Dynamical Modeling of Fresh Vegetables while Considering Degradation Effect on Pricing

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Abstract

One of the most critical issue that challenges many fresh vegetables logistics is the transportation. Any delay on transportation would negatively impact the price of fresh vegetables and lead to a huge financial consequences. Transport the perishable food in a specific time is one of the difficult issues that supply chain management face. This paper developed a novel dynamic pricing model that consider the effect of fresh vegetables degradation on pricing. It introduces a dynamical model that aims to minimize the impact of delay through comparing five different delivering strategies while having limited transporting resources. In this research, five strategies have been modeled and analyzed. Each strategy has a situation different than the others. These strategies are Direct Shipment based on Highest Daily Profit Rate, Direct Shipment based on Shelf-Life, Direct Shipment based on the Highest Selling Price, Shipping by Grouping the Highest Profitable to the Nearest Neighbor, and Shipping by the Whole Fleet to the Nearest Neighbor. A case study consists of multiple vegetables with different degradation rates, multiple retailers, and limited transportation capacity that is performed to demonstrate the effectiveness of proposed models.

Keywords
Dynamic pricing, fresh vegetables, logistics, Optimization.

1. Introduction

The term of supply chain has become widely spread over the past few years. It has many different definitions but in general all of them represent the same objective that is either to maximize the total profit or to minimize the cost and waste simultaneously. Basically, supply chain (SC) is an integration of many different entities starting from the supplier, distribution centers, and retailers and to the end-customers. One of the three degrees of supply chain complexity that Mentzer et al. 2001 mentioned is the direct supply chain. This term refers to the set or network of three or more organizations that flow from the source to the end such as products, services, finance and/or information. In manufacturing industries, this network consists of suppliers, manufacturers, plants, inventories, warehousing, distribution centers and retailers. However, performance is really important in supply chain in order to get the best linkage among all entities especially when trading globally. One of the worst things that can corrupt the entire supply chain is uncertainty (Davis 1993; Wang at el. 2014; Almaktoom at el. 2016; Krishnan at el. 2016). Therefore, the supply chain routing represents the most challenging aspect in case of cost and customers' satisfactions. Also, many of companies if not all focus on supply chain in different aspects in order to cut off a lot of cost and maintain smooth services.

There has been several studies in traditional supply chain systems. However, when supply chain systems are used for perishable products, the models and solution techniques have to consider the finite life-period of perishable products.

Physical deterioration most likely appears in food such vegetables, fruits and meat. It is about the losing of quality and freshness over the time but in contrast the value deterioration is about the worth of product, such as a ticket in theater. Moreover, some products lose the value because of aged technology or features such as an old cell phone.
However, we carefully need to propose this study in many different models that effectively deal with some perishables' characteristics. As well as using some technology such as, Radio Frequency Identification (RFID) to maintain quality as well as to decrease the total cost. Furthermore, identifying the risk and mitigating risk is crucial and performed in this research. Some of those barrios are variability and demands fluctuation. Also, one of the main criteria for the perishable products is to focus on the vehicle routing problem (VRP), and vehicle routing problem with time windows (VRPTW).

1.1 Physical Deterioration vs. Value Deterioration

Deterioration is a continuous degradation for any perishable commodities. This running condition of any food products may have a significant effect in the entire supply chain. However, preserving goods in best condition of temperature and into proper storing will reduce the risk of getting them unusable and hence, the total cost will be minimized. Many studies reveal the deterioration rate based on different factors. However, we can notice the physical change of any perishable food by common sense, such as odor, color, and taste. Also, the change could be noticed by its economic value, for example: dollar cost & market value. Therefore, it is always not smooth to figure out the decrease rate of degradation because of many criterion involvements in the assessment of measurement.**.** Degradation is effect on customer's behavior and welling to pay (WTP). Therefore, sellers adjust their prices according to the main factors of dynamic pricing. One of these factors is the time remaining in the selling period. (Wang, Fan, Wang, & Li, 2015).

There are many studies aim to reduce the impact of vegetable deterioration effects using different techniques. For example, Osyald and Stirn (2008) considered the deterioration as a reduction of the vegetable value and the quality as valuation during dispatching from the distributor to retailers. However, when the quality continually drops and almost reaches 0%, there will be a significant loss in the entire supply chain. Another study conducted in 2009 by Chen, Hsueh and Chang categorized the deterioration into two different types. The first one becomes no longer used (outdated) at the end of planning horizon. The other type is deteriorated throughout the cold chain process. However, as the authors stated, this kind divided into two different levels: (1) fixed shelf life; and (2) continuous decay.

In 2009 Blackburn and Scudder determined the loss of the perishable products' value over the time by expressing marginal value of time (MVT). Shukla and Jharkharia (2013) a literature review paper stated that most of publications consider the rate of deterioration as constant and however a few consider it as exponentially change. Moreover, in most of those publications decisions combined with cost in the deterioration rate. One of the highest causes of wastes in the transportation process is deterioration. However, according to this literature, there is no rich contribution in the field of transportation deterioration. Rong, Akkerman, and Grunow (2011) determined the decay rate by considering the loss of quality over the time. However, the quality degradation was modeled based on many variables during storage or transport periods. Cai et al. (2012) formulated the model for both quality and quantity in perishable products. However, they consider the products' degradation throughout the transportation process (quality decline) and obsolete that is responsible for quantity reduction. In 2010 Li, Lan and Mawhinney mentioned that the deterioration for perishable items can be classified into two levels, the item itself decay until becomes outdated and the loss of value due to many factors such as, season or technology. According to Fred Raafat (1991) there are different concepts of deteriorating inventory. However, during the planning horizon, there is some products decay over time and accordingly some have fixed life-time but others have variable life-time. When products become no longer useable, obsolete at the end of season or planning horizon, it is another kind of deterioration in inventory. However, this kind of deterioration appeared in fashion business and hence it loses the value and the products become antique.

1.2 Modeling Perishable Products

There are tremendous contribution in the field of modeling perishable products supply chain. Many papers concern about the vehicle routing problem (VRP) and the distribution of perishable products. In 1986, Fedegruen, Prastacos, and Zipkin developed a model to minimize the transportation, shortage and outdating costs. The study where mainly focused on perishable food and it flows from a central depot to a set of retailers.
Tarantilis and Kiranoudis (2002) introduced a paper titled distribution of fresh meat, the presented research extended the traditional (VRP) to open multi-depot vehicle routing problem (OMDVRP). However, this model is combination of open vehicle routing problem (OVRP) and multi-depot vehicle routing problem (MDVRP). They proposed this model to deal with a real distribution problem in the city of Athens, Greece. In order to solve the distribution of fresh

meat from different depots to many customers, they used a meta-heuristic called list-based threshold accepting (LBTA) algorithm.

In 2007 Hsu, Hung and Li, extended the vehicle routing problem with time-windows (VRPTW) by considering some of perishability characteristics during the dispatching process. After that, they came up with the stochastic vehicle routing problem with time window (SVRPTW) in order to minimize the total costs. Therefore, their proposed model becomes more efficient and valuable than the traditional VRPTW. Since they include the inventory and energy costs, the result shows a significant cost reduction during delivery process. Zanoni, and Zavanella (2007) presented a mixed integer programming model and proposed heuristics algorithm to solve the distribution of perishable products between a single vendor and a single retailer. However, they showed effective results and good performance for minimizing the total transportation and inventory costs that associated with frequent deliverers between the vendor and customer. In 2008, researchers Osvald and Stirn formulated a model as combination of vehicle routing problem with time windows and time-dependent travel-times (VRPTWTD) to solve the distribution problem by using a heuristic approach, Tabu search in presence of some perishable characteristics. They defined the quality as a criterion and consider it in the model in order to minimize the total distribution costs by considering vehicles number, distance, traveling ,and the quality loss. In, 2009, Chen, Hsueh and Chang proposed a combination model for scheduling and delivering perishable products. The developed model is formulated as production scheduling and vehicle routing problem with time windows for perishable goods (PS-VRPTW-P). The objective function of their model is to maximize the total profit of the supplier by identifying when to produce the right quantity at the right time and dispatch the consignment at the minimal costs. Xunyu and Tomohiro (2010) proposed a model for delivering and scheduling perishable products in order to meet the customers' satisfactions and minimize the total expected costs. They developed a meta-heuristics genetic algorithm in order to provide a solution for minimizing the total associated costs for production and scheduling. Govindan at el. (2014) introduced a two-echelon location–routing problem with time-windows (2E-LRPTW) for sustainable SCN design and optimizing economic and environmental objectives in a perishable food (SCN). The goal of (2E-LRPTW) is to determine the number and location facilities and to optimize the amount of products delivered to lower stages and routes at each level. Most of previous research did not consider fresh vegetable in that has rabid degradation rate. Thus in this research author is focusing on developing method that aims to help fresh vegetable wholesaler to minimize cost.

The initial purpose of the supply chain is to maximize the total profit or to minimize the total costs and wastes and accordingly gives the customers the first priority of satisfactions. Joining different facilities together in order to deliver the fresh vegetables to the end customer is a complex process and hence that requires a significant attention. This chain is an integration of many different entities such as; Grower (Farm), Packing Shade, Distribution Center (wholesaler), retailer, and end customer. Fresh vegetables gets rot, spoil, or deteriorated rapidly and accordingly soon after, this prod vegetables might become unusable or completely obsolete. Therefore, fresh vegetables logistics have special nutritional characteristics and hence that requires close attention and unique treatment. This study focuses in wholesaler entity of the SC. The objective of this study is to find the best way of distributing multi vegetables as early as possible in order to minimize the wholesaler total costs. Satisfying customers and fulfill required demand. To keep vegetables fresh and in good shape, wholesalers need to find the fasts way to satisfy all demands as soon as possible in order to avoid the loss. Remainder of this paper is organized as follows. Section two introduces a novel dynamic pricing model based on shelf-live and optimization model to minimize total cost. In section three, a case study is performed to illustrate the effectiveness of the proposed methodology. Lastly, the paper ends with a brief conclusion and some suggestions for future work.

2. Dynamic Optimization Modeling based on Shelf-live

2.1 Dynamic pricing model based on shelf-live

In this research is consider dynamical variables that there values change over time based on the freshness of the vegetables. Vegetables selling price is based on the shelf life and the day of selling. This section introduces model that help in calculating value of vegetables based on shelve live. In general the price fresh vegetables decreases over time until reaches zero value at the last day of its shelf-life period. The selling price for each type of vegetable can be calculated using equation (1).

$$S_{\mathrm{n,d}} = TS_n - \left(\left(\frac{d_{\mathrm{n}} - 1}{sh_n} \right) * TS_n \right) \quad (1)$$

$S_{n,d}$: the selling price for product (n) in day (d)
TS_n: the targeted selling price for product (n)
Sh_n : the shelf-life of product (n)
d_n : the day of selling product (n)

Example:
This example is to illustrate the capability of developed model in evaluating the value of fresh vegetable based on its shelf life. This example calculate the value of three types of vegetables which are Cucumber, Tomato and Okra. The selling price for 1000 kg of cucumber is 8000 SAR and average shelf-live for cucumber is 10 days. The selling price for 1000 kg of Tomato is 4000 SAR and average shelf-live for Tomato is 7 days. The selling price for 1000 kg of Okra is 16000 SAR and average shelf-live for Okra is 3 days.
After applying developed model to this example, price of vegetables for each day is obtained (Figure 1).

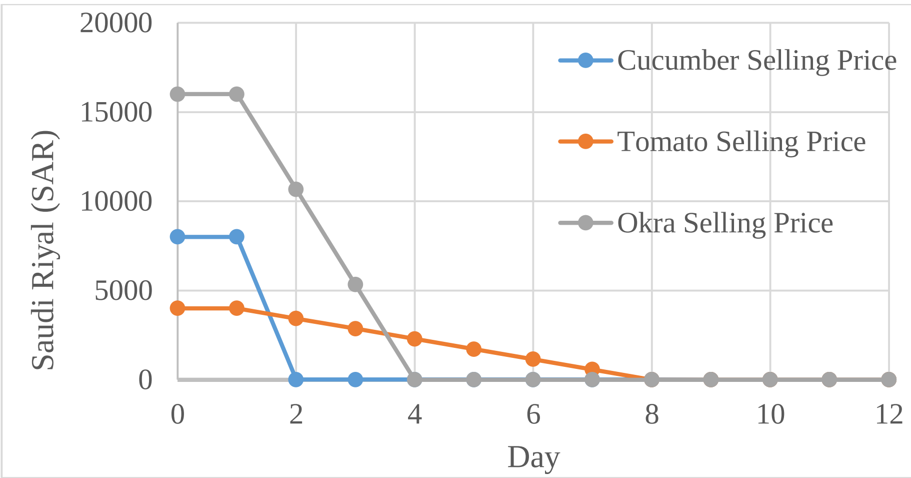

Figure 1. Shelve live vs. Vegetables price

The figure shows that when number of days increase selling price decrease based on vegetables shelf life. For example, the selling price for 1000 kg of tomato in day three is 2, 857 SAR where in day five the price decreased to 1,714 SAR.

2.2 Dynamic Revenue Model based on Shelf-live

Pricing model is been considered in calculating revenue. The revenue can be calculated by calculating the quantity of each vegetable types sold in day (d) times the selling price for the same product type in the same day (d).

$$\mathrm{Re}v_{n,d} = \sum_{n=1}^{N}\sum_{d=1}^{D} P_{n,d} * S_{n,d} \tag{2}$$

$Rev_{n,d}$: revenue from selling product (n) in day (d)
$P_{n,d}$: product (n) sold in day (d)
$S_{n,d}$: selling price for product (n) in day (d)

2.3 Cost Modeling

In this research, the total cost consist of transportation cost and product cost that represents the cost of production plus handling and storing.

i. Calculating the transportation cost (TC) by sing this following equation (3).

$$TC = \sum_{k=1}^{K} C_{ij}^{k} * dis_{ij}^{k} \tag{3}$$

TC: the transportation cost

C^{k}_{ij}: the cost per mile charged for truck k for traveling from node i to node j
dis_{ij} : travel distance from node i to node j

ii. Calculating the total cost which is the product cost and transportation cost. However the total cost (AC) is calculated as the following equation (4)

$$AC = TS + PC \tag{4}$$

AC: total cost
TC: transportation cost
PC: product cost that represents the cost of production plus handling and storing

2.4 Dynamical Optimization Modeling of Fresh Vegetables Pricing

$$Max. \quad TP = \mathrm{Re}\, v_{n,d} - AC$$

$$s.t.$$

$$\begin{aligned}
&\mathrm{Re}\, v_{n,d} = \sum_{n=1}^{N}\sum_{d=1}^{D} P_{n,d} * S_{n,d} \\
&AC = TC + PC \\
&TC = \sum_{k=1}^{K} C_{ij}^{k} * dis_{ij}^{k} \\
&S_{\mathrm{n,d}} = TS_n - \left(\left(\frac{d_{\mathrm{n}} - 1}{sh_n} \right) * TS_n \right) \\
&Sh_n \ \geq 0 \\
&S_{n,d} \ \geq 0 \\
&y^{k}{}_{r} \ \leq \sum k \\
&dis_{ij} \ \leq dis^{U}{}_{ij} \\
&k_{cap} \leq k_{cap}{}^{U}
\end{aligned} \tag{5}$$

3. Case Study

This case represent wholesaler which invests in distribution of fresh vegetables from a central depot to a set number of retailers. Moreover, this case consists of many different vegetables and accordingly each vegetable type has different production cost, shelf-life and selling price deterioration rate as shone in Table 1. The five different vegetable types are labeled as product P1, P_2, P_3, P_4 and P_5. Whenever vegetables are resaved and kept at the depot, the deterioration rate is considered zero but typically the deterioration affect occurs from the first day of selling (second day after receiving products) as shown in Table 2. The life time is variable i.e. P_1 expires at day 12 but P_5 at day 6. Moreover, the production costs of each product are variable as well; and again P_1 has one of the highest producing costs while P_5 has the lowest one. These variables make the investment more risky and complicated especially when the products continuously losing the quality every day.

The expiry day for each vegetable type represents zero value and therefore it is considered the most loss in the distribution process. In contrast, the distributor devotes too much work and money to keep the vegetable as fresh as possible or in the highest quality condition. This mission requires the distributor to deliver the whole stock at once in the first day in order to guarantee the maximum profit. Since the company has limited resources such as; 6 vehicles to distribute all products, it is impossible to deliver all of them at the first day.

The objective of this case is to minimize the total costs by delivering all products as soon as possible to guarantee the higher selling prices. One of the most dominant factors in this process is the vehicle fleet size. In this case study it assumed that the wholesaler cannot increase the vehicles' numbers or make it unlimited to increase the efficiency because of increasing the set-off cost of vehicles.

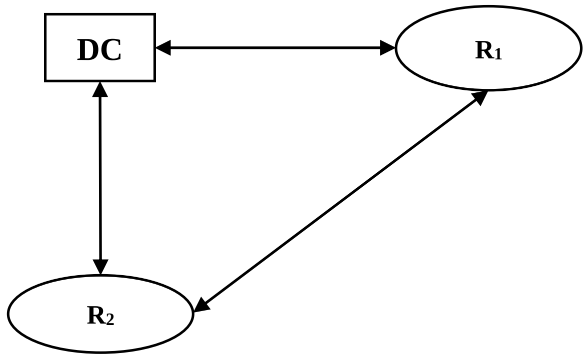

Figure 1: Supply chain network

Table 1: Case Study Parameter

	Traveling Distance (mile)			Demand Quantity				
	Distribution Center (DC)	**Retailer 1**	**Retailer 2**	**Product 1**	**Product 2**	**Product 3**	**Product 4**	**Product 5**
Distribution Center	**0**	**90**	**110**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Retailer 1	**90**	**0**	**50**	**3000**	**2750**	**2900**	**2800**	**3150**
Retailer 2	**110**	**50**	**0**	**2650**	**2800**	**3150**	**2950**	**2800**
Shelf-life (days)	**N/A**	**N/A**	**N/A**	**12**	**10**	**8**	**7**	**6**
Product Cost ($)	**N/A**	**N/A**	**N/A**	**11**	**15**	**6**	**10**	**4**
Selling Price ($)	**N/A**	**N/A**	**N/A**	**33**	**45**	**18**	**30**	**12**

Five different delivering techniques been investigated in this research. This case study assess the best way of selling these vegetables with highest profit. These techniques are Direct Shipment based on Highest Daily Rate (M1), Direct Shipment based on Shelf-life (M2), Direct Shipment based on the highest selling price (M3), Shipping by grouping the highest profitable products to the nearest neighbor (M4) , and Shipping products by the whole fleet to the nearest neighbor M(5).

3.2 Results

This section analysis the result for all five delivering techniques following the proposed methods and models in section 2.

After applying the data showed in table 1 using proposed models in section 2, result showed that optimal delivering techniques to distribute vegetables is M4. Summary of results are shown in the following table (2) and Figure 2.

Table 2: Final results of all methods

Delivering Techniques	Total Cost	Total Revenue	Total Profit
M1	363200	491367.9	128167.9
M 2	380800	401058.9	20258.93
M 3	363200	479082.1	115882.1
M 4	358800	490975	**132175**
M 5	369100	494641.07	125541.1

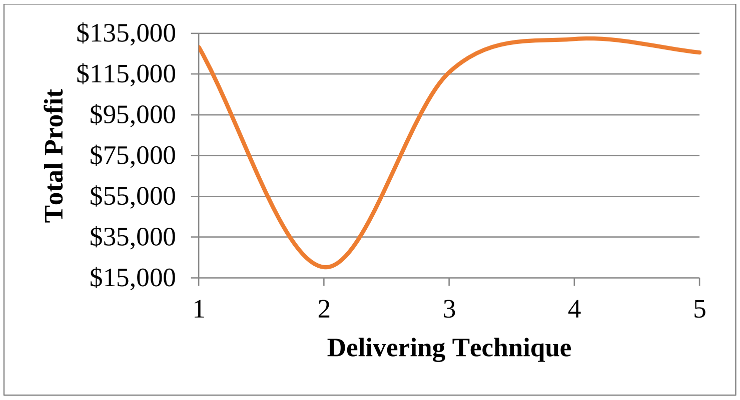

Figure 2: Total Profit

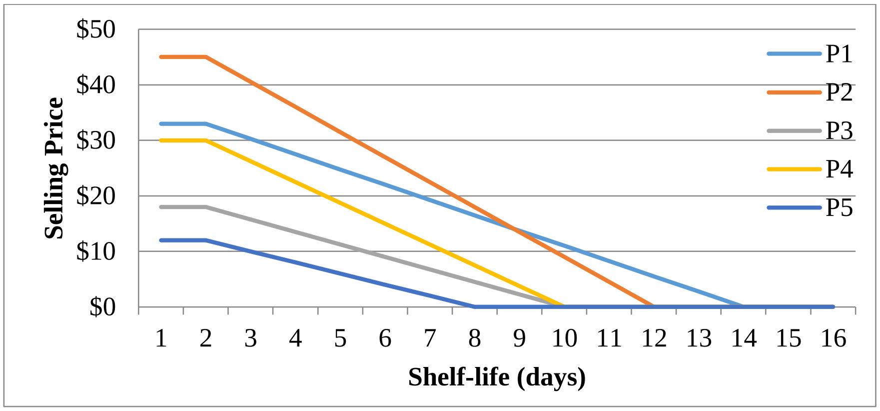

Figure 2: Vegetables price based on shelf life

Most profitable result is M4 which is grouping vegetables together. Grouping vegetables is based on similarities in vegetables profitable ration for both retailers. So we sorted products from the highest profitable to the lowest one as (P_2-P_4-P_1-P_3-P_5). The first group consists of P_2&P_4 representing the highest ration. Moreover, P_1&P_3 as one group and then P5 in one group. The distribution is going to be by groups for both retailers starting with the nearest retailer to the central depot. This process gives very good values until the end of the first round trip of day 4. In day 5 there is little bit lost in P_3 for retailer 1 because of the effect of deterioration rate of P_4 in day 4. The day next we can notice that the P_1 is giving good profit because of the selling price in day 5 ($19.25) too much higher than P_3 in day 4 only ($9). Since P_1 has the longest shelf-life period, P_3 can give one-third of its original price until day 8. So P_1 is considered a rescue product and helpful in the middle days. For the whole day 6 there is significant lose in selling P_3 but the company want to get rid of those goods and get some cash in return before they completely expired. In days 7 & 8 the company cannot make any money and cannot deliver any P_5 because they already expired and therefore company incurred the products' production costs. From Figure 3, we see the P_5 expires in day 6 so there is no benefit or profit expected in days after.

4. Conclusion

This paper presented dynamic optimization model based on shelf-live. In the proposed approach, the freshness of the vegetable is considered in pricing. Also, five transportation techniques are proposed and analyzed in the case study. This paper discussed the deterioration effect of the perishable food pricing. As a future work from this research must continue to enhance optimization techniques. Other techniques such as genetic algorithms to determine faster solutions should be attempted. Need to collect more data from different wholesalers and apply it to the developed model. Also, Applying different scenarios to further test the effectiveness of proposed method.

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Biography

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