

Inventory Management Analysis of a HomeGrown Coffee Shop Using the System Dynamics Approach

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Abstract

Inventory management is a method of optimizing the flow of goods in and out of an organization. The objective of inventory management is to get the most benefit from a business inventory with minimal venture costs. It is vital to ensure the business's longevity. In this article, the modeling of the system dynamics pertaining to inventory management was carried out. This study aimed to attain an accurate analysis of the management of the inventory of home-grown coffee shops in terms of sourcing, storing, and to sell coffee – both raw materials and finished goods thereby enabling the company to make inventory related decisions that will benefit the firm. The perennial problem confronting the company lies in the mismanagement of inventories. The results of the study obtained from the methodology applied in this undertaking, was a correct and adequate analysis of the dynamics modeling of a system in inventory management to ensure that the right stock, at the proper levels, and at the right cost, as well as price, is made available to the coffee shop customers. This was attained using the simulation software known as Stella and quantitative methodology-based mathematical calculations. This is a case study of a home-grown coffee shop.

Keywords: Coffee Shop, Inventory Management, Modeling System Dynamics Approach

Introduction

Inventory management assumes a critical role in many organizations as the inefficient inventory system will lead to a loss of customers, sales, and

ultimately profits. An efficient inventory system can generate more sales for the firm, directly affecting the company's profitability and other metrics [8] In addition, inventory management significantly affects organizational productivity [4].

Many organizations had downplayed the possibility of savings from adopting appropriate inventory management. Most business people view inventory as a necessary component of business, not an asset that calls for effective management. This concept has resulted in the creation of numerous inventory systems based on subjective rules. Along this line, it is not unusual for some organizations to have their resources tied up in inventory more than necessary. However, these firms do not have the capability to serve the customers' demands because of inefficient allocation of funds among inventory items [49].

Inventory management ensures that all activities involved in storekeeping and stock control are carried out efficiently and economically by those employed in the store. There has been a question for management about the efficiency of inventory management procedures in place resulting from inconsistencies of inventory levels leading to various weaknesses like losses that come as a result of over, under-stocking, expiry inventory, failure to meet targets and low morale of the company members [18].

Inventory embodies a critical decision variable at all stages of product manufacturing, distribution, and sales, aside from being a significant component of the total current assets of many companies, including coffee shops [4], while poor inventory management hampers operations that diminish customer satisfaction and increase operating costs [47].

The café and coffee shop industry in the Philippines includes all unlicensed specialist outlets that focus on selling coffee in addition to hot and cold drinks and light snacks. In Cebu, Philippines, the so-called 'café culture' has developed rapidly over the past decade, and there are now about a thousand coffee shops and cafés throughout the province, with around four hundred believed to be independent coffee shops. These independent coffee shops account for 20% of the Cebuano market and face fierce competition from large chains such as Starbucks, the Coffee Bean, and Tea Leaf, among others which account for 31% of the local market.

Farmers market coffee to small processors, large companies, and specialty coffee shops. These buyers process coffee into various forms – green coffee beans (GCB), roasted, ground, and instant. The continuous drop in production was caused by various factors such as the increasing number of coffee growers shifting to other crops, old age of trees with limited or no rejuvenation; poor farm practices – limited knowledge of appropriate coffee technology of farmers, aged farmers; limited access to certified planting materials and limited access to credit [10]

Over the years, the market of coffee shops (e.g., Starbucks, Figaro, Bo's Coffee, Coffee Bean, and Tea Leaf) in Cebu has increased. The homegrown coffee shop is an important industry for employment and contribution to the Philippine economy. However, sustainability in terms of longevity is an issue. Despite the low barriers to entry into the industry, cafés are a very high-risk business, and most start-ups fail [6]. Office for National Statistics data shows that for any business started in 2011, the 2-year survival rate is 75%, with the 3-year survival rate 60%, the 4-year survival rate 49%, and the 5-year survival rate 44%. One of the major contributing factors to the failure of the business is the ineffective and poor inventory management systems adopted by the coffee shops.

Since a business' inventory is a significant asset, adopting effective and efficient inventory management practices is imperative to ensure the sustainable operations of a firm [14]. Global markets and operations have prompted companies to revisit their corporate, business, and functional strategies and focus on outsourcing, virtual enterprise, and supply chain management. Sustainability research on supply management has received limited attention. Nevertheless, considering the physically disbursed enterprise environment, supply management is critical for organizational competitiveness [3].

This article seeks to analyze the current inventory management system of a homegrown coffee shop that operates several branches in the Philippines, as the case, using the system dynamics approach. This homegrown coffee shop started its operations in 1996 and has expanded to more than 90 branches across the Philippines. Currently, the organization has encountered severe challenges in providing adequate coffee beans to its various branches due to imbalances in the supply of the raw materials that lead to erratic tendencies in the production process.

This article aims to understand and improve the company's inventory management system where different demand patterns exist, and supply rate is critical. Simulation of the scenarios will be done using the Stella software, and mathematical computations will be utilized to determine the right level of quantity of stocks, cost, and price for the products offered by the homegrown coffee shop to its varied clientele.

Literature Review

Inventory Management

A company's success depends on providing services to clients or users and remaining financially feasible. Inventory management allows a business to sustain logistics, processing, and customer service activities by maintaining appropriate inventory levels. Inventory management contributes to earnings by meeting the marketing and financial

requirements of the company. The primordial objective is to boost commercial activities in three significant aspects: customer service, inventory costs, and operating costs [53]. Inventory management covers the quantity to be retained, reordering frequency, and how much to order.

In the just-in-time manufacturing environment, inventory is considered waste. However, in environments where an organization suffers poor cash flow or lacks strong control over (1) electronic information transfer among all departments and all significant suppliers, (2) lead times, and (3) quality of materials received, inventory plays essential roles. Some important reasons for obtaining and holding inventory are predictability, fluctuations in demand, the unreliability of supply, price protection, quantity discounts, and lower ordering costs [33].

Effective inventory management practices entail holding an appropriate quantity of inventory to ensure that manufacturing goals and customer demands are met all the time [26], [36], [35]. Too much inventory consumes physical space, creates a financial burden, and increases the possibility of damage, spoilage, and loss. On the other hand, too little inventory often disrupts business operations and increases the likelihood of poor customer service. Hence, there is an increased need for business organizations to embrace effective inventory management practices as a strategy to improve their competitiveness [38], [37].

Inventory management is primarily about specifying the size and placement of stocked goods [39]. Inventory management concerns how much to keep on hand, how frequently to reorder, and how much to order. It is essential for day-to-day operations with the objective of meeting customer needs while keeping inventory costs at a reasonable level [30], [31]. Inventory control may range from holding no stock and reordering only when customers place an order (Just-in-time inventory management) to keeping relative inventory levels after anticipating customer needs [43], [30]. Just in time is an approach in inventory management designed to minimize inventory and eliminate excess inventory by producing or purchasing parts, subassemblies, and final products only when and in exact amounts needed [36], [27], [12].

Effective inventory management practices depend on developing efficient planning, control techniques, and proper implementation and administration. Inventory management practices need to be comprehensive in scope because they comprise the policies and procedures by which organizations systematically regulate the range of items held in stock, the quantities of goods in stock, and their replenishment as needed. The inventory provides an essential link in the production and sale of products and constitutes a large proportion of the cost of production [23], [8], [11], [37].

The proper inventory control system is directed at maintaining adequate inventory to meet production targets and customer demand, introducing checks and balances, approvals and authorization to acquire and use materials, tracking inventory movement from acquisition to final dispositions, and monitoring systems' compliance. Inventory, indeed, prevails as one of the largest categories of assets representing a significant investment of funds [37].

Companies like coffee shops need to establish or adopt an adequate standard for controlling and managing inventory to reduce costs and be competitive. This will serve as the basis by which the firms systematically regulate the range of items held in stock, the quantities of goods in stock, and their replenishment as needed [41], [24], [27]. Cost reduction helps prepare employees for managing the inventory ideology and equips the organization with sufficient resources, and that inventory cost reduction helps in achieving profitability objectives [24]. Since inventory represents an investment of financial resources, an effective system of maintaining established stock levels to make profitable use of productive resources must be implemented in storage, ordering, and processing [41], [24], [27]. This means that the inventory-related processes must be attuned to retaining stocks at appropriate levels, safeguarding supplies against loss, and ensuring that stocks are properly used and accounted for.

The entire profitability of an organization is tied to the volume of products sold, which directly relates to the quality of the product [4]. The emergence of a changing economic order has also made companies worldwide seriously consider manufacturing and service sustainability [3]. It has been observed that there is a lack of effective and efficient inventory management practices in some organizations [39].

The business goal of sustainable business operations is challenging, if not impossible, to attain without a comprehensive inventory management system. The system must monitor the business' progress in achieving the objective of effective inventory management by measuring customers' satisfaction, stock availability, profits, operating costs, and expenses [23], [4], [40], [22]. Implementing effective inventory practices can impact the enterprise's upstream sustainability and downstream customer satisfaction [7], [39], [3].

Moreover, a study explored the effect of inventory management on organizational profitability using Gumutindo Coffee Cooperative Enterprise Limited as a case study. It was revealed that inventory management positively affected the profitability of the organization [23].

System Dynamics Modelling

The impressive improvements continuously being made in the cost-effectiveness of computer hardware are causing an enormous expansion in the number of applications for which computing is becoming a feasible and economical solution. This, in turn, is placing greater demands on the

development and operation of computer software systems. A conservative estimate indicates a hundredfold increase in the demand for software [34]. System dynamics is a methodological paradigm for investigating complex systems and is considered a subset of the broader paradigm of simulation models [43], [29]. In analyzing and understanding the inventory management system of a homegrown coffee shop, many elements can be ignored. However, to understand a system, it is preferable to incorporate variables and interactions, even if their representation is complex, and to avoid omitting them [16]. The idea of this approach is to be able to evaluate in a novel way the impacts of possible management and policy interventions and to observe changes in complex systems [48], [45], [50]. A paper uses the system dynamics to analyze the inventory system of a homegrown coffee shop in Cebu, Philippines, to enhance the profitability and sustainability of its operations [16].

System dynamics combines theory, methods, and philosophy to explain system behavior in a wide range of disciplines, such as business management [41], politics [4], economics [46], software engineering [1], medicine [4] and other fields. System dynamics methodology provides a framework for analyzing how actions and reactions cause and influence each other and how and why elements and processes change the system. In this manner, it allows interested parties to understand how the system works and to predict how situations might develop over time [32], [43], [16].

System Dynamics is a computer-aided approach for analyzing and solving complex problems focusing on policy analysis and design. It originates in control engineering and management; the approach uses a perspective based on information feedback and delays to understand the dynamic behavior of complex physical, biological, and social systems [13], [1]. System dynamics involve looking at the information/feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decisions and actions) relate to affecting the success of the enterprise [15]. The systems process the interactions between information, money, orders, materials, personnel, and material flows within a company, industry, or national economy.

Social systems should be created as related flows and accumulations through information feedback loops involving delays and non-linear relationships. Computer simulation is, therefore, the way to deduce the endogenous temporal evolutionary dynamics created by these system structures. The goal is to understand the behavior patterns and design policies that improve performance [25]. Since social systems have many non-linear relationships, an analytical solution to solve model equations is not viable. Hence, Forrester employed an experimental or simulation approach to be used in system dynamics [45], [52]. A salient feature of system dynamics is that feedback and delay cause the behavior of systems

(for example, that dynamic behavior is the result of system structure) [44].

Causal loop (influence) diagrams exhibit the system's structure in system dynamics methodology; a causal loop diagram captures the central feedback mechanisms. These mechanisms are either negative (balancing) or positive feedback (reinforcing) loops. A negative feedback loop exhibits a goal-seeking behavior: after a disturbance, the system seeks to return to an equilibrium situation. In a positive feedback loop, an initial disturbance leads to further change, suggesting the presence of an unstable equilibrium [17], [45], [51].

Causal loop diagrams play two essential roles in SD. First, during model development, they serve as preliminary sketches of causal hypotheses, and second, they can simplify the representation of a model. The structure of a dynamic system model contains stock (state) and flow (rate) variables. Stock variables are the accumulations (i.e., inventories) within the system, while flow variables represent the flows in the system (i.e., order rate), which are the by-product of the decision-making process. The model structure and the interrelationships among the variables are represented by stock-flow diagrams [17], [45], [51]. The mathematical mapping of a stock-flow diagram (SD) occurs via a system of differential equations, which is numerically solved via simulation. Nowadays, high-level graphical simulation programs (such as i-think, Stella, Vensim, and Powersim) support the analysis and study of these systems.

Barlas and Aksogan [5] used a case study in the apparel industry to develop a System Dynamics simulation model of a typical retail supply chain, in this case, a three-echelon chain consisting of the manufacturer, wholesaler, retailer, and end customer. The purpose of the simulation exercise was to develop inventory policies that increase the retailer's revenues and, at the same time, reduce costs.

Rachman et al. [42] developed a dynamic simulation model that included social, economic, and environmental aspects in the supply chain of Gayo coffee in the province of Aceh, Indonesia. Changes in price, demand and environmental terms and the effect of certifications were considered. A sustainability indicator of the coffee supply chain is defined, and improvements are evidenced after intervening key factors are implemented. Hakim et al. [19] developed a system dynamics model for the supply chain of Gayo Arabica coffee in Indonesia, which seeks to simulate the effects of a hybrid production system, quality engineering, governance, climate change, productivity, and competition on the profitability of the chain.

Based on the review of related literature, analyzing the inventory management elements associated with a chain of coffee shops using system dynamics is a novel topic and deserves more research.

Methodology

The research adopted the case study method. The strength of the case study strategy is its ability to examine a case within its real-life context, and it is pertinent when the research addresses descriptive questions of what happened and how it happened or when a researcher wants to illuminate a particular situation, to get an in-depth understanding of the situation [54]

The data were collected based on the financial reports prepared by the homegrown coffee shop's top five performing branches (in terms of profits) for the years 2020 - 2021. Unstructured interviews were also conducted to validate and verify some aspects of the financial information presented in the reports.

The researchers opted to use systems dynamics since it is a powerful methodology and computer simulation technique for understanding and explaining complex issues and problems. The methodology explains how one quantity affects another through the flow of information, and such flows come back to the original quantity causing a feedback loop [16].

In inventory management, a systems dynamics approach can be a simulation method in describing relationships among variables comprising the complexity in natural systems. Causal loop (influence) diagrams exhibit the structure of the inventory system in the System dynamics methodology. The causal loop diagram captures the major feedback mechanisms. Stock-flow diagrams represent the model structure and the interrelationships among the variables. The mathematical mapping of a stock-flow diagram (SD) is done through a system of differential equations, which is numerically solved via simulation. In this study, the researchers used Stella – a high-level graphical simulation program to support the analysis and study of the inventory system of the homegrown coffee shop.

Results And Discussions

Figure 1 presents a single-echelon inventory system's stock and flow structure in its corresponding causal loop diagram. The verbal descriptions coincide with the variables of the model. The arrows represent the relations among variables. The direction of the influence lines displays the direction of the effect.

The three (3) essential variables in the model for this study are the bean stock, the new bean, and the usage rate. The bean stocks are the inventory kept in the storage area where these will be affected by the new bean, the usage rate, and the reorder point. The New Bean is the inflow to the bean stock, which causes the bean stock to increase each time there is a delivery. New Bean is also affected by many other variables,

namely the Economic Order Quantity (EOQ), the Interval, the delivery fraction, the reorder point, and the freshness date.

The Economic Order Quantity is the optimum order quantity that should be placed to minimize the costs of placing the order and the costs of carrying the stock. Ordering costs are the costs associated with placing the order, such as looking for suppliers and receiving them. Carrying costs are the costs associated with storing the items, warehouse payment, electricity, and others. The interval is the time between receiving the order and placing the following order, and the Freshness Date is the maximum time when the stock is considered fresh and tastes good. Reorder point is also considered since this will be the inventory level that will trigger another order.

The outflow to the bean stock is the usage rate which causes its quantity to decrease each time there is a stock withdrawal for use in serving the customers. The variables affecting the usage rate are bean per usage and bean at expiry. Bean per usage is the amount of coffee used per serving. The bean at expiry is the maximum time when the stock is considered safe for consumption, or it may be referred to as the best-before date.

Bean stock is the primary variable, and its behavior will depend on the inflow, the new bean, and, the outflow, the Usage rate. Another vital variable added is the reorder point since this will tell us at what inventory level we will place an order for coffee beans. It is essential to manage the inventory level of the Bean Stock so as not to have too much inventory, which will cost management much money and a waste of resources if the stock is stored for a more extended period of time which could affect the taste of the coffee.

A System Dynamics Approach to Inventory Management of a HomeGrown Coffee Shop

In order to effectively manage the inventory of coffee of a homegrown coffee shop business, a system dynamics approach is used to understand its behavior. In the model, the bean stock is the amount of inventory in the storage area, and this must be monitored so as not to run out of stock which may lead to a loss of customers. The initial inventory is 2,385 grams, considered the average quantity needed by the five most profitable branches. The bean stock is affected by the new bean, the reorder point, and the usage rate. The new bean is influenced by the following variables, the bean stock, delivery fraction, freshness date, the Economic Order Quantity, the Reorder point, and the interval.

The formulas used for the different variables are highlighted as follows:

$$\text{New Bean} = \frac{(\text{Bean Stock}) (\text{Delivery Fraction})}{\text{Freshness Date}} + \frac{\text{Economic Order Quantity}}{\text{Interval}}$$

$$\text{Usage Rate} = \frac{(\text{Bean Stock}) (\text{Bean per Usage})}{\text{Bean at Expiry}}$$

$$\text{Economic Order Quantity} = \sqrt{\frac{2DS}{H}}$$

$$\text{Orders per Year} = \frac{\text{Annual Demand}}{\text{Economic Order Quantity}}$$

$$\text{Annual Demand} = \text{usage per day} \times \text{working days per year}$$

$$\text{Interval} = \frac{\text{Working Days per Year}}{\text{Orders per Year}}$$

Average Values of the other variables in the model:

Delivery Fraction = 0.05

Freshness Date = 120 days

Working Days per Year = 365

Ordering Cost = P50

Holding Cost = P2.00

Bean per Usage = 1.8

Bean at Expiry = 180 days

The annual demand will be based on the usage rate of 750 grams per day (based on the average daily consumption of the most profitable branch) multiplied by the number of working days in a year. The usage rate is affected by the variables bean stock, bean per usage, and the bean at expiry. The bean per usage is the amount of coffee used per serving which is 1.8 grams. The bean at expiry is 180 days since the coffee is at its best when used within two (2) to six (6) months.

Figure 1. Systems Dynamic Model of Coffee Bean Inventory Management

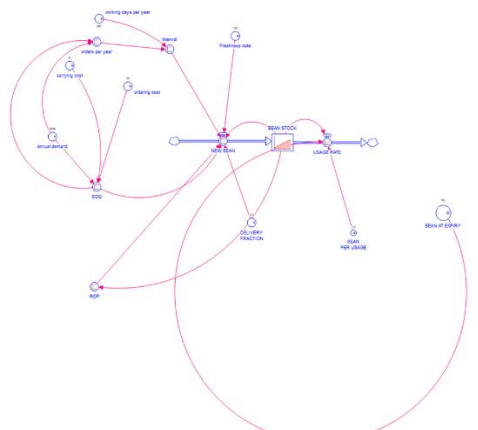


Table 1 shows the quantities of the three (3) significant variables: the bean stock, the new bean, and the usage rate. As seen from the table, the three variables are increasing in the 30 runs since the stock is constantly replenished every time there is a withdrawal from the storage area.

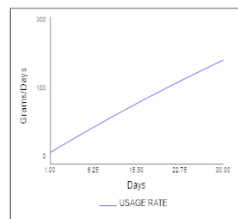
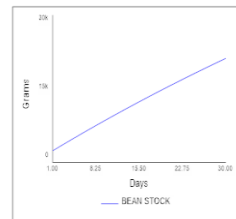
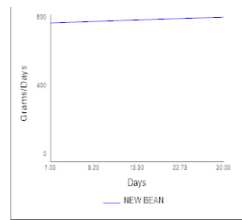
Table I. Quantities of New Bean, Bean Stock & Usage Rate for 30 Days Run (Grams per day)

	NEW BEAN	BEAN STOCK	USAGE RATE
1	751	2.38k	23.9
2	751	3.11k	31.1
3	752	3.83k	38.3
4	752	4.54k	45.4
5	752	5.24k	52.4
6	752	5.94k	59.4
7	753	6.63k	66.3
8	753	7.31k	73.1
9	753	7.99k	79.9
10	754	8.66k	86.6
11	754	9.33k	93.3
12	754	9.99k	99.9
13	754	10.6k	106
14	755	11.3k	113
15	755	11.9k	119
16	755	12.6k	126
17	755	13.2k	132
18	756	13.8k	138
19	756	14.4k	144
20	756	15k	150
21	757	15.6k	156
22	757	16.2k	162
23	757	16.8k	168
24	757	17.4k	174
25	757	18k	180
26	758	18.6k	186
27	758	19.1k	191
28	758	19.7k	197
29	758	20.3k	203
Final	759	20.8k	208

The bean stock showed an initial inventory of 2,385 grams up to the final run on the 30th day, which gives an inventory level of 20,800 grams. The bean stock is increasing since we see to it that orders are placed immediately based on the supplier's lead time and also considering the usage rate, the freshness date, and some other variables, as shown in the model.

The usage rate is also increasing since fewer beans at expiry will tend to give a higher Usage Rate since we see that coffee is used before it reaches its expiry date. Changing the values of beans at expiry will affect the usage rate.

The new bean is also increasing since higher values of freshness date will tend to give a lower value of the new bean, meaning as the freshness of coffee is extended, the order frequency will be decreased. Manipulating the values of the freshness date will affect the new bean.



Conclusion

This paper gave an overview of system dynamics modeling in general and its application to Inventory Management related issues. The analysis of the inventory system of a homegrown coffee shop in Cebu, Philippines, is a topic that deserves more research. As a case in point, several concerns were identified in the management of the inventory of the coffee beans of the business, which had implications on the overall performance of the organization as the coffee beans are its main product.

The use of system dynamics modeling showed that the company could keep track of what is in stock and order only the amount of inventory the firm needs to meet the market demand. The model can also help reduce the costs associated with carrying the inventory since a high inventory level increases carrying costs which also affects the freshness of the product, and ordering costs will be reduced by having the right quantity at the right time, thus controlling the frequency of the ordering process. The company can easily spot sales trends or track expiration dates with

improved inventory tracking and stock control. The model can be an effective tool in the analysis of inventory management.

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