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Demand Responsive Transportation Service Problem with Time Windows

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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Abstract

Most countries have high unemployment levels of which Ghana is not an exception (www.ask.com). Most of these unemployed people, especially women engage themselves in wholesale and retail trading of fruits and vegetables. In Ghana, locally produced fruits are of high demand (www.myjoyonline.com/bussiness/2014/january-3rd), but its non-availability results in people patronizing imported fruits. Watermelon business in Bantama market, Kumasi-Ghana, was chosen as a case study. The study focused on an entrepreneur handling the purchasing and transportation of the fruits from source to the market instead of wholesalers. A mathematical model was used to estimate the number of vehicles needed to serve the requests of the wholesalers thereby minimizing cost of transportation with no option of non-availability in the market. In

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pursuit of the objectives, primary data was collected from the general public and wholesalers. The result showed that three (3) vehicles can be used to serve the twenty (20) wholesalers at Bantama market in Kumasi.

Keywords: Transportation service problem; time windows; watermelon.

2010 Mathematics Subject Classification: 53C25; 83C05; 57N16.

1 Introduction

Fresh fruits and vegetables are major food products in human diets and consumption trends show that they are becoming a more important sector in grocery stores. Retail sale of fruits and vegetables keep increasing and there is little evidence of the trend slowing, according to the Produce Marketing Association [1].

Concern for more balanced diets involving lower proportion of carbohydrates, fats and oils, higher proportion of dietary fiber, vitamins, and minerals have measurably influenced the growth in fresh produce consumption. A desire for foods that preserve their nutritional value, retain freshness, natural color, flavor, texture, and contain fewer additives contributes to the development of new markets for fresh fruit and vegetables.

Based on the report from PMA [1], the trend in retail fruit and vegetable produce sales grew 6% in 2006, reaching $56.3 billion. The market for fresh produce has experienced similar increases since 1998. With a clearer health benefits associated with eating fruit and vegetables, a general tendency towards greater consumption and variety in fresh produce market can be expected.

The fruit and vegetable sector comprises both large and small-scale production units geographically throughout the world depending on the specific produce. Most of these products enter commercial channels through retail markets and food services, [2]. Retail markets include but not limited to supermarkets, farmer fresh markets, regional markets, farm stall sales, and some on the farm (you-pick-it).

Watermelon, Citrullus lanatus, is considered a warm season crop. The fruit has a globe or oblong shape, with pulp coloration varying from scarlet to red, yellow, and cream, [3]. Watermelon remains primarily an outdoor fresh fruit delight being popular as a summertime treat, see [4], [5]. It has been found to be the lycopene leader in fresh produces. Although watermelon and tomatoes both have lots of lycopene, watermelon contains higher levels of lycopene than fresh tomatoes and thus human body can use the lycopene from watermelon more easily than lycopene from raw tomatoes. Watermelon has increasingly been marketed as fresh-cut along. It is commonly found in the Ghanaian market as whole, halves, quarters, slices or cubes, which can be bought separately or mixed with different kinds of melons, or with other kinds of fruits. Other than being served as a dessert or fruit salad, watermelon can be compressed into juice.

Since it is a perishable product, it is hard to store and carry into non-producing months. Imports have increased especially in the last several years with nearly all of the imports entering neighboring countries market in the off months of the domestic production cycle. With the imports from other nearby countries, watermelons are generally available throughout the year.

Increasing variety in sizes and different combination with other fruit gives customer more choice and makes it more convenient to purchase melons as ready-to-eat products. For the last decade, watermelons health benefits have been published and more acknowledged by customers. A rapid growth in per capita consumption could be predicted. As a normal commodity, watermelon consumption should change depending on watermelons price, other substitutes price and quantity, personal income, and understanding of product attributes. External factors such as commoditys quality, availability in supply, market outlet, consumers preference, information, and promotion programs may influence demand as well, [6]. The major issue and interest is analyzing and quantifying the factors influencing the consumption of watermelons and the sensitivity of demand to these factors.

Demand models are used to measure the different factors that influence the consumption of watermelon, such as transportation, price, quantity, income, and demographic effects. Transport plays important part in economic growth and globalization. Good planning of transport is essential to make traffic flow and restrain urban sprawl, see [7]. Third world countries such as Ghana face a lot of problems in the public transportation system due to the bad road networks in various remote communities. This makes transportation difficult for suppliers to transport watermelons from various villages to the cities. The large number of users of the roads has also constituted most road network problems. Transportation and communication networks in Ghana have been blamed for impeding the distribution of economic inputs and food as well as the transport of crucial exports.

There are a lot of economical inefficiencies detected in the watermelon business. For instance, more fruits getting spoilt at the market, unavailability of fruits on the market, high pricing of the fruit due to the cost involved in getting the fruit to the market. However, the extensive datasets needed to perform such analyses are usually unavailable. This work, therefore seeks to find a remedy to the above mentioned problem.We also seek to determine the required number of vehicles needed to meet a given demand level with a predetermined level of service.

2 Methodology

Primary data were obtained through the use of questionnaire. These questions were carefully selected to address the problem for the study. Closed-ended questionaires were designed to guide the respondents in order to provide pertinent answers and information for this study. Secondary data sources were obtained from academic journals, internet, and textbooks.

The population for this study is finite. As proposed by Yamane [8], this will allow the researcher to use the Burleys formula for determining the sample size.

$$S = \frac{N}{1 + N(e)^2} \tag{2.1}$$

where: S = required sample size, N = research population, e = margin of error, which was fixed at 5% significance level.

Purposive sampling technique, a non-probability sampling method was used to select the wholesalers of water melon. Convenience random sampling technique was also used to select individuals who reside in Bantama. The method used for the analysis of data for the study was descriptive. Descriptive statistics such as percentages and mean were employed on the data collected for the study. The descriptive statistics dealt with the demographic data of the respondents perceptions on water melon, the respondents views on the time taken to get water melon from the farm to the market, the demand on water melon and the spoilage level of water melon, see, [9].

The operating scenario is partially adopted. Our demand responsive transit (DRT) system consists of a fleet of vehicles with no predefined schedules, [9], [10]. The vehicles travel at a constant speed and cannot be idle. We later show where relaxing the no idling assumption vis-à-vis considering a more idealized scenario simplifies the problem. The service time at the locations is zero and we do not consider capacity constraints since they are dominated by time window constraints in most pragmatic cases.

When making a reservation, the customer has to specify the origin and the destination of the trip, as well as the pickup time. Assume that the load is ready at the source and also the coordinates of the pickup and the delivery points are random variables drawn from the same distribution. Given this distribution, it is possible to compute the distribution of the Euclidean travel distances (the shortest and fastest in view of reducing cost) between any pair of points.

Let $L(A, B)$ be a random variable from the latter distribution, representing the distance between points A and B.

In order to ensure an acceptable quality of the service, the vehicle has to pick up the customers load no earlier than the pickup time and no later than a specified time interval from the pickup time, see [11]. The vehicles cannot pick up a load earlier than the pickup time because the load may not be ready at that time. Also the maximum length of the trip must be somewhat limited. To do this, a maximum wait state is fixed, WS, which is the same for all the customers. A maximum ride time MRT_k is also computed for each request k. The maximum ride time of each customers load is computed in the following way:

$$MRT_k = a + \frac{b.L(P, D_k)}{v} \tag{2.2}$$

where a and b are two parameters that are specified by the scheduler, with $a \geq 0$ and $b \geq 1$. The above scheduling constraints related to the maximum wait state and maximum ride time for each request k define the quality of the service. The most practical way to take them into account in the scheduling process is to define time windows for all the pickup and delivery locations.

Let EPT_k be the earliest pickup time requested by customer k. Then, let (EPT_k, LPT_k) and (EDT_k, LDT_k) be the time windows associated with the pickup and delivery times for customer k, respectively. It is possible to define these time windows on the basis of $\frac{L(P,D_k)}{v}$, WS and MRT_k in several different ways, each method having benefits and drawbacks. The following method is used to compute the time windows:

$$LPT_k = EPT_k + WS \tag{2.3}$$

$$EDT_k = EPT_k + \frac{L(P, D_k)}{v} \tag{2.4}$$

$$LDT_k = EPT_k + MRT_k = EPT_k + a + \frac{b.L(P, D_k)}{v} \tag{2.5}$$

2.1 A model for estimating the required number of vehicles

There are a list of n requests scattered in a service area. The objective is to estimate the number of vehicles needed to serve these requests using the DRT system introduced in the previous section. Where n is the total number of requests, p_r is the probability of serving a set of r requests out of the n requests with the same vehicle. By the above definition of the time windows, $p_1 = 1$. That is, each request can be satisfied if assigned to a vehicle [12]. If for example it is stated that each vehicle cannot serve more than two requests, then there will be on average of $\frac{n}{2}p_2$ vehicles that serve two requests and $n.(1 - p_2)$ serve the remainder. The expected total number of vehicles $E(h)$ needed to serve n requests is then

$$E(h) = \frac{n}{2}p_2 + n(1 - p_2)$$

If now, suppose that each vehicle can serve three requests, there will be on average $n3p_3$ vehicles that serve three requests and $\frac{n}{2}p_2(1-p_2)$ serve two requests. Here, $p_2(1-p_3)$ is the joint probability of serving two requests with a vehicle that could not serve three of them and finally $n.(1-p_2)(1-p_3)$

that serve only one request. Thus, the expected number of vehicles is

$$E(h) = \frac{n}{3}p_3 + \frac{n}{2}p_2(1 - p_3) + n(1 - p_2)(1 - p_3) \tag{2.6}$$

The expected number of vehicles needed to serve n requests can be computed,

$$E(h) = n \sum_{i=1}^{n} \frac{r_i}{i} \prod_{j-i+1}^{n} (1 - p_j) \tag{2.7}$$

It can be noted that the succession of the probabilities $p_1, p_2, p_3, \cdots, p_n$ rapidly converges to zero so that there is the need to determine only the first r values, with $r \ll n$.

2.2 Estimation of the probability of serving two request with a load

From the definition of the problem, if one vehicle has to serve r requests it will have to visit $1 + r$ nodes (1 pickup and r deliveries). Theoretically, there are $(1 + r)!$ possible visiting sequences, and the probability associated to each one should be computed. If an assumption is made that the fleet dispatching process seeks for cost minimization, then the scheduler would choose the visiting sequence that maximizes the possibility of serving all the r requests. It follows that p_r would simply be the maximum of all the probabilities of success that are associated with the $(1 + r)!$ possible visiting sequences. However the presence of the pairing constraints (each pickup point must be visited before the corresponding delivery point) limits the number of feasible sequences (that is, of the sequences that have probability greater than zero) to $(1 + r)!/2^r$

Focusing on the case, that is for $r = 2$. The probability of success in serving with one vehicle any pair of requests (say, 1 and 2) among the n requests waiting to be served will be computed. The vehicle must then visit three nodes: the pickup and delivery point for the first and second requests each one having the above defined time window. These points are indicated with $P, D1$, and $D2$ respectively. Considering the pairing constraint, the feasible sequences are only the following two:

$$PD1D2PD2D1$$

Now, assume that p_2 is equal to the probability of realizing the most likely sequence among the above two. Each sequence is determined by two different events: for example, the first one is feasible if and only if we can serve first P and then $D1, D1$ and then $D2$. Since ther was as assumption that the location of any point is not related to the location of all the others, the travel times of these three events are independent. However, the arrival times to $D2$ is independent on the travel time of the first two legs. In order to simplify the computation of the joint probability of the realization of the above sequence (i.e., P to $D1$ to $D2$), assume that it is the product of the probabilities of the single events. This assumption of independence of the events related to a sequence overlooks the links between the arrival time at a node and the departure time from the same node. We will refer to the probabilities of the single events in a sequence and pd_j indicates the probability of success in visiting the pickup point (p) and then the delivery point (d) of request j, where $j = i+1$. Similarly, there exist pd_i, pd_j, dd_{ji} and dd_ij. p_2 can now be espressed as a function of those quantities:

$$p_2 = max(pd_2.dd_21,\ pd_1.dd_12) \tag{2.8}$$

Considering again the definition of the time windows, therefore, $pd_i = 1,\ \forall i$.
Since the nodes D_i and D_j have a time window, the vehicle can serve both only if the travel time $\frac{L(D_i,D_j)}{v}$ between them is within a certain range. The random variable $L(D_i, D_j)$ and the constant v have been introduced above. If the vehicle is not allowed to idle, there is limit represented by the trip duration when the vehicle visits D_i at the latest time and D_j at the earliest.

$$EPT\left[a + b.\frac{L(P, D_i)}{v}\right] \le WS - \left[\frac{L(P, D_i)}{v}\right] \tag{2.9}$$

This interval can be rewritten as:

$$(EPT - a) \leq bL(P, D_i) \tag{2.10}$$

$$L(P, D_i) \leq v.(EPT + WS) \tag{2.11}$$

$$pd_j = v(EPT - WS) \leq L(P, D_j) - L(P, D_i) \tag{2.12}$$

$$L(P, D_j) - bL(P, D_i) \leq v.(EPT + a) \tag{2.13}$$

$$dd_{ij} = v.(EPT - a) \leq +bL(P, D_i) - L(P, D_j)$$

$$L(D_i, P) - bL(P, D_j) \leq v(EPT + a) \tag{2.14}$$

In the above equations, EPT, and L(,) are random variables, whereas v, a, b and WS are constants. Considering only a subset of requests that can be considered having the same EPT, then the probability intervals associated to each elementary probability become:

$$\begin{aligned} dp &: 0 \leq L(D_i, P) + L(P, D_i) \leq v.WS \\ pd &: -v.WS \leq L(D_i, P) - L(P, D_i) \leq v.a \\ dd &: -v.a \leq L(D_i, P) + L(P, D_i) - L(P, D_j) \leq v.a \end{aligned}$$

For any r, only 3 elementary probabilities that can be computedcan be considered, given the above probability intervals in the following manner:

$$\begin{aligned} dp &= \int_0^{WS} f(L(D_i, P) + L(P, D_i))d(L(D_i, D_j)) \\ pd &= \int_{-v.WS}^{va} f(L(D_i, P) - L(P, D_i)d(L(D_i, D_j)) \\ dd &= \int_{-va}^{va} f(L(D_i, D_j) - L(P, D_j))d(L(D_i, D_j) - L(P, D_j)) \end{aligned}$$

Considering again the case r = 2, equation 2.13 can then be rewritten in the following way:

$$p_2 = max(pd_2.dd_21,\ pd_1.dd_12)$$

Combining this equation with equation 2.6 gives a formula to compute the expected number of vehicles needed to serve n requests having the same pickup time, but different delivery locations. Since the random variable X also follow the binomial distribution with parameters n and p, we write, $X \sim B(n, p)$

The probability of getting r successes in n trial is given by the probability mass function:

$$f(r; n, p) = P(X = r) = \binom{n}{r} p^r (1 - p)^{n-r}, \ \forall r \ = \ 0, 1, 2, 3, \cdots, n$$

Where, n = total number of requests, r = the number of requests that can satisfied by a load, p = the probability of success (serving a load on a day out of the working days), $\binom{n}{r} = \frac{n!}{r!(n-r)!}$ is the binomial coeeficient.

This implies r successes (p^r) and $(n - r)$ failures $(1 - p)$.

However, the r successes can occur anywhere among the n trials and there are $\binom{n}{r}$ different ways of distributing r successes in a sequence of n trials.

3 Results and Discussion

The chosen population of the public was 1600 hence the sample size for the public who eat water melon was:

$$s = \frac{N}{1 + N(e)^2}$$

$$s = \frac{1600}{1 + 1600(0.05)^2} = 320$$

sample size of 348 for the public (consumers) was therefore used for the study. For instance, for a total population(N) of 30 wholesalers is chosen for the study, the sample size:

$$s = \frac{30}{1 + 30(0.05)^2} \approx 28$$

3.1 Distribution and return of questionnaires

Questionnaires which were formulated to obtain the views of the respondent on the demand responsive transportation service problem with time windows were distributed to the selected sample which was made up of 20 wholesalers of water melon and 300 public (customers) of water melon in Bantama. Table 1 gives the summary of the questionnaires to each category and their response rate. From 3.1, 348 questionnaires which were distributed on the selected sample, 320 respondents representing 91.95% were completed and returned which is an adequate response data for the study.

Table 1.Summary of questionnaires to each category and their response rate

Respondent	Administered	Completed and returned	Percentage (%)
Wholesalers	28	20	71.43
Public(customers)	320	300	93.75
	348	320	91.95

3.2 Demographic characteristics of the respondents

It was reported that 253 of the public representing 84% were males while 48 persons who were not wholesalers and representing 16$ were females. This finding shows that majority of the people who ate water melon were males. With regards to the wholesalers, it was revealed that 5 of them who represent 5% were male while 19 representing 95% were female. The results suggests that majority of the females were wholesalers of water melon.

With respect to age distribution, 70 of the respondents representing 21.9% were under 20 years, almost 51 of the respondents representing 15.9% were within the ages $20 - 30, 83$ of the participants representing 25.9% were within $30-40$ years while 116 respondents who represent 36.3% were above 40 years. The result indicates that majority of the respondents were within $31 - 40$ years. Based on this analysis, it implies that majority of the people who patronize water melon are young indicating the business will grow in the near future.

Concerning the educational level of the participants, it was reported that 9 out of the respondents representing 2.8% had no formal education, 6 respondents representing 1.9% had basic education, 124 participants who represent 38.85 had SHS/Vocational/Technical certificate while 119 of the respondents who represent 59.7% had tertiary qualification. The result indicates that majority of the respondents had tertiary qualification.

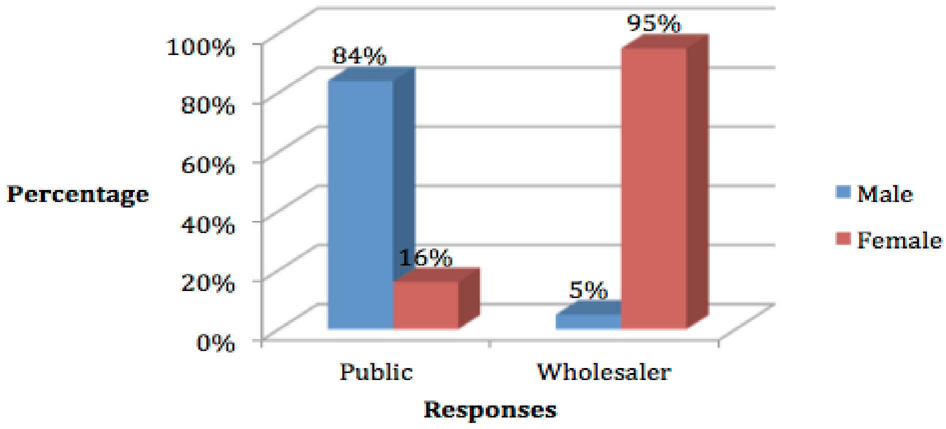

Fig. 1. Gender of respondents

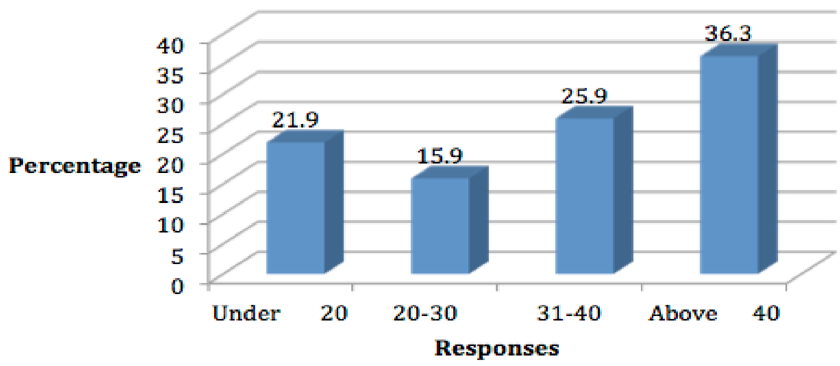

Fig. 2. Age of respondents

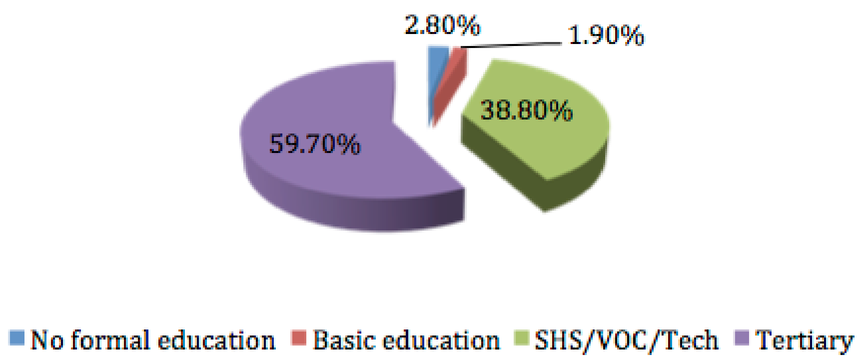

Fig. 3. Level of education of respondents

When we consider the marital status of the respondents, it was revealed that 154 of the respondents representing 48.1% were single; 146 of the respondents representing 45.6% were married; 17 of the participants who represent 5.3% were divorced while 3 respondents representing 0.9% were widowed. The finding indicated that most of the respondents were single.

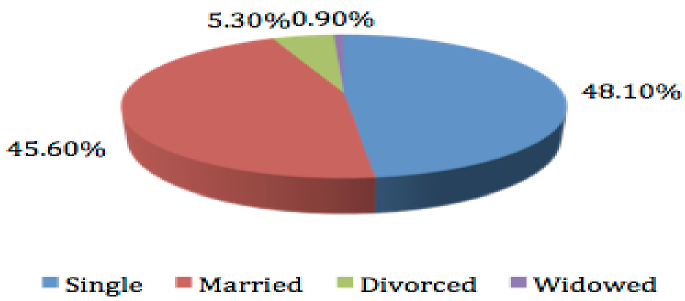

Fig. 4. Marital status of respondents

With respect to occupation of the respondents; the study revealed that 48 respondents who represent 15% do their private work; 164 participants representing 51.3% were government employees; 99 respondents 30.9% were unemployed while 9 of the participant representing 2.8% were retired government employees. The result shows that majority of the participants were government employees.

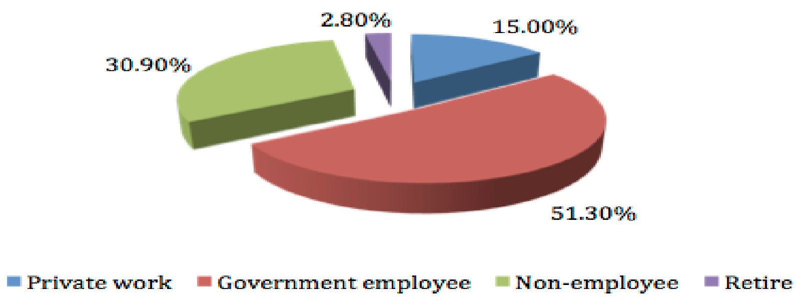

Fig. 5. Occupation of respondents

3.3 Time taken to get fruits from farm to the market

When the wholesalers of water melon were presented with the question where do you buy your water melon from? 4(20%) out of the 20 bought their watermelon from the Ashanti region, 6(30%) of the respondents bought their watermelon from Brong Ahafo region and 10(50%) bought their watermelon from Northern region. The finding shows that majority of the wholesalers buy their water melon from Northern region.

Furthermore, when the wholesalers were presented with the question: Do you buy the fruits fresh from farm? it was reported that 20(100%) of the wholesalers indicated Yes. Based on this analysis, it can be deduced that all the wholesalers of water melon buy the fruits from farm. When the wholesalers were asked how many farmers do you buy one load of truck from?, 4 (20%) of the 20 wholesalers indicated One, 10(50%) of the 20 wholesalers indicated Three while 6(30%) out of the 20 indicated More than 3. The result indicates that majority of the wholesalers buy one truck load of water melon from two farmers.

When the wholesalers were presented with the question: How many days does it take for you to get the required quantity of water melon, 5 of them representing 25% indicated A week or more. The finding indicates majority of the respondents were of the view that they take three days to get the required quantity of water melon.

When the wholesalers were asked how long does it take them to get the fruits from the Source to Kumasi? 19 of the respondents representing 95% indicated One while 1(5%) indicated More than three days. The finding indicates that majority of the wholesalers were of the view that it takes them one day to get the fruit from Source to Kumasi

3.4 Demand for the fruit

When the wholesalers were presented with the question "How does the farmer sell the fruit to you from the farm?" it was revealed that 13 of the wholesalers representing 65% indicated Single, 6 of them who represent 30% indicated In groups of 10; while 1(5%) indicated In groups of 50. The finding indicated most of the wholesalers buy the water melon from farmers in singles.

In another response received, it was revealed that 1(5%) of the wholesalers indicated (14) and 19 of the wholesalers representing 95% indicated $(5-9)$. When they were again posed with the question How much do you sell one ball of water melon?. the result indicates that majority of the wholesalers sell one ball of water melon in the range of 5 to 9.

When the wholesalers were posed with the question What type of vehicle do you use?. It was registered that 3(15%) of the 20 respondents indicated Small cargo trucks while 17(85%) indicated Big cargo truck. The finding indicates that majority of the wholesalers use big cargo truck in transporting their water melon from the source to Kumasi.

In another response received, it was revealed that 17(85%) indicated Full truck while 3(15%) indicated Half truck when they were presented with the question what quantity of water melon do you normally order?. Based on this analysis, it can be inferred that most of the wholesalers normally order full truck of water melon.

When the wholesalers were presented with the question How long does it take one truck load to be sold?, it was reported that 11(55%) indicated 2 weeks while 9(45%) indicated 3 weeks. The result indicates majority of the wholesalers take 2 weeks to sell one truck of load of water melon.

Again the wholesalers were asked How often do you travel to purchase water melon in a year?. It was found that 7(35%) indicated monthly while 13(65%) indicated in every two months. The results indicate that majority of the wholesalers purchase water melon every two months in a year. When the wholesalers were asked how many vehicles arrive in the market in a week?, 3(15%) indicated one, 7(35%) indicated two, 9(45%) indicated three and 1 (5%) indicated more than three.

The results indicate that the majority of the wholesalers were of the view that three vehicles arrive in the market place in a week.

3.5 Spoilage level

When the 20 wholesalers were presented with the question : "How long does it take to offload a truck of water melon?", 19 (95%) indicated one while 1(5%) indicated two. The finding indicates that most of the wholesalers take one day to offload a truck of water melon.

Out of the 20 wholesalers, 19(95%) indicated less than 5% while 1(5%) indicated 5% when they were asked what percentage of the load get spoiled at the time of arrival at the market?. The finding indicated that majority of the wholesalers were of the view that less than one 5% of the water melon gets spoilt at the time of arrival at the market.

When the wholesalers were presented with the question “How do you store water melon?”, it was revealed that 8(40%) of the wholesalers indicated “metal container”, 1(5%) indicated “open space” while 11(55%) indicated “wooden structure”. The result indicates that majority of the wholesalers stored their water melon in a wooden structure.

When the wholesalers were presented with the question “Do you sort the water melon out before storage?”, it was reported that all the 20 wholesalers representing 100% indicated Yes. The finding indicates that all the wholesalers sort the water melon out before storage.

When the wholesalers were asked “Between the time the fruit arrive in the market and the time they get finished, what percentage of fruits get spoiled?”, 12(60%) of the wholesalers indicated $(2-5)\%$ while 8(40%) indicated $(6-10)\%$. Therefore the findings indicate that majority of the wholesalers are of the view that $(2-5)\%$ of the water melon gets spoiled between the time of arrival in the market and the time it gets finished.

3.6 Estimation of the required number of vehicles

Since the survey revealed that the wholesalers work six days in a week and also averagely, it takes them two weeks for their stuff to get sold, it indicates that each of the 20 wholesalers has to be served within the period of twelve days. Therefore, the probability of success is $\frac{1}{12}$, implying that of failure is $\frac{11}{12}$

The probability of serving two requests out of the 20 requests will be:

$$p_2 = \binom{20}{2}\left(\frac{1}{12}\right)\left(\frac{11}{12}\right)^{18} = 0.276$$

Therefore,

$$E(h) = \frac{20}{2}(0.3) + 20(1-0.3) = 17$$

4 Conclusion

Majority of the wholesalers buy their water melon from the Northern region. They buy the watermelon fresh from the farms. Majority of the wholesalers buy one truck load of water melon from two farmers. It was revealed that it takes three days for the wholesalers to get the required quantity of water melon they want. The study also revealed that it takes one day to get the water melon from the source to Kumasi. The wholesalers buy the water melon from the farmers in singles. Majority of the wholesalers sell one ball of water melon between 5.00 to 9.00 and also, they used big cargo trucks to transport watermelon from the source. It was revealed that the respondents take 2 weeks to sell one truck of load of water melon and majority of the wholesalers purchase water melon from source in every two months in a year.

The study revealed that three vehicles (big trucks loads) arrive at their market place a week. The wholesalers take one day to offload a truck. The study revealed that less than 5% of the water melon gets spoilt at the time of arrival at the market. It came to light that majority of wholesalers store their water melon in wooden structures and sort them before the storage. Lastly, between 2% to 5% of the water melon get spoiled between the time it arrives in the market and the time it gets finished.

From the Computational experiment, the probability of serving two requests at a time was found to be 0.3, the mean number of requests to be served a day was 2 and the number of vehicles was also found to be 17.

The study also revealed that it takes a day to get the fruit from the sources to Kumasi. Therefore, the loading, transporting and offloading a load takes a maximum of two days. Meaning one truck can bring supplies three times in a week. It can also be concluded that it takes the wholesalers two weeks to sell a truck load of water melon (a request), therefore, each of the 20 wholesalers will be served within the two-week period and the cycle will continue.

The model estimated the number of vehicles to be 17 (which is for the appearances of loaded vehicles that will serve the 20 wholesalers). But from the above analogies, if one vehicle is able to bring six loads within the two-week period (three supplies in a week), then the number of vehicles needed to be used by the entrepreneur to supply the wholesalers will be approximately 3. The survey also revealed that the wholesalers do the purchasing from three different regions, therefore, the entrepreneur can assign on vehicle to each of the regions.

The problem studied in this work is to envision the application of our methodology in different contexts, for example in problems of distribution of goods in which there are severe time constraints. Another useful generalization of the present work might be the inclusion of the proposed methodology in a demand-supply equilibrium model for a general DRT system, similarly to what has been proposed for the specific case of a deviation service.

Competing Interests

Authors have declared that no competing interests exist.

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