

Can Demand Forecasting Help Supply Chain? Evidence from Beer Distribution Game

Nengah Widiangga Gautama¹, Andi Harmoko Arifin²
Poltrada Bali Logistics Management, Indonesia ¹, Universitas Terbuka, Indonesia ²
530087873@ecampus.ut.ac.id

ABSTRACT

The aims of this study untuk mengetahui Can Demand Forecasting Help Supply Chain? Evidence from Beer Distribution Game. One of complex process known nowadays which involves production, delivery and services to consumers is supply chain. Supply chain often can be simplified and analyzed with simulations like Beer Distribution Game. This research uses simulation experiment method by designing electronic version of BDG. The objective of this simulation is similar to the original version, which is minimizing the total cost spent on a distribution process. In this research, we use an extended version of Beer Distribution Game, built by AnyLogic, and equipped with additional feature such as information sharing. This research uses a simulation experiment method, and from the experiment's result we draw a conclusion based on the effect of SMA forecasting. It is shown that by adding SMA forecasting only at the Retailer unit, does not conclusively reduce the BDG's Total Cost.

Keywords : anylogic; beer distribution game; sma forecasting; total cost

INTRODUCTION

A supply chain can be referred to the specified network of entities, such as organizations, resources, activities, and processes. These entities then become involved during the creation and delivery of a product or service from manufacturer until it reaches the end point, customer. Supply chain management undoubtedly involves a complex mix of activities and entities which can give rise to various challenges and problems. Some of the general problems frequently faced in supply chain management such as: uncertainty in demand forecasting, inventory management as stated in (Bloomfield & Kulp, 2013), and information sharing in (Wei, Zhao, & Hou, 2019). These rising problems in supply chain require solutions, but fortunately we don't have to build a real system for finding those solutions. Recent methods such as process modeling library with computer simulation can be used to provide an overview and analysis of system, including a supply chain (Grigoryev, 2021). One of the known simulations acting as an approach to supply chain is Beer Distribution Game or BDG (Alabdulkarim, 2020).

BDG was introduced as a simulation game by Jay Forrester at the MIT Sloan School of Management in the 1960s. According to (Peng, 2020), simulation can be viewed as imitating the real-world process by using certain model, equipped with certain key characteristics and behaviors. BDG consists of four main units or players: Retailer, Wholesaler, Distributor and Factory. After playing BDG, the first highlight of this game experienced by the four players involved, is the common situation: lack of information. This happened because the only information conveyed from one unit to another is the number of stocks ordered. Lack of information is exacerbated by the absence of history data in each unit and unavailability of forecasting the future trends. The second highlight is the supply chain structure, which is related to lead time. In other words, every order can always be fulfilled as long as there is sufficient stock in the warehouse, but fulfillment time changes randomly. Other things such as cost minimization with the concept of consolidation and collaboration factor is not discussed in this research.

Problems that occur in the supply chain are mainly the result of uncertainty, factor that is inherent in stochastic business processes. Uncertainty in business, happened in Tanzania during the Covid-19 Pandemic lead to supply chain and certain negative effects (Sallwa, 2024). The existence of uncertainty makes each supply chain unit try to prepare reserves to fulfill consumer

orders at any time. Reserve will incur inventory costs or commonly known as warehouse costs in storage process. On the other hand, every player could meet the exact opposite situation. There is a possibility that supply chain units are unable to fulfill consumer's or other unit requests. This situation leads to a situation which give birth to a certain cost, namely backlog cost. According to (Dizikes, 2012) there are three advantages of using BDG:

- a. Managers are able to learn how the system works as a whole.
- b. Actions taken by each unit usually depend on the context of the unit, not as a whole.
- c. Each player realizes that their thinking about the system is often too simplistic and potentially wrong.

RESEARCH METHOD

This research uses simulation experiment method by designing electronic version of BDG. The objective of this simulation is similar to the original version, which is minimizing the total cost spent on a distribution process. The rules applied are largely similar to the original (non-electronic) version of BDG.

- a. Four units in BDG have an initial stock of 25 in each of their warehouse. The process flow is ignited by order from the customer. Then the flow goes to the Retailer, Wholesaler, Distributor and ends at the Factory. Factory in this case does not make an order to fulfill its stock like other units do, but instead make a unique kind of process, which is production.
- b. BDG in this research uses two user's inputs namely: **Threshold** and **Order**. These two inputs are more or less similar to Q (order size) and ROP (reorder point) showed in (Alabdulkarim, 2020). Threshold can be viewed as the lowest point of stocks in each unit. When number of stocks reached below Threshold, unit will start to make ordering process. Number of stocks that every unit will order, are determined by Order. In this case, Order by Retailer is received and fulfilled by Wholesaler, while Order by Wholesaler is processed by Distributor, and so on.
- c. We can run BDG for different lengths of time; in this research we use 1 cycle which is equal to 50 days. The simulation runs in 5000 cycles, so each unit have the same value of Threshold and Order for 5000 cycles (Grigoryev, 2021), while we observe the Total Cost of the system. To simplify the experiment, we only use Threshold value of: 1, 5, 10; while Order is limited as: 5, 10, 15 and 20. Lead time, which represent delay time to fulfill Order, is set between $\frac{1}{2}$ to $1\frac{1}{2}$ days using triangular distribution (Fairchild, Misra, & Shi, 2016).
- d. Demand by consumer is set according to uniform distribution, with values ranging from 0 to 20 per day. This level of consumer's demand is based on (Liu, Howley, & Duggan, 2009) which discusses BDG optimization strategies using genetic algorithms and particle swarm optimization (PSO). According to (Almaktoom, 2024), the consumer's demand belongs to uncontrollable variables, while controllable variables represented by Threshold and Order, lead time and cycle can be categorized as constraints.
- e. The Total Cost calculation is obtained from two components, namely inventory cost and backlog cost. Inventory cost is set at 0.5 per stock, while backlog cost is 1 per stock. Inventory cost is based on the number of stocks remaining in the warehouse, while the backlog cost is based on the difference between customer's (or other unit's) orders and available stock.
- f. Factory determines the number of stocks produced, based on Order. Factory can also send them to Distributor, Wholesaler and Retailer if stocks in each of those units are still lacking. This condition is based on a system understanding strategy (Thompson & Badizadegan, 2015). The main role on this strategy is carried out by the Factory with the ability to control the number of stocks in the supply chain system. This is the counter for "lack of information" problem, which is stated earlier. In the meantime, ability to anticipate consumer's orders is carried out by Retailers through SMA forecasting. Retailers equipped with such capability based on idea of damped oscillation and reaching stability in BDG (Lu, 2021). This forecasting

ability will be automatically started 7 days after the simulation run. Formula used in the SMA forecasting is given as:

$$P_{t+1} = \frac{X_t + X_{t-1} + \dots + X_{t-n+1}}{n} \quad (1)$$

with P_{t+1} depicts forecasting value in the future (t+1) on n amount of data.

We then combine all rules and conditions to create a variant of BDG, built in AnyLogic software, namely Poltrada Beer Game.

RESULT AND DISCUSSION

Within Anylogic, we use the Process Modeling Library facility by applying necessary blocks. To describe the entire simulation process, we need four Delay blocks, one Sink block, and one Source block. The four Delay blocks are the embodiment of the four units in BDG: Retailer, Wholesaler, Distributor, Factory; while one Source block acts as a consumer and one Sink block to end one cycle of simulation. This model is shown in Figure 1.

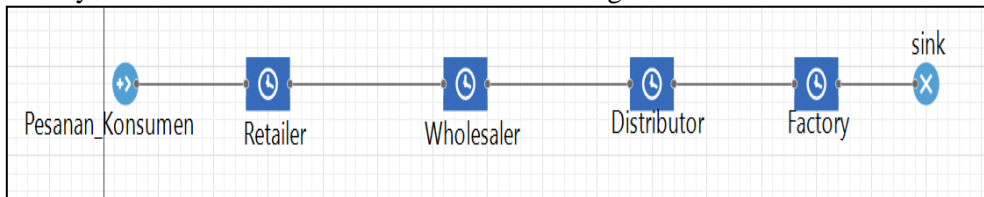


Figure 1. All the six blocks used in AnyLogic

In the Source block, namely Pesanan_Konsumen, in addition to set consumer's orders to the uniform distribution, we also store the history of these orders (in Collection) that can be used later in the Retailer's forecasting. In the Retailer block, we have two conditions. First condition is when consumer's order in Pesanan_Konsumen is more than stock available in Retailer's warehouse, thus creating backlog cost. Second condition triggered when consumer's order can be satisfied by retailer's stock, thus creating inventory cost for the remaining stocks. The ideal situation will be when number of consumer's order is exactly the same as number of stocks available in the Retailer, thus not generating any backlog cost or inventory cost. We use pseudocode as shown in Figure 2.

```

IF (consumer's order is more than retailer's stock)
{
  calculate backlog cost;
  emptying the retailer's stock;
}
ELSE //second condition
{
  reduce the retailer's stock according to consumer's
  order;
  set backlog stock to zero;
}

```

Figure 2. Pseudocode in the Retailer Block

Then we calculate Total Cost and Retailer's only cost, according to backlog stock and retailer's stock. Later in the experiment we experience that Retailer's stock could reach negative value, which is impossible in real life, so we handle this problem by setting it to zero. Pseudocode for this process is shown in Figure 3.

```

IF (retailer's stock reaches negative)
{
  set retailer's stock to zero;
}
calculate retailer's only cost;

```

Figure 3. Pseudocode when retailer's stock reaches negative value

Also In Retailer block, we apply forecasting method using SMA after seven days and history data of consumer's order. We can easily switch between system with SMA forecasting and without, by modifying pseudocode in Figure 4.

```
IF (retailer's stock is less than Threshold AND not
yet reach seven days)
{
  make an order according to Edit Box value;
}
//already reach seven days
ELSE IF (retailer's stock is less than Threshold)
{
  set SMA to zero;
  for (every data in history of consumer's order)
  {
    calculate SMA;
  }
  set retailer's order according to SMA;
}
//not making an order
ELSE
{
  set retailer's order to zero;
}
```

Figure 4. Pseudocode for SMA forecasting in Retailer

After completing all the pseudocode in Retailer block, we do the same thing in the Wholesaler and Distributor block. An additional process occurs in the Factory block, where we demonstrate the stock control capability. The capability is stated in pseudocode as shown in Figure 5.

```
//factory can supply stock to another block
//stock reduction happens, not all stock could be
delivered

IF (stock in Distributor is lower than Distributor's
Threshold)
{
  Factory adds stock with reduction varies from 0 to
10;
}

IF (stock in Wholesaler is lower than Wholesaler's
Threshold)
{
  Factory adds stock with reduction varies from 0 to
15;
}

IF (stock in Retailer is lower than Retailer's
Threshold)
{
  Factory adds stock with reduction varies from 0 to
20;
}
```

Figure 5. Stock control capability in Factory

The initial display of our simulation is shown in Figure 6. Before the simulation starts, user input the Threshold and Order values through each of Edit Box according to each role: Retailer, Distributor, Wholesaler or Factory. Here we introduce notation of **T/O value** to depict the number of **Threshold and Order**.



Figure 6. Initial Display of Poltrada Beer Game

Figure 7 shows when the simulation runs with T/O value of 1/5. Around the top right corner is the value of the Total_Cost, shown here as 1805.5. Below are the costs of each unit: Retailer’s cost is shown as 172, while Wholesaler has 218.5 for its cost, Distributor has the cost of 690, and the cost of Factory is 725. The initial version of Poltrada Beer Game can be seen on: <https://cloud.anylogic.com/model/fa6601a7-b56a-42d1-b73a-b1a96ab05ada?>

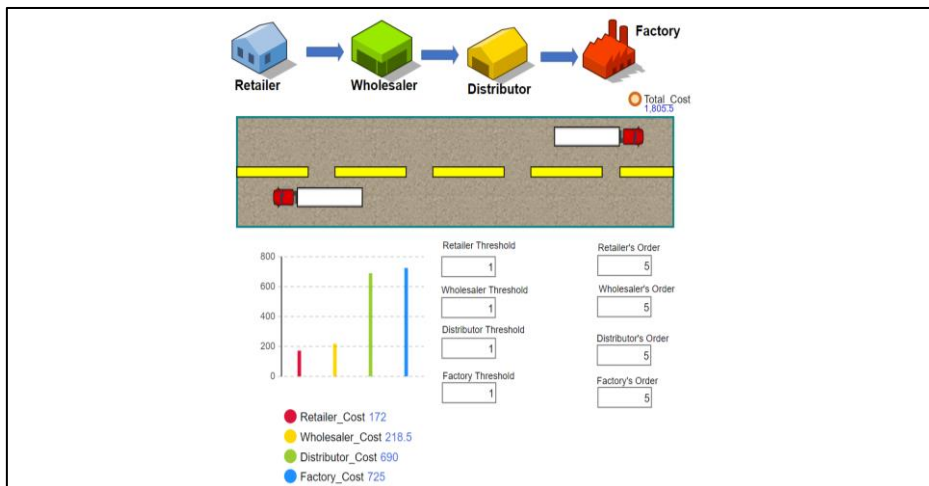


Figure 7. Simulation runs with T/O value of 1/5

Then we collect all the Total Cost data from T/O value of 1/5 and run the experiment with and without the help of SMA. We continue the experiment until the last T/O value available which is 10/20. The average value of Total Cost for 5000 cycles then summarized as shown in Table 1.

Table 1. Summary of Total Cost Calculation with and without SMA Forecasting

T/O	Total Cost without SMA	Total Cost with SMA
1/5	1306.03	1322.01
1/10	1289.99	1315.16
1/15	1443.66	1432.67
1/20	1589.34	1517.13
5/5	1209.29	1252.81
5/10	1246.09	1250.83

5/15	1424.01	1388.26
5/20	1588.71	1515.21
10/5	1158.08	1276.29
10/10	1311.92	1314.04
10/15	1493.29	1483.49
10/20	1868.63	1842.11

From Table 1, we observe an interesting pattern related to T/O. By increasing Order with the same Threshold, number of stocks in each block tend to increase. This increasing stock along the supply chain led to higher Total Cost. Because inventory cost is only half of backlog cost, player may think that it could be better to endure an inventory cost rather than have an out-of-stock situation (and endure the backlog cost instead). This is the exact opposite situation observed in (Darmayanti et al., 2023), when the researcher switches the value of inventory cost and backlog cost.

Understandably, this situation came from the original version's rule of BDG. It is stated that all the order must be fulfilled under any circumstances. When facing out-of-stock situation, backlog cost appears. In reality it can be interpreted that Retailer (or other units) is willing to pay just to fulfil the coming order. This backlog concept can be debatable in some researcher's view, while variant of BDG that can substitute this concept would be an interesting proposal in the future.

We also see that adding SMA forecasting give us mixed results for every T/O experiment. They show us that adding SMA in the Retailer block failed to reduce Total Cost in T/O: 1/10, 5/10, 10/5, 10/15. Thus, it remains inconclusive whether adding SMA forecasting in Retailer block will help reduce Total Cost in Poltrada Beer Game. This research also supports the idea that information sharing was not always effective in increasing supply chain's performance (Tajima, Ishigaki, Takashima, Nishida, & Okamoto, 2023).

CONCLUSION

We like to notify that the research has certain limitation, such as the limited options of T/O that we experimented with. There is still a puzzling question about the optimal setting and strategy of T/O, mainly because of the constantly changed consumer's demand. While adding SMA forecasting method at Retailer does not conclusively reduce the Total Cost yet, there are plenty opportunities in development of this system. Interested researcher can explore more options by adding SMA forecasting to all blocks including Wholesaler, Distributor and Factory. Other computation method such as EMA (exponential moving average) or WMA (weighted moving average) is also worthy to be explored. For educational researcher, there are also opportunities in observing human behavior while human player reacts to response from other units

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Declaration of Conflicting Interests

The authors declared that there are no potential conflicts of interest regarding to publication, research and authorship of this article

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