Multi-Objective Supply Chain Design Modeling for Fresh Fruit Products in Vietnam

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Abstract. Despite the developing industrialization, Vietnam is still an agricultural country with over 80 percent of the total area are agricultural land. However, this economic sector has not been effective organization, especially the control of the product quality and information flow. In this an article, Goal Programming (GP) approach has been suggested for solving a multi-objective mathematical model for the design of the fresh fruit product supply chain. Whereby, cost optimization is the first objective, the second objective is minimize delivery time and the third goal is to minimize the impact of the supply chain on the environment to ensure sustainable development. Because the statistics activities of agriculture in Vietnam is not really adequate, the application scope of this study focuses only on several fresh fruit products that the data collection is feasible.

Keywords: goal programming, supply chain, multiple objective decision making, sustainable development

1. INTRODUCTION

During recent two decades, supply chain and logistics is getting critical role in many economic sectors including agriculture in many countries around the world, especially the developing countries. Due to the requirements for food safety and quality, the concept of supply chain and logistics increasingly more popular. The concept that ensures the development of both the effectiveness and efficiency of agricultural production including cultivation planning, collection, processing, storage and distribution to final customers. The activities is done through a link of information, materials and capital between stakeholders such as farmers, purchasing, processing plants, distribution centers, warehouses, retailers and customers. As shown in the figure above, the accurately management of information flow and material flow at all stages of the chain is necessary to keep the product quality was good when the hands of consumers.

Despite the developing industrialization, Vietnam is still an agricultural country with over 80 percent of total area. In 2013, agriculture, forestry and fishing accounted for 17.96 percent of Vietnam's GDP. Moreover, the employment in this economic sector was much higher than its share of GDP shared for 46.73 percent or approx. 24399.3 thousand persons. In other words, In other words, nowadays, the economy and the competitiveness of Vietnam is still deeply influenced by the strength of agriculture. However, the growth of economic activity is mainly focused on quantity rather than quality, so the benefits it provides not really deserve. In other words, Vietnam's agriculture consumes a lot of land and human resources, but economic efficiency is very low.

In the Asian, Vietnam is one of the biggest agricultural export and the value of the product increased continuously over the years. In which commodities are mainly rice and products from perennial crops. However, the weakness of technology in cultivation, storage and transportation has significant impacts on yields and quality of agricultural products in Vietnam.

2. PROBLEM STATEMENT

Firstly, due to traditional small-scale cultivation and the harvesting is not concentrated in the fields, the activities of purchasing, transporting agricultural products to the market is inefficient and the quality of fresh agricultural products in Vietnam continuously decreased through each stage of the supply chain as a result. Besides, significant post-harvest loss, approx. 25 percent, occurs with vegetables, fruits by physical damage because of the absence of science, technology leads to reduce their competitiveness in both domestic market and exporting.

Secondly, the information flow throughout the chain has not really smooth and precise. Consumers do not know the source and quality of the products they are consumers, while farmers do not know where their products are sold to. In other words, the lack of information on the time and number of products in accordance with market demand led to farmers almost passive in planning cultivation and harvesting. So that in a few years, Vietnam's agriculture is always facing the reality that farmers massive produce due to the inaccurate information or by the attraction of the price of agricultural products in a certain time. However, when the products entering the stage that ready for sale to the market, the needs of the market has changed and the impact on the significant reduction of agricultural product prices.

Last but not least, agriculture of Vietnam is one of the most agricultural methane and nitrous oxide emissions in Asia. Whereby, the CO2 emissions of agriculture Vietnam from 1998 to 2008 increased from 53232.8 thousand metric tons to 57685.5 thousand metric tons. Therefore, environmental factors need to be considered in the design of supply chain and logistics aiming to the sustainable development of Vietnam's agriculture.

3. LITERATURE PREVIEW

Zahra Alizadeh Afrouzy et al. (2016) formulated a stochastic multi-objective optimization model for supply chain. The first objectives is to maximize the profitability of the supply chain, the second objective considers the consumer satisfaction and the third goal is to optimize the development of new products. This study also consider the uncertainties of the market with the fuzzy stochastic model.

In 2014, “Competitive Supply chain Network Design: An overview of classification, models, solution techniques and applications”, Farahani et al. indicated that, the performance of product and costs or the structure of a chain affected by supply chain network design because of deal with these factors such as determining number, size, and location of facilities in supply chain. Also, the preparation for possible future competitive situation at this stage should be implemented to capture more market shares.

Benita M.Beamon (1999) have analyzed and classified performance measures that are necessary components in any supply chain performance measurement system: resource, output and flexibility. This study also develops volume flexibility and delivery flexibility measures for supply chains, and presents existing measures for mix flexibility and new product flexibility.

Hamideh Etemadnia et al. (2015) formulated a mixed integer linear programming (MILP) that minimized the total network cost including transportation and location of facilities in order to constructing hub locations for food supply chain in U.S. Sensitivity analysis on parameter change such as travel distance, hub capacity, transportation cost,… was applied to demonstrate how these factors affected the optimal locations and number of facilities.

Peyman Bahrampour et al. (2016) proposed the three states supply chain network design model and showed the comparison with the genetic algorithm which based on the priority-centered encoding. The research give the acceptable answers for the complicated supply chain network design.

The study of Jafar Razmi et al (2016) developed the integrated mathematical model to optimize the configuration of the supply chain with the effect of seasonality. The model is also consider to the quality decreasing of the product. The answers from their model showed that it can be used in many economic sector including agriculture.

Leung et al. (2003) have introduced the GP model for multiple objectives APP accompanied by assumptions such as multi-product, multi-location, etc. Following their study but in a different context and objectives, this research aimed to solve the multi-objective APP problem by GP with goals and target values proposed by the managers of the companies mentioned above. These goals include minimizing decreasing of workforce level, maximizing profit, minimizing late orders and maximizing machine utilization for a multi-site production system. To suitable with the requirements of the future, a variety of data on demand and a change in manufacturing rate also were proven to the decision maker can handle unexpected and complex changes.

In the “Multi-objective design of multi-modal fresh food distribution network”, 2016, Bortolini et al has presented a mathematical model aimed at optimizing the distribution network of fresh food. Besides the calculation of operating costs, the model also consider the quality of the food through the transit time management. In addition, the authors integrate environmental factors into the model to meet the needs of sustainable development in the operation of the supply chain.

4. MATHEMATICAL MODEL

4.1 Notation

4.1.1 Sets

P	The set of the fresh fruits
R	The set of the retailers
H	The set of the potential hubs
S	The set of the fresh fruit suppliers
Z	The set of the possible paths
T	The set of the transportation modes
(I,J)	Network node

Due to time constraints, this study considered several major fruits and their market in southwestern Vietnam as sweet potatoes, tangerines, oranges, straw mushrooms. Supply chain is designed to include three states: supplier, storing hub, and retailer. In which, each product will be shipped through the supply chain in the path defined by the distance from suppliers to the hub and the distance from the hub to retailers with two transportation modal are truck and barge can be selected for each distance.

4.1.2 Parameters and Decision Variables

AS_{zs}	1 if supplier s can use path z, 0 otherwise
AR_{zr}	1 if retailer r can use path z, 0 otherwise
CAP_{sp}	Supplier s production capacity for fruit p $(ton/month)$
$CAPC_p$	Production cost for fruit p (VND/ton)
cs	Inventory cost for fruit (VND/ton)
D_{rp}	Demand of fruit p in retailer r $(ton/year)$
ep_p	Production emission for fruit p $(kgCO_{2EQ}/ton)$
es	Inventory emission for fruit $(kgCO_{2EQ}/ton)$
QRP_p	Quality reduction point for fruit p
sl_p	Shelf life for fruit p (h)
tc_{zp}	Transportation cost for path z and fruit p (VND/ton)
te_{zp}	Transportation emissions for path z and fruit p
ts	Inventory fix time for fruit (h)
tt_{zp}	Transportation time for path z and fruit p (h)
DI_{tij}	Distance between the nodes i and j using the transportation mode t (km)
SS	Discount factor for economies of scale
φ_{zp}	Quality loss function for path z and fruit p
$\alpha(DI_{tij})$	Transportation cost function (VND/ton)
$\beta(DI_{tij})$	Transportation time function (h)
$\gamma(DI_{tij})$	Transportation emission function $(kgCO_{2EQ}/ton)$
$G1$	The aspiration level of average transportation cost
$G2$	The aspiration level of delivery time
$G3$	The aspiration level of emissions
X_{zp}	Shipped quantity of fruit p uses path z $(ton/year)$
$d1^+$	The deviation variable of overachievement of the total cost goal
$d1^-$	The deviation variable of underachievement of the total cost goal
$d2^+$	The deviation variable of overachievement of the delivery time goal
$d2^-$	The deviation variable of underachievement of the delivery time goal
$d3^+$	The deviation variable of overachievement of the emission goal
$d3^-$	The deviation variable of underachievement of the emission goal

4.2 Model development

As mentioned above, the quality is very important factor of agricultural products fresh and this factor will decrease over time. In other words, the longer shipping time, lower product quality. In their study, Osval and Stirn (2008) mentioned the relationship between quality and time so-called quality loss function is shown in the below.

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

Whereby, the shelf life (sl_p) of the fruits is from the "eatbydate" database and the quality reduction point is from the Bortolini et al (2016) for several fruits with the similar family. In the next step, the transportation cost (tc_{zp}), transportation time (tt_{zp}), and transportation emissions (te_{zp}) are computed by the equation (2), (3), and (4).

$$tc_{zp} = \alpha(DI_{tij}) + (1 - SS)\alpha(DI_{tjk}) + cs \qquad \textbf{(2)}$$

$$tt_{zp} = \beta(DI_{tij}) + \beta(DI_{tjk}) + ts \qquad \textbf{(3)}$$

$$te_{zp} = \gamma(DI_{tij}) + \gamma(DI_{tjk}) + es \qquad \textbf{(4)}$$

The distance between 2 locations is estimated by the data from the Vietnam Inland Waterways Administration for the barge mode and from the google map distance calculator for the truck mode. According to Bortolini (2016), the transportation cost function (in euro) and transportation emissions function by truck mode are determined. While the information from the Hoen's study (2011) showed waterway mode have transportation costs and emissions are less than approximately 10 times.

Table 1 Transportation cost, emission and time function

	Truck	Barge
$\alpha(DI_{tij})$	$0.2872.DI_{tij}^{-0.183}$	$0.02872.DI_{tij}^{-0.183}$
$\gamma(DI_{tij})$	$0.484.DI_{tij}$	$0.0484.DI_{tij}$
$\beta(DI_{tij})$	$\frac{DI_{tij}}{Average\ truck\ velocity}$	$\frac{DI_{tij}}{Average\ barge\ velocity}$

4.2.1 Single objective model

$$Minimize \quad \frac{\sum_z \sum_p (tc_{zp}X_{zp}) + CAPC_p X_{zp}(1-\varphi_{zp})}{\sum_r \sum_p D_{rp}} \tag{5}$$

$$Minimize \quad \frac{\sum_z \sum_p (tt_{zp}X_{zp})}{\sum_r \sum_p D_{rp}} \tag{6}$$

$$Minimize \quad \frac{\sum_z \sum_p (te_{zp}X_{zp}) + ep_p X_{zp}(1-\varphi_{zp})}{\sum_r \sum_p D_{rp}} \tag{7}$$

The equation (5), (6), and (7) are the average cost (VND/ton), delivery time (h), and emissions $(kgCO_{2EQ}/ton)$ objective functions.

$Subject\ \ to$:

$\sum_z AS_{zs}X_{zp} \leq CAP_{sp} \qquad \forall s,p$

(8)

$\sum_z AR_{zr}X_{zp}\varphi_{zp} = D_{rp} \qquad \forall r,p$

(9)

$X_{zp} \geq 0 \qquad \forall z,p$

(10)

The equation (8) ensures the shipped quantity of each type of fruit are not over the supplier capacity, and the equation (9) is the constraint of market demand satisfaction. Then, the research finds the optimal solution for each single objective and based on those solution to develop the aspiration level of the goals ($G1$,$G2$, and $G3$) which are showed in the following table.

Table 2 the aspiration level of the goals

Goal	Value	Unit
$G1$	125864.593	(VND/ton)
$G2$	51.916	(h)
$G3$	10.711	$(kgCO_{2EQ}/ton)$

4.2.2 Goal programming approach for multiple objective model

$$Minimize \quad P1(d1^+) + P2(d2^+) + P3(d3^+) \tag{11}$$

$Subject\ \ to$:

$\frac{\sum_z \sum_p (tc_{zp}X_{zp}) + CAPC_p X_{zp}(1-\varphi_{zp})}{\sum_r \sum_p D_{rp}} + \ d1^- - \ d1^+ = G1$

(12)

$\frac{\sum_z \sum_p (tt_{zp}X_{zp})}{\sum_r \sum_p D_{rp}} \ + \ d2^- - \ d2^+ = G2$

(13)

$\frac{\sum_z \sum_p (te_{zp}X_{zp}) + ep_p X_{zp}(1-\varphi_{zp})}{\sum_r \sum_p D_{rp}} \ + \ d3^- - \ d3^+ = G3$

(14)

$\sum_z AS_{zs}X_{zp} \leq CAP_{sp} \qquad \forall s,p$

(15)

$\sum_z AR_{zr}X_{zp}\varphi_{zp} = D_{rp} \qquad \forall r,p$

(16)

$X_{zp} \geq 0 \qquad \forall z,p$

(17)

The model are modified with the new objective is minimize the overachievement of the goals according to their priority. In order to give the overall view when the objective's priorities change, this research has been developed several numerical experiments, with the priority changing for experiments, were listed in the table 3. For each experiment, the objectives have been solved sequentially from the highest priority (P1) to the lowest priority (P3).

Table 3 numerical experiments

Set	Cost	Delivery time	Emission
1	P1	P2	P3
2	P1	P3	P2
3	P2	P1	P3
4	P2	P3	P1
5	P3	P1	P2
6	P3	P2	P1

5. COMPUTATIONAL RESULTS

The result of objectives has been presented in the following table and figure.

Table 4 computational results

Set	Cost	Delivery time	Emission
1	125864.593	55.575	22.279
2	125864.593	55.575	22.279
3	130021.284	51.916	82.850
4	137281.702	55.575	10.711
5	130023.148	51.916	82.815
6	137281.663	55.575	10.711

For the set (1), where cost are considered as the most important goal which has the highest priority (P1), the solution provides a supply chain configure through which can get the cost as proposed as G1. However, to achieve that, they also have to sacrifice other goals. Besides that, the proposed profit can still be achieved with the sacrifices of G2 and G3 on the desire of the decision makers as the result of the set model (2). In the case, the priority of other objectives change, it means that the managers concerned about other factors in the system, such as Emission or Delivery time rather than cost. The result of running model (3), (4), (5), and (6). Decision makers can completely avoid the adverse impacts on emission and the fruit quality through controlling the delivery time, but with higher cost.

6. CONCLUDING REMARK

An efficient and sustainable supply chain becoming more important for a country whose economy still depends too much on agriculture as Vietnam. From that motivation, this study proposes a mathematical model for the design of a sustainable supply chain with three goals is to reduce the cost, increase the quality of agricultural products, and minimize the impact of the chain supply to the environment. At the same time, this study also presents a goal programming approach in the design of supply chain aiming to creating more flexibility for the management and operation of supply chains. However, because of time limits and the statistical activities in Vietnam has not been done professionally, the collection of data was impeded. In further studies, the adequacy of the data as well as considering the seasonal factors will likely bring many practical applications for agriculture in Vietnam.

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