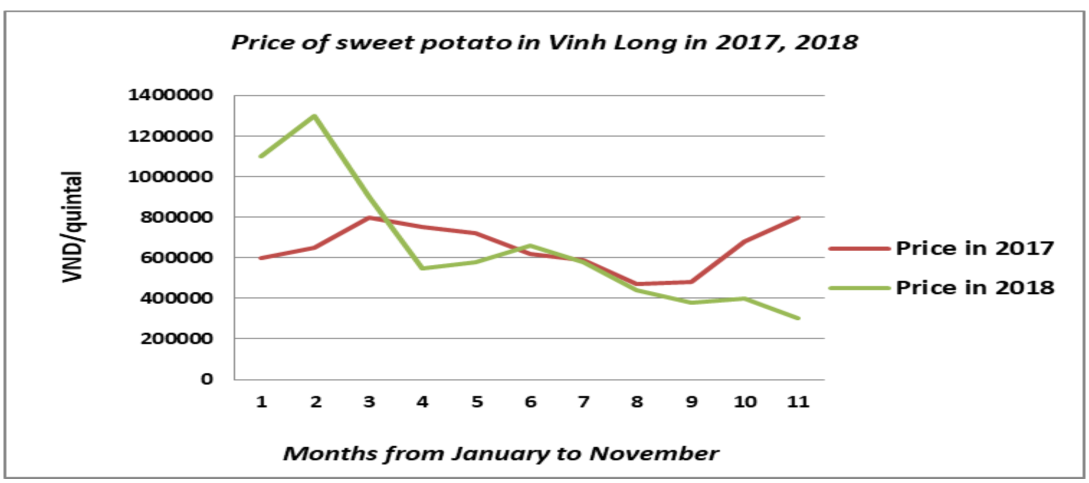

Figure 3. Sweet potato price during the period 2017-2018 in Binh Tan district, Vinh Long province, Vietnam.

4.2 Literature review related to sweet potato supply chain

In terms of cultivation and production, solutions for increasing the competitiveness and sustaintable development of sweet potatoes such as allocate a land fund associated with appropriate farming regime, create new sweet potato varieties with high productivity research [5], [6] and develop sophisticated processing technologies of intensive farming to increase productivity, quality and economic efficiency to discover new products from sweet potatoes towards sustainable consumption and export, increase productivity, income and improve living standards, reduce costs related to fertilizers, drugs and seed for sweet potato farmers , especially to settling jobs for poor farmers and ethnic minorities in remote areas in the Mekong Delta [11]. Besides, the effect of harvest time should be considered because of tuber morphological characteristics, tuber yeild [7].

Factors influencing on consumption of processed sweet potato products mostly are attractive packaging and nutritional value. Beside approaching levels in the provision of inputs, small production, farmers, processing, distribution, retail business and transport through the supply chain [8], while the behavior of stakeholders is determined by their position in the market system.

To improve Vinh Long sweet potato supply chain management, this part points out the research should conduct new supply chain strategy initiallly based on optimization, multiple criteria decision making and simulation, including proposal locations of distribution center, technological solutions and production processes, and how to bring sweet potato to market in time, increase competitiveness, reduce product costs [17]–[20].

4.3. Proposing the new sweet potato supply chain model

4.3.1 Current Vinh Long sweet potato supply chain

From the results of surveys, the current sweet potato supply chain in Vinh Long is drawn, consisting of small farmers, farmer cooperatives, producers, traders, wholesalers, retailers, supermarket, distributors, and consumers, involved in supplying the sweet potato produced from farm- to- fork tend to operate independently along the chain. More seriously, the infrastructure connecting these stakeholders is so poor.

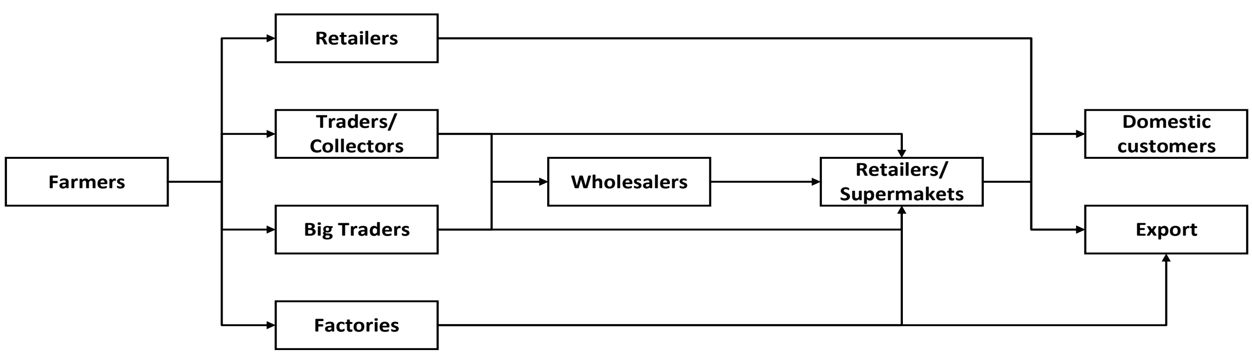

***Figure 4**: Present flow of sweet potato supply chain in Vinh Long*

Source: Created by the authors

Figure 2 depicts the diagram of current sweet potato supply chain in Vinh Long, mainly collected by those who live within districts or come from near districts. Most collectors travel to towns to collect these products from farmers and then transport them to the wholesalers in surrounding locations. Wholesale market plays an important role in sweet potatoes distribution, packaging, and sorting. This figure also shows the significant intermediaries along the supply chain, which lead to the high transaction cost. Consequently, farmers always suffer the dramatic fluctuation in price of yams when they sell their goods to these middlemen. They earn only around

30% of the end price and even lose profit. Obviously, the inadequate cold chain facilities and the lack of coordination among the supply chain partners of the current inefficient sweet potatoes supply chain in Vinh Long result in the post- harvest losses, the wastage in transit, and the poor-quality products when reaching the end consumers.

4.3.2. Proposed new sweet potato supply chain model

As a result, regarding upgrading the emergent traditional supply chain to new efficient supply chain, the authors offer a proposed the appropriate model to improve the present supply chain model in terms of reducing the inefficiencies in the current supply chain, in which focuses on increasing the shelf-life of sweet potatoes, decreasing the post-harvest losses, wastage and improving the quality of the end products is launched. In Figure 5, all farmers bring their products to Distribution Centers directly. All activities from raw materials to final products are made in these areas.

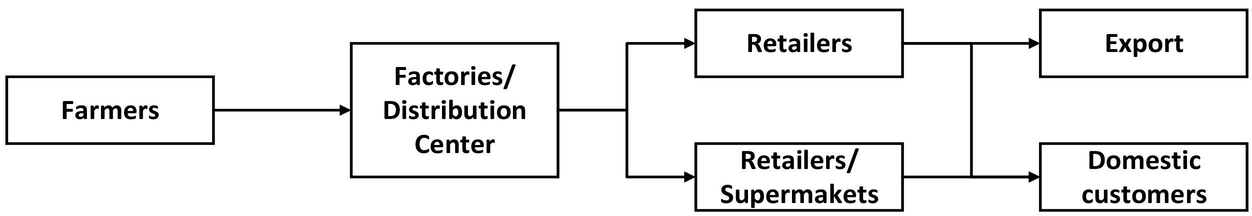

Figure 5. Proposed sweet potato supply chain in Vinh Long **(Determined and drawn by the authors)**

4.3.3. Hybrid optimization and coordination approach

The conceptual model presented in Figure 4 shows a network design problem in combination with a network control problem, tackled by a hybrid of mathematical optimization, namely production - distribution decisions and supply chain coordination. The objectives of the proposed work are likely to make decisions based on historical price information, resource availability, and the factors that are usually not considered by the farmers, such as price dynamics, transportation, and inventory costs. Since the fresh produce market is highly dynamic and uncertain, we decompose the overall planning problems into two phases: tactical and operational.

4.4. Mathematical model

Table 6. Notation of the mathematical model

No.	Notation	Set Name	Index	Description
1	P	Set of products	p	{Japanese Sweet Potato}
2	R	Set of market	r	{HCMc, Tan Thanh-Lang Son}
3	H	Set of potential distribution center	h	{BinhMinh, Hoa Phu, Tan Quoc, Binh Tan}
4	S	Set of plant	s	{11 plant in Binh Tan}
5	L	Set of periods	l	{1 … 12}
6	T	Set if transportation mode	t	{Roadway, waterway}
7	(i, j)	Set of arcs	i, j	
8	Z	Set of routes	z	

From Vinh Long Province, sweet potatoes are transported in the supply chain on possible routes that each route that is defined by the transportation mode using in two stage. There are four feasible routes in this case, shown in figure 6

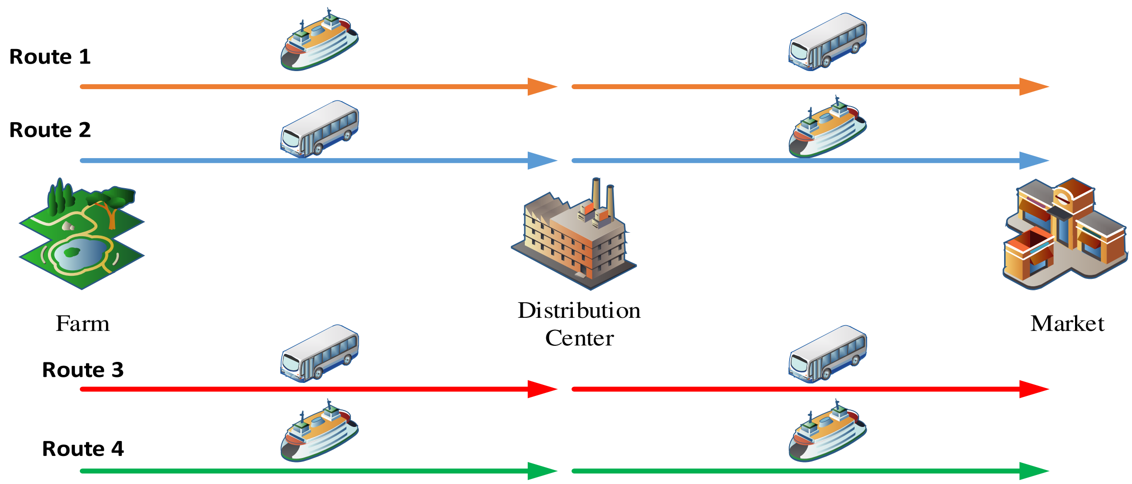

Figure 6. Defined four possible routes (Created by the authors)

Notation	**Unit**	**Transportation mode**	
		Roadway	**Waterway**
$\alpha(DI_{tjk})$	VND/ton	$1023 * DI_{tij}$	$102{,}3 * DI_{tij}$
$\gamma(DI_{tij})$	Hours	$\frac{DI_{tij}}{Average\ velocity\ in\ roadway}$	$\frac{DI_{tij}}{Average\ velocity\ in\ waterway}$

The case study is purple sweet potatoes in Vinh Long Province, Vietnam. There are particularly solutions for each single-objective model. In this case, while the solution of minimizing total cost proposed to select the distribution center at Hoa Phu – Long Ho – Vinh Long, the distribution center at Tan Quoi – Binh Tan – Vinh Long is selected to minimize transportation time.

Table 7. Payoff matrix of the mathematical model

Objective	Minimize Objective 1	Minimize Objective 2
Objective 1: Total cost	9,815,945,883,146 VND » 421,285,231 USD	9,708,356,051,270 (F_1^*) » 416,667,642 USD(F_1^*)
Objective 2: Transportation time	46,64 (F_2^*)	50,34

Selection of Distribution Center	Tan Quoi – Binh Tan	Hoa Phu – Long Ho

4.5. Compromise programming

To find a solution for both two objective functions, compromise programming is applied by developing a new objective function:

$$\boldsymbol{Minimize}\ \boldsymbol{W_1} \times \left(\frac{\left[\sum_z \sum_p \sum_l \left(\left(\boldsymbol{tc_{zp} X_{zpl}}\right) + \boldsymbol{CAPC_p X_{zpl}(1-\varphi_{zp})}\right) + \sum_h (\boldsymbol{Q_h FC_h})\right] - \boldsymbol{F_1^*}}{\boldsymbol{F_1^*}}\right) + \boldsymbol{W_2} \times \left(\frac{\left[\frac{\sum_z \sum_p \sum_l \left(\boldsymbol{tt_z X_{zpl}}\right)}{\sum_r \sum_p \sum_l \boldsymbol{D_{rpl}}}\right] - \boldsymbol{F_2^*}}{\boldsymbol{F_2^*}}\right)$$

Where:

$\boldsymbol{F_1^*}$ and $\boldsymbol{F_2^*}$ are the optimal values of each objective function when separately solving, respectively.

$\boldsymbol{W_1}$ and $\boldsymbol{W_2}$ are weights of two objective functions, which is determined equivalent, $W_1 = W_2 = 1$.

After forming a compromised objective function, the mathematical model is resolved with the results showed the location at Binh Minh with the average total cost and time of transport is ***9,851,717,842,346VND*** and ***47.34 hours/ton,*** respectively.

4.6. Analyzing and evaluating

As the results of this formulation, there are three alternatives for DC, including Tan Quoi – Binh Tan; Hoa Phu – Long Ho; Binh Minh. Thus, the results of the optimal model show that the best solution in terms of cost is to place distribution center at Tan Quoi Commune, Binh Tan District - based on the resource area as option 1. While the best solution in term of the average transit time is to place DC at Long Ho District. The authors also test a compromise programming model to satisfy both cost and time goals to obtain distribution center in Binh Minh Town. The following table expresses the value of the two objective functions of the model is the total cost and average transit time.

Table 8. Weighted of Alternatives

Objective value	*Option 1: DC at Binh Tan*	*Option 1: DC at Binh Minh*	*Option 1: DC at Long Ho*
Total cost (billion VND)	9,816	9,852	9,708
Total cost (million USD)	421.3	422.8	416.7
Average transit time (hours/ton)	46.64	47.34	50.34

4.7. Using SAW for decision support

Accordingly, the more displacement distribution center is from the resource area, the lower the cost and time of transport. However, to ensure the results of the project to achieve high applicability, the research team proposed other criteria to make a decision on the location selection for the distribution center as follows:

• **Satisfaction of transport infrastructure**: This criterion shows the capacity of the infrastructure for transport activities. This criterion is evaluated based on the design load of the bridge and the road compared to the load requirement of vehicles, level of transport infrastructure connection.

• **Degree of feasibility**: This criterion represents the status of the management organization available at legally considered positions, premises, management, etc.

• **Human resources:** Criteria show the ability to supply human resources for the operation of distribution centers such as the rate of local skilled workers, unemployment rate, ...

• **Environmental impacts:** Criteria show the forecast of impacts of distribution center operations on the environment based on the condition of the facilities at the locations considered.

To increase the objectivity for the determination of the location of the distribution center as well as to match the actual situation and the socio-economic development of the locality, the research team conducted a survey asking for opinions of experts, including scientists, managers, and representative leaders of Vinh Long province for options according to the criteria as well as the importance between the criteria.

The results of the survey of experts assessing the importance between the criteria and evaluation points of the alternatives (the larger the better) for each criterion are presented in the following table

Table 9. Weighted of alternatives

Weight	*Criteria*	*Average weight*		
		Alternative 1: Tan Quoi – Binh Tan	*Alternative 2: Hoa Phu – Long Ho*	*Alternative 3: Binh Minh*
17.49%	Level of traffic infrastructure	0.59	1.00	0.78
18.20%	Level of possibility	0.87	1.00	0.83
16.01%	Impact of resources	1.00	0.69	0.62
15.52%	Impact of environment	1.00	0.64	0.84
17.17%	Total cost	0.98	0.99	1.00
15.62%	Average transportation time	1.00	0.99	0.93
	Total evaluation	**0.9**	**0.89**	**0.83**

According to the weighting, Alternative 1, where Distribution center would be in **Tan Quoi – Binh Tan,** is the most suitable solution.

6. Conclusion

This paper presents the mathematical model designed for providing decisions for planning, transportation, and distribution of crops with the objective of maximizing the revenues of the trader coordinator of perishable agricultural products. The model deals with labor availability, price dynamics, and the variable effects on costs. The main benefit of this research is providing a model which can assist the trader in making decisions during complex changing environments. Obviously, the use of the proposed modeling tool would be extremely useful for maximizing the revenue of traders under different climate and dynamic markets. By considering the perishable nature of crops and different alternatives for distributing them, the model could be easily extended to determine the profitability of potential customers and analyze new markets. The contribution of proposing the mathematical model is to choose a suitable place for saving costs and reducing transport times. In additon, this approach method could be applied to other Vietnamese agri-fresh products for upgrading the competitiveness, compared with other countries' agricultural products in terms of price and quality so far.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

Assoc.Prof Phong guided and supported into my research directly, and even edited the manuscript. All authors read and approved the final manuscript.

Corresponding author

Assoc.Prof Ho Thanh Phong – The advisor of my desertation. He is a president of International Hong Bang University. His email: phonght@gmail.com

Acknowledgments

This work is supported by Industry and Trade Department, Agriculture and Rural Development Department and People's Committee of Binh Tan District in Vinh Long Province, Vietnam due to our surveys.

Reference

[1] M. Shukla and S. Jharkharia, "Agri-fresh produce supply chain management: A state-of-the-art literature review," *Int. J. Oper. Prod. Manag.*, vol. 33, no. 2, pp. 114–158, 2013, doi: 10.1108/01443571311295608.

[2] J. (Junmin) Shi, Y. Zhao, and R. Kiwanuka, "Managing Inventories for Agricultural Products: The Optimal Selling Policies," *SSRN Electron. J.*, pp. 1–41, 2015, doi: 10.2139/ssrn.2664155.

[3] D. Murthy, T. M. Gajanana, M. Sudha, and V. Dakshinamoorthy, "Marketing & post-harvest losses in fruits: its implications on availability & economy - A study on pomegranate in Karnataka," *Ind.Jn.of Agri.Econ*, vol. 64, no. 2, pp. 34–43, 2009.

[4] S. Nahmias, "Perishable Inventory Theory: a Review.," *Oper. Res.*, vol. 30, no. 4, pp. 680–708, 1982, doi: 10.1287/opre.30.4.680.

[5] M. CHRISTOPHER, " Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service (Second Edition) ," *Int. J. Logist. Res. Appl.*, vol. 2, no. 1, pp. 103–104, 1999, doi: 10.1080/13675569908901575.

[6] H. Min and G. Zhou, "Supply chain modeling: Past, present and future," *Comput. Ind. Eng.*, vol. 43, no. 1–2, pp. 231–249, 2002, doi: 10.1016/S0360-8352(02)00066-9.

[7] A. Nagurney, “Optimal supply chain network design and redesign at minimal total cost and with demand satisfaction,” *Int. J. Prod. Econ.*, vol. 128, no. 1, pp. 200–208, 2010, doi: 10.1016/j.ijpe.2010.07.020.

[8] S. Chopra and P. Meindl, *Supply Chain Management. Strategy, Planning & Operation*. 2007.

[9] S. J. Liu, Z. Wang, R. Miao, J. Xu, and H. Huang, “Research of location selection of distribution center for service based on gravity method,” *Appl. Mech. Mater.*, vol. 433–435, pp. 2419–2423, 2013, doi: 10.4028/www.scientific.net/AMM.433-435.2419.

[10] T. Bender, H. Hennes, J. Kalcsics, M. T. Melo, and S. Nickel, “Location Software and Interface with GIS and Supply Chain Management,” *Facil. Locat.*, vol. 23, no. 23, pp. 233–274, 2002, doi: 10.1007/978-3-642-56082-8_8.

[11] S.-L. et al.- David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi, *Designing and Managing the Supply Chain_ Concepts, Strategies, and Cases (1999)*. 1999.

[12] P. Amorim, H. Meyr, C. Almeder, and B. Almada-Lobo, “Managing perishability in production-distribution planning: A discussion and review,” *Flex. Serv. Manuf. J.*, vol. 25, no. 3, pp. 389–413, 2013, doi: 10.1007/s10696-011-9122-3.

[13] D. BOSELIE, D., HENSON, S., WEATHERSPOON, “SUPERMARKET PROCUREMENT PRACTICES IN DEVELOPING COUNTRIES: REDEFINING THE ROLES OF THE PUBLIC AND PRIVATE SECTORS,” *Amer. J. Agr. Econ*, vol. 85, no. 5, pp. 1155–1161, 2003.

[14] J. K. Gigler, E. M. T. Hendrix, R. A. Heesen, V. G. W. Van Den Hazelkamp, and G. Meerdink, “On optimisation of agri chains by dynamic programming,” *Eur. J. Oper. Res.*, vol. 139, no. 3, pp. 613–625, 2002, doi: 10.1016/S0377-2217(01)00191-6.

[15] J. Van Der Vorst, “Performance measurement in agrifood supply chain networks: an overview,” *Quantifying Agri-Food supply Chain*, no. January 2006, pp. 13–24, 2006, doi: 10.1007/1-4020-4693-6.

[16] V. Salin, “Information technology in agri-food supply chains,” *Int. Food Agribus. Manag. Rev.*, vol. 1, no. 3, pp. 329–334, 1998, doi: 10.1016/s1096-7508(99)80003-2.

[17] H. Tsubone, R. Muramatsu, and M. Soshiroda, “Designing an effective production system for processing agricultural products,” *Int. J. Prod. Res.*, vol. 21, no. 1, pp. 17–30, 1983, doi: 10.1080/00207548308942333.

[18] L. H. Aramyan, O. Van Kooten, and A. O. Lansink, “Performance indicators in agri-food production chains,” *Quantifying Agri-Food supply Chain*, no. January, pp. 47–64, 2006, doi: 10.1007/1-4020-4693-6.

[19] T. J. Lowe and P. V. Preckel, “Decision technologies for agribusiness problems: A brief review of selected literature and a call for research,” *Manuf. Serv. Oper. Manag.*, vol. 6, no. 3, pp. 201–208, 2004, doi: 10.1287/msom.1040.0051.

[20] J. H. Dorfman and A. Havenner, “State- Space Modeling of Cyclical Supply, Seasonal Demand, and Agricultural Inventories,” *Am. J. Agric. Econ.*, vol. 73, no. 3, pp. 829–840, 1991, doi: 10.2307/1242835.

[21] S. Seuring and M. Müller, "From a literature review to a conceptual framework for sustainable supply chain management," *J. Clean. Prod.*, vol. 16, no. 15, pp. 1699–1710, 2008, doi: 10.1016/j.jclepro.2008.04.020.

[22] C. N. Verdouw, A. J. M. Beulens, J. H. Trienekens, and J. Wolfert, "Process modelling in demand-driven supply chains: A reference model for the fruit industry," *Comput. Electron. Agric.*, vol. 73, no. 2, pp. 174–187, 2010, doi: 10.1016/j.compag.2010.05.005.

[23] O. Ahumada and J. R. Villalobos, "Application of planning models in the agri-food supply chain: A review," *Eur. J. Oper. Res.*, vol. 196, no. 1, pp. 1–20, 2009, doi: 10.1016/j.ejor.2008.02.014.

[24] H. J. Greenberg, "Mathematical programming models for environmental quality control," *Oper. Res.*, vol. 43, no. 4, pp. 578–622, 1995, doi: 10.1287/opre.43.4.578.

[25] C. R. Carter and P. L. Easton, "Sustainable supply chain management: Evolution and future directions," *Int. J. Phys. Distrib. Logist. Manag.*, vol. 41, no. 1, pp. 46–62, 2011, doi: 10.1108/09600031111101420.

[26] S. Pokharel and A. Mutha, "Perspectives in reverse logistics: A review," *Resour. Conserv. Recycl.*, vol. 53, no. 4, pp. 175–182, 2009, doi: 10.1016/j.resconrec.2008.11.006.

[27] Z.-J. Simchi-Levi, D., Wu, S.D., Shen, *Handbook of Quantitative Supply Chain Analysis: Modeling in the E-Business Era*. 2004.

[28] N. Arumugam, M. A. Fatimah, E. F. C. Chiew, and M. Zainalabidin, "Supply chain analysis of fresh fruits and vegetables (FFV): Prospects of contract farming," *Agric. Econ.*, vol. 56, no. 9, pp. 435–442, 2010, doi: 10.17221/30/2009-agricecon.

[29] R. Akkerman, P. Farahani, and M. Grunow, *Quality, safety and sustainability in food distribution: A review of quantitative operations management approaches and challenges*, vol. 32, no. 4. 2010.

[30] W. Zhang and W. E. Wilhelm, "OR/MS decision support models for the specialty crops industry: A literature review," *Ann. Oper. Res.*, vol. 190, no. 1, pp. 131–148, 2011, doi: 10.1007/s10479-009-0626-0.

[31] N. K. Tsolakis, C. A. Keramydas, A. K. Toka, D. A. Aidonis, and E. T. Iakovou, "Agrifood supply chain management: A comprehensive hierarchical decision-making framework and a critical taxonomy," *Biosyst. Eng.*, vol. 120, pp. 47–64, 2014, doi: 10.1016/j.biosystemseng.2013.10.014.

[32] P. Paam, R. Berretta, M. Heydar, R. H. Middleton, R. García-Flores, and P. Juliano, "Planning Models to Optimize the Agri-Fresh Food Supply Chain for Loss Minimization: A Review," *Ref. Modul. Food Sci.*, no. December, pp. 0–24, 2016, doi: 10.1016/b978-0-08-100596-5.21069-x.

[33] P. D. Larson, "Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies, David Simchi-Levi Philip Kaminsky Edith Simchi-Levi," *J. Bus. Logist.*, vol. 22, no. 1, pp. 259–261, 2001, doi: 10.1002/j.2158-1592.2001.tb00165.x.

[34] N. Raak, C. Symmank, S. Zahn, J. Aschemann-Witzel, and H. Rohm, "Processing- and product-related causes for food waste and implications for the food supply chain," *Waste Manag.*, vol. 61, pp. 461–472, 2017, doi: 10.1016/j.wasman.2016.12.027.

[35] M. Balaji and K. Arshinder, "Modeling the causes of food wastage in Indian perishable food supply chain," *Resour. Conserv. Recycl.*, vol. 114, pp. 153–167, 2016, doi: 10.1016/j.resconrec.2016.07.016.

[36] M. S. Daskin, L. V Snyder, and R. T. Berger, *Facility Location in SUpply Chain Design Department of Industrial Engineering and Management Sciences Facility Location in Supply Chain Design*, no. December. 2005.

[37] C. G. Chatzopoulos, D. Gracanin, I. Veza, and A. C. Tsigkas, "Demand-driven Supply Chain using Lean & Agile principles: A Culture for Business Excellence," *Proc. 5th Int. Conf. EIRD*, no. January, 2012, doi: 10.13140/2.1.1422.8488.

[38] P. V Saraph, "Shared resource capacity analysis biotech manufacturing," pp. 1247–1250, 2003.

[39] K. Siahaan, Andysah Putera Utama, Khairul, "Decision Support System in Selecting the Appropriate Laptop using Simple Additive Weighting," *Int. J. Recent Trends Eng. Res.*, vol. 2, no. 12, 2016, doi: 10.31227/osf.io/3t9re.

Figures

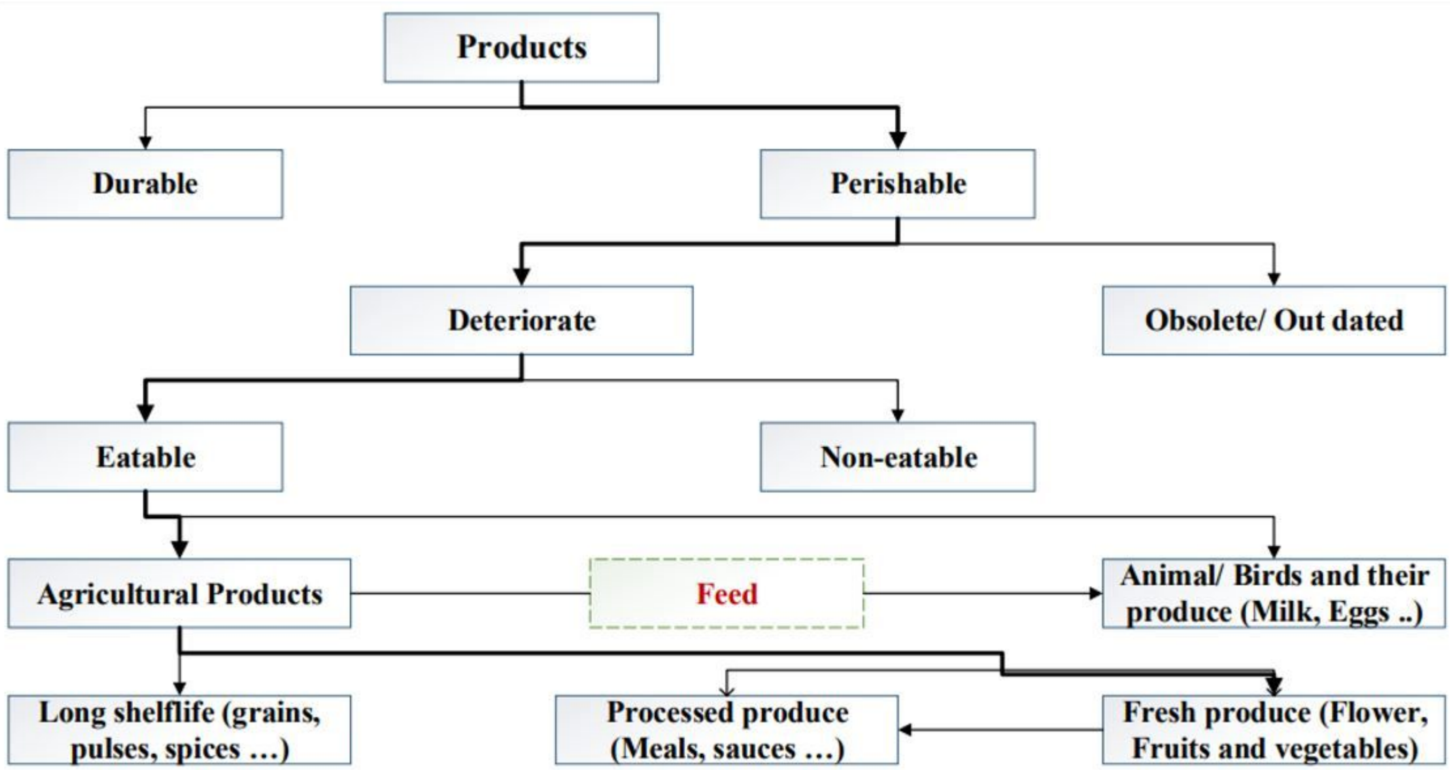

Figure 1

Product differentiation, adapted from Shukla and Jharkharia (2013)

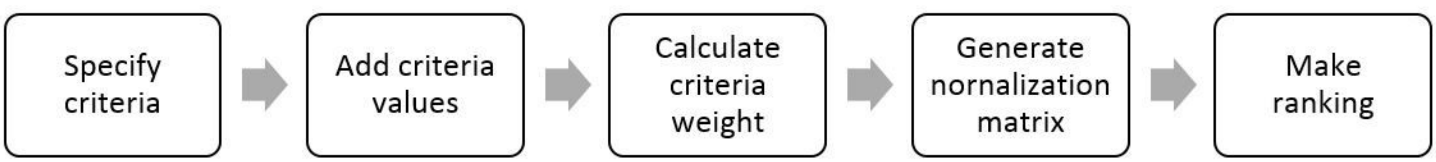

Figure 2

Simple additive weighting diagram

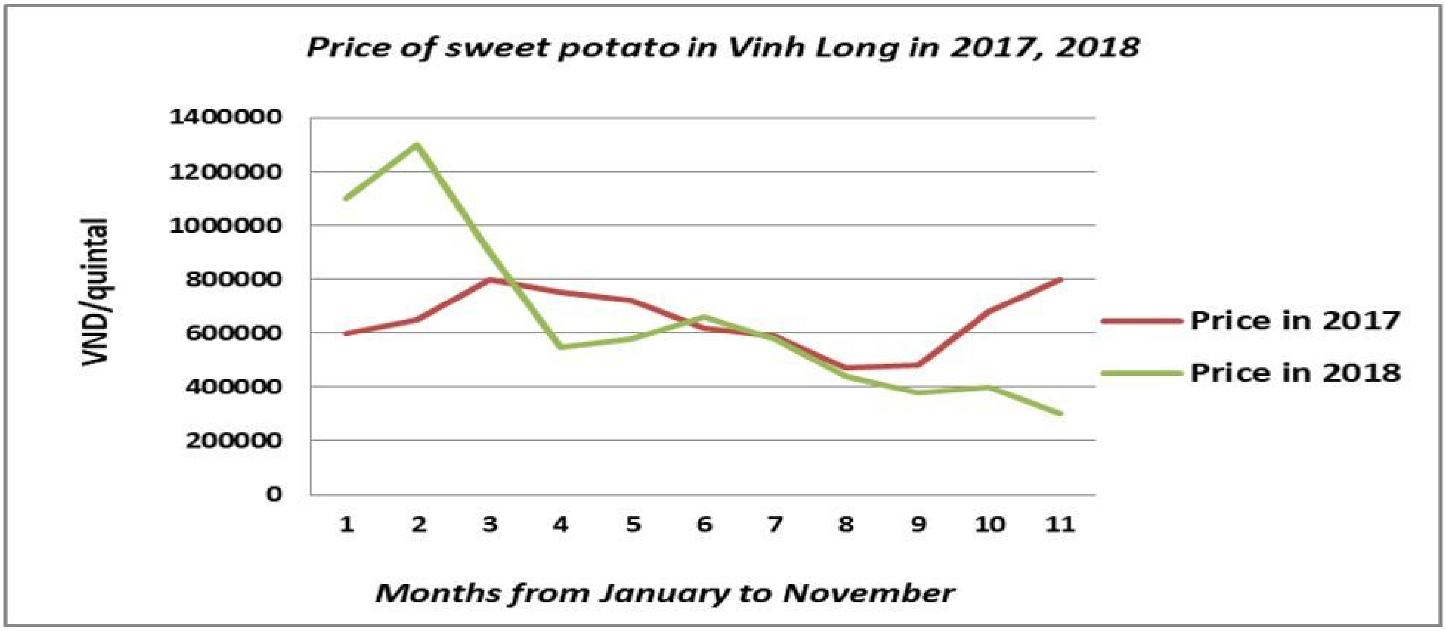

Figure 3

Sweet potato price during the period 2017-2018 in Binh Tan district, Vinh Long province, Vietnam.

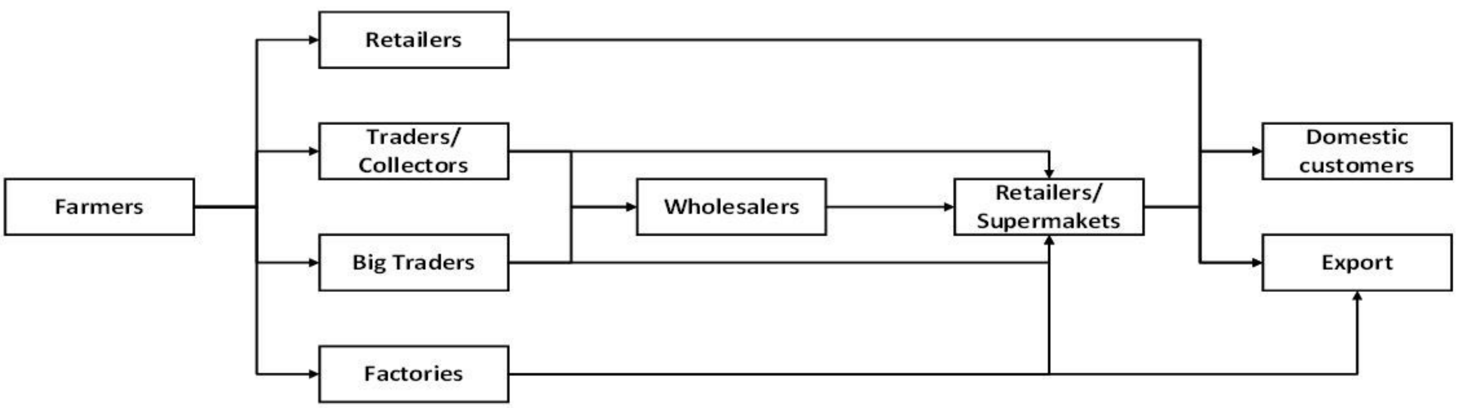

Figure 4

Present flow of sweet potato supply chain in Vinh Long

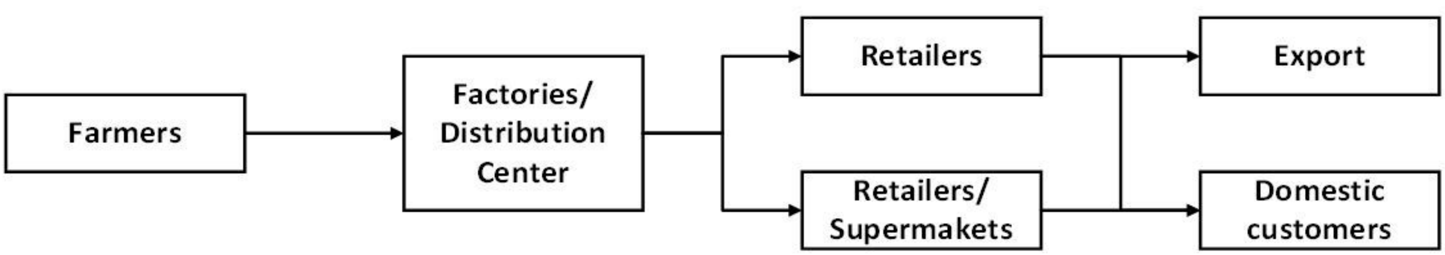

Figure 5

Proposed sweet potato supply chain in Vinh Long (Determined and drawn by the authors)

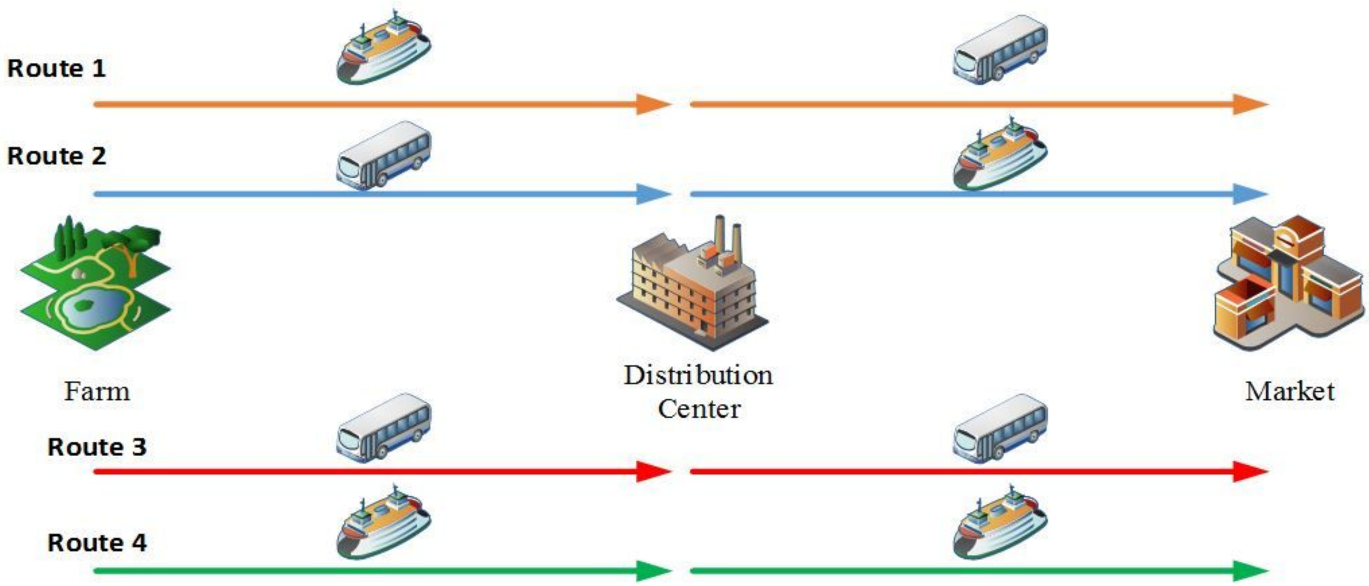

Figure 6

Defined four possible routes (Created by the authors)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- DataVinhLong.xlsx