Hypothetical Modeling of a Supermarket Queue-An Approach
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Abstract- Opening a new supermarket is a task especially when there is no other supermarket to make a comparison with. Decision on the number of tills or point-of-sale (POS) terminals to use becomes an issue. The consequences of not getting the number of tills right could lead to wastage due to too many POS terminals acquired that are not needed, and shoppers reluctance to patronize the supermarket due to an incessant queue caused by too few POS availability. This paper objective is to model hypothetically the supermarket queue in such a way that the aforementioned problems being experienced are reduced if not removed. Formulated data were used for the model on spreadsheet. The automation of the model is left for future work.

Keyword- Supermarket; POS; Tills; Terminals; Spreadsheet; and Shoppers

I. INTRODUCTION

Supermarkets are an important component of modern economies. A supermarket is a business enterprise that provides a service. It does not produce a physical product of its own in the usual sense. Instead, it adds value by acquiring existing products from remotely-located suppliers, assembling them in regional warehouses, distributing them to local stores, and finally selling the supplier’s products to local customers (Fig. 1). [1] A supermarket’s customers are primarily local residents and small businesses that periodically need to replenish their stock of household products. A supermarket’s suppliers are primarily producers of household products that are established far from the locations of their final customers. In effect, the supermarket provides a virtual marketplace that brings remote suppliers together with local customers. Given this arrangement, the supermarket “product” is its supply chain. The inputs to the supermarket model include (1) how many people are waiting (2) how many POS terminals or tills there are (3) how long each person takes to be served. This will have to be an average time, since the time depends on the number of items the person is buying and the method of payment (e.g. credit card, debit card, cheque or cash). Producing the simplest model to start with will help to get a grasp of the problem and you can refine it later. The supermarket model introduces a comprehensive framework for managing the complexity of a supermarket structure, and a reusable blueprint for visualizing how a supermarket company actually does business. The model’s clearly-defined core-processes and their functions provide a powerful baseline for improving business performance. [1] By viewing a supermarket business as a single functional system, the nature of its underlying core processes becomes clear. Then by managing and improving them as parts of a single system, substantial improvements can be made on critical success factors, such as lead-time requirements and the precise availability of stock when needed, throughout the supply chain.

Fig. 1. Supermarket business showing the general flow of stock from suppliers through the supermarket business to local customers. (Frank Steeneken and Dave Ackley, 2012)
II. RELATED LITERATURE

[2] present and estimate a simple model of supermarket behavior that has several attractive properties: (1) it permits the incorporation of the (distribution) services provided by a supermarket as an output of supermarkets and a determinant of demand for supermarket products; (2) it generates, as a special case, one of its main competitors in the supermarket literature—the so called full price model of services; and, (3) it can be estimated with a unique data set originally constructed by the Economic Research Service of USDA. The main results of the analysis are three. First, the aggregate demand for a supermarket’s products depends critically on distribution services: at the substantive level, a 1% increase in these services increase quantity demanded by 0.4%; at the methodological level, the restrictions on the parameter values implied by the model are critical in the evaluation of functional forms for demand. Second, supermarkets exhibit constant marginal costs with respect to the quantity of output or turnover and substantially declining marginal costs with respect to (distribution) services, which implies substantial multiproduct economies of scale. Third, in response to an exogenous increase in competition those supermarkets that have adopted newer formats such as superstores and that employ newer technology such as optical scanners choose prices and (distribution) services in ways that increase consumer welfare, whereas those that do not have these characteristics choose prices and services in ways that lower consumer welfare. In [3], a conceptual design model of an automated customer-friendly supermarket has been proposed. In this model a 10-sided, space benefited, regular polygon shaped gravity shelves have been designed for goods storage and effective customer-specific algorithms have been built-in for quick automatic delivery of the randomly listed goods [4]. Although the effective volume of the proposed polygon shaped rack is relative lesser than the conventional rack occupied in the give space, the remaining unused space can be effectively utilized for storage place for the highest consumable items for quick automatic refilling. In this model the algorithm is developed with two main objectives, viz., delivery time and priority. For meeting these objectives the randomly listed items are reorganized according to the critical-path of the robotic arm specific to the identified shop and its layout and the items are categorized according to the demand, shape, size, similarity and nature of the product for an efficient pick-up, packing and delivery process. An experiment was conducted implementing the algorithm to find the shortest path in picking up items for various item sets comparing the conventional design and the proposed design. Literature review and the hands on experiences reveal that if there is one thing that the observations of retail markets from the past years has taught us, it is that there is a lot of demand for various types of items in the day to day life, which are not scientifically processed for a better delivery to the customer. This demand has only increased over the years because of several reasons such as population growth and changing lifestyle. Owing to the change in lifestyle, there is an exponential increase in the number of brands of a particular product under each category. So, as the number of items increase, the size of the conventional supermarket naturally increases. Hence, the time taken for an average person to search for items also increases. This brings about the need for automation in this regard [4]. The heart of automation lies on the disentanglement of the sophistication in the routine activities. According to the data collected by American Time Use Survey (ATUS), an average person spends 40.14 minutes for shopping in a week [5]. According to another survey, Canadians go on 37 general stock-up trips per year at an average of 44 minutes in the store – with an additional 13 minutes of travel time – for a total of 57 minutes on average [6]. Canadians also go on an average of 76 quick pick-up trips per year at an average of 18 minutes in the store – with an additional 9 minutes of travel time – for a total of 27 minutes on average [6]. Thus, from the two independent reports, we can conclude that the minimum average time taken for shopping is 27 minutes and the maximum comes to be 57 minutes on average. The layout of a supermarket has been found to significantly impact a retailer’s overall performance. Layouts are not only concerned with improved utilization of buildings and land but are very much concerned with increasing sales [7]. The results of a survey conducted by Punjaisri and Wilson [8] proved that layout has a big influence on customers and that the customers want stores to spend whatever it takes to create a layout that minimizes wasted steps and motion in the shopping process. Note that the usual retail stores originally displayed their product categories in an industrial department approach, which have produced the store layouts based on fruits, vegetables, magazines, cds, and so on. Despite improvements, the store remains organized in product categories as defined by the manufacturers or category buyers. This approach is company oriented and it fails to respond to the needs of the time-pressured consumer. Most retailers nowadays face challenges such as how to respond consumer’s ever-changing demands and how to adapt themselves to keen competition in dynamic market. These are succinctly reported by Ibrahim Cil [7]. It is well known that in the dynamic retail market, understanding changes in customer behavior can help managers to establish effective store layouts. But in this era it is extremely difficult to understand the customer behavior a priori. Rack design according to [9] plays a major role in shopping scenario. The shape, size and location of each rack are sometimes based on the buying patterns of the customers. Conventional supermarket is closely related to manual order picking warehouses in terms of operation. Searching and picking accounts for nearly 35% of overall timing of the manual order picking in a warehouse [9]. So time spent in these processes can be considerably reduced by applying certain algorithms and optimal rack design which complements the algorithms to the maximum. A conventional rack
consists of rows and columns arranged in a rectangular shape (Fig. 2). Automated Storage and Retrieval System (AS/RS) is placed in front of the rack to retrieve items. Many criteria are available for designing objectives for shelf space allocation. The most frequently used objectives can be categorized to three classes: cost, sales or profit, productivity [10]. The store capacity constraint which designates that the aggregate shelf space allocated to all products cannot exceed total available shelf space in the store [10].

Fig. 2. Conventional rack design. (Sathya Narayanan V., Sidharth P., and Sanal Kumar. V. R., 2014.)

III. THE MODEL

Let us assume there are 100 shoppers waiting to pay for the goods they purchased and there are 40 checkouts. Let us also assume that, on average it takes a shopper two minutes to pass through the checkout. We will have to assume that the shoppers will distribute themselves equally in the queues. We can then calculate the average number of shoppers in each queue using the formula:

\[
\text{Average number of shoppers in each queue} = \frac{\text{number of shoppers waiting}}{\text{number of tills}}
\]

Using our figures we get:

\[
\text{Average number of shoppers in each queue} = \frac{100}{40} = 2.5 \text{ (Fig. 3).}
\]

Now, the last person in each of these queues will have to wait a time which is given by the following formula:

\[
\text{Time last person in queue has to wait} = \text{average time for a person to go through the checkout in minutes} \times \text{average number of shoppers waiting in each queue.}
\]

Using our figures we get:

\[
\text{Time last person in each queue has to wait} = 2 \times 2.5 = 5 \text{ mins (Fig. 4).}
\]
IV. RESULTS AND DISCUSSION

According to the data collected by American Time Use Survey (ATUS), an average person spends 40.14 minutes for shopping in a week [5]. According to another survey, Canadians go on 37 general stock-up trips per year at an average of 44 minutes in the store – with an additional 13 minutes of travel time – for a total of 57 minutes on average [6]. Canadians also go on an average of 76 quick pick-up trips per year at an average of 18 minutes in the store – with an additional 9 minutes of travel time – for a total of 27 minutes on average [6]. Thus, from the two independent reports, we can conclude that the minimum average time taken for shopping is 27 minutes and the maximum comes to be 57 minutes on average. The layout of a supermarket has been found to significantly impact a retailer’s overall performance. Layouts are not only concerned with improved utilization of buildings and land but are very much concerned with increasing sales [7]. The results of a survey conducted by Punjaisri and Wilson [8] proved that layout has a big influence on customers and that the customers want stores to spend whatever it takes to create a layout that minimizes wasted steps and motion in the shopping process. Looking carefully at the model in III and the spreadsheet representation of the model in Fig. 3 and Fig. 4, one will see that the model has been able to address the limitations of some supermarkets regarding customers’ time management as found in the literature by revealing the simple approach for achieving this. The output generated from the model portrayed average number of shoppers in each queue and time the last person in the queue has to wait.

V. CONCLUSION

Time is money so says the adage. This paper has been able to reveal the effect of queuing on customers’ time spent shopping. Taking cognizance of the time spent in a supermarket will in no small measure have a long time effect on both the customers and the shop owner. Considering the model approach used in this paper, the notable consequences of not getting the number of tills right which could lead to wastage due to too many POS terminals acquired that are not needed, and shoppers reluctance to patronize the supermarket due to an incessant queue caused by too few POS availability have been tackled. To make this work an automated work with total flexibility is a future work and the in-depth understanding and appreciation of this paper is a key to developing the automated application.

REFERENCES


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