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System Dynamic Modeling: A Case Study of a Hotel Food Supply Chain

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Abstract

Supply chain management (SCM) has become an integral and indispensable part of the tourism and hospitality industry. However, a closer examination reveals that many firms are battling inventory bottleneck as the covid pandemic spike in demand converges, which results in unpredictability and unstable sale fluctuation. This situation forced the hotel industry to find a balance between fulfilling demand and inventory turnover, which is impossible to predict accurately. Therefore, this research aims to combine system dynamics modelling with a hotel food supply chain system to solve the unpredictability of supply chain dynamics. In addition, The Causal Loop Diagram (CLD) and Stock and Flow Diagram (SFD) are used in this study to model the complexity of the case study supply chain, with an objective model to minimize the instability of inventory turnover and to stabilize the sales movement. This study proposes five policy scenario simulations where standard deviation (SD) and Standard of Error (SE) are used as the decision-making parameters. The simulation result suggests that the fifth scenario provides the highest SD (49.484) and the lowest SE (6.336). Therefore, controlling the customer response time variable to a maximum of 25 minutes and the menu unavailability variable to 15 occurrences per week will result in higher stability of the case study inventory turnover.

Keywords: *Hotel Food Supply Chain, Inventory, Sales, System Dynamic*

1. Introduction

Travel, tourism, and hospitality industries continue to be essential drivers of economic development and employment creation worldwide. However, the growth of the tourism industry has affected a fierce competitive rivalry among tourism and hospitality businesses due to the dynamic life cycle of the industry [1, 2]. This situation is often called the easy entry and exit competitive market concept. Therefore, it is suggested that a proper supply chain management (SCM) strategy adoption has become a precondition for an industry to function effectively.

Unfortunately, hospitality industries also operate in a uniquely different pattern than any other industries. Hotel management tends to make a decision that affects employee-related costs to reduce capital expense [3]. At the same time, a strict SCM system is essentially required for the industry to survive [4, 5].

Furthermore, in the significant hospitality and tourism industry, effective planning and procurement of food and beverage should be one of the areas that must be operated at a higher hierarchy. Food and beverage items are regarded as one of the fastest moving items that require closer attention and handling due to the perishability of the product. Therefore, this condition requires adopting strategic SCM planning that explicitly manages the procurement of food and beverage in the hotel industry [3, 6–8].

Despite its importance in adopting SCM planning, the supply chain recognizes seven distinct challenges the food processing industry must encounter. Challenges such as the dynamic of human resource management, information and technology adoption, massive facilities requirement, strict supplier relationship management, governmental law and regulation and as well as logistic management system have presented a constant boundary for the hotel industry to adopt [9].

Moreover, challenges related to inventory management have also become apparent as a constraint to be managed. In many cases, the fluctuation of demand creates instability in the raw material inventory

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turnover, where the gap between the minimum and maximum demand can be considered too extreme. This condition occurs due to the hotel procurement management's relatively low response and planning in managing stock replenishment. In addition, the Covid-19 pandemic restriction has posed a more unprecedented challenge to the hotel industry. Global strategies to flatten the Covid-19 curve, such as public lockdowns, social distancing, and travel restrictions, have resulted in the temporary closure of the hotel industry, as well as a significant decrease in demand for businesses that were allowed to continue operating [10–13].

Alternatively, these challenges can be mitigated with appropriate policies and regulations that specifically address the problem. An effective and efficient flow of material, product, and information from the supplier to the consumer can be regulated accordingly to align with sustainability-related challenges. One strategy that can be used to assist companies in handling and managing the food supply chain is to use a dynamic system modelling approach. System dynamics is a modelling and simulation framework that provides a method for explicitly representing dynamic complex systems in the actual world [14–17]. In other words, real-world events and conditions can be modelled and simulated to create a framework or strategy that can provide the desired results without having to be applied directly to the object [18, 19].

Therefore, this research aims to apply a system dynamic method that can be applied to the inventory turnover of the hotel industry. The framework of the dynamic system modelling in the study follows the objective function of minimizing the extreme value of the fluctuating inventory movements.

2. Research Methods

This section contains the information required for the data processing sequences. Figure 1 shows the flowchart of research methods.

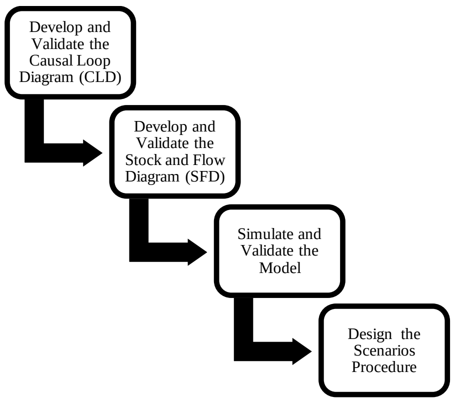

Figure 1. Flowchart of Research Methods

2.1 Developing and Validating a Causal Loop Diagram (CLD) for The Food Supply Chain

This study utilizes several data as the input variable for the proposed model. The data is comprised of the consumption report, which will be the input for the actual demand data, as well as the market list and store requisition data which will be the input for the demand forecasting planning. Furthermore, the raw material demand used in this model consists of two raw materials: wet and dry. Table 1 shows the data input variable used in the modelling.

Table 1. Input Data Variable

Variable Input	Unit
Consumption Report (Wet Raw Material)	818 Kg
Consumption Report (Dry Raw Material)	1,419 Kg
Market List	865 Kg
Store Requisition	1,500 Kg

Therefore, table 1 explains that the consumption report is considered the primary input in registering the menu demand and the raw material (dry and wet raw material) purchased history from the consumer. In addition, the market list is a list of the wet raw material re-purchasing to fulfil the kitchen's inventory demand. While the store requisition is a list of the dry raw material that was prepared from the kitchen to the accounting for inventory demand.

The data processing activity in this study begins by constructing a causal loop diagram (CLD) based on the elements and variables that have been obtained. The constructed CLD is expected to thoroughly characterize the state of the hotel's food supply chain system, with cause-and-effect links depicted through positive and negative feedback loops. The CLD formulation consists of several main stages: first, a preliminary and working CLD is constructed based on the related literature in SCM, while the working CLD is modelled based on a direct interview on the observed model, which will be later compared with the preliminary CLD model.

Furthermore, the constructed CLD is validated based on the literature studies and expert validation of the object in question. This stage aims to measure whether the constructed model represents the actual system or condition. The validation process is carried out using a working CLD that has been built, where the validated model will then be referred to as the final CLD.

2.2 Developing and Validating a Stock-Flow Diagram (SFD)

The following step is constructing a stock-flow diagram (SFD) to represent the system. SFD illustrates the stock in and out of the built CLD by emphasizing the difference between the system's physical structure and dynamic behavior. In this stage, the diagram is constructed using a quantitative formula describing the relationship between the casual loop's variables.

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To validate the SFD diagram, SFD can be validated manually by cross-checking the suitability of the unit of each element and variable within the diagram. Validation is required to ensure that the behavior between variables can be described thoroughly.

2.3. Simulating and Validating the Model

The constructed model is then simulated to reveal the system behavior that can represent the actual condition of the hotel food supply chain. The simulation process in this study is conducted and validated using *Powersim®* software. The model is valid if the simulation results do not contain any error message or result.

2.4 Designing the Scenario Procedure

The formulation of the scenario procedure in system dynamic aims to construct the most optimal result that can be achieved in the simulation. The result is expected to solve he simulation's objective function based on the events and parameters that have been designed previously.

In this case, the best scenario selection depends on the value of a Standard Deviation (SD) and a Standard of Error (SE) from the average simulation result that was addressed to the forecasting planning for the next two months. SD and mean value is considered the most accurate measurement of data variability to calculate normally distributed data [18, 19]. Meanwhile, SE gives the accuracy of a sample mean by measuring the sample-to-sample variability of the sample means. Therefore, SE is more practically used for a statistical report due to its intuitive comparison function that can be presented via graphs or tables [19, 20].

As a result, this paper's selection of the best modelling scenario is based on the smallest range of SD and SE values gained from the sales variables. The expected result will indicate that the Sales value will not fluctuate and scatter in an extreme movement, resulting in a more steady flow of inventory.

3. Results and Discussions

In dealing with the stock management system, the Hotel industry often utilizes a Bar Stock strategic control to show information regarding the minimum stock required in their operation. In general, the minimum stock in a food and beverage industry is generally influenced by the shelf life of the ingredients. Unlinked dealing with a nonperishable product, the inventory of a hotel food industry is constrained by the relatively short shelf life of a product; this indicates that most hotel industries are unable to stock a large number of items in an extended period. While the other side, not having enough of the correct quantity of items can diminish customer satisfaction.

Therefore, bar stock control helps the hotel management maintain the balance between actual and forecasted demand. At the same time, bar stock also provides hotel management with the necessary tool to avoid the risk of unfulfilled orders due to the stock deficit. In addition, bar stock control also maintains the stock level of the ingredients in the inventory by prioritizing the ingredients that are nearing the expiration date.

In this stage, the primary variable is defined as the variable that has a signification value and a dynamic characteristic to cause a change in another variable. In this study, the primary variable is identified based on a direct interview with the Chief Accounting of the case study hotel. The identified variable is later used as a foundation for constructing the Causal Loop Diagram (CLD). The list of the primary variable is described in Table 2.

Table 2. The identified Variables

Variable	Unit
Inventory	Kg
Sales	Pax

Accordingly, this study sums up two main variables in the overall supply chain system of the company, namely inventory and sales. The inventory variable refers to the total of the company-owned food and beverage ingredients and supplies. This variable is regarded as the critical variable in fulfilling the objective function of the proposed model. At the same time, the sales variable refers to the company's total transactions from the external consumer.

In this study, the CLD's variable balances and minimizes the extreme level of inventory fluctuation from the inventory turnover. This condition can be achieved by observing a stable sales movement of the company. Therefore, both variables are regarded as the focus of the simulation

3.1 Causal Loop Diagram (CLD)

Developing CLD in this study began with creating and referencing a preliminary CLD. The preliminary CLD in this study is referred to as the previously constructed CLD in the fast-food supply chain by [23] as the based model for the proposed CLD. Figure 2 shows the preliminary CLD by [23].

The preliminary CLD in figure 2 shows two balancing loops within the diagram, namely B1 and B2. The balancing loops reveal several interrelated variables in one loop and provide a balance of positive and negatives relation. The first balancing loop explains that inventory has a positive value in reinforcing sales and vice versa. In contrast, the second balancing loop illustrates that the variable of Transportation Capacity Shortages is regarded as the reinforcer of transportation capacity. This condition explains that the transportation

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capacity negatively reinforces the value of transportation capacity shortages.

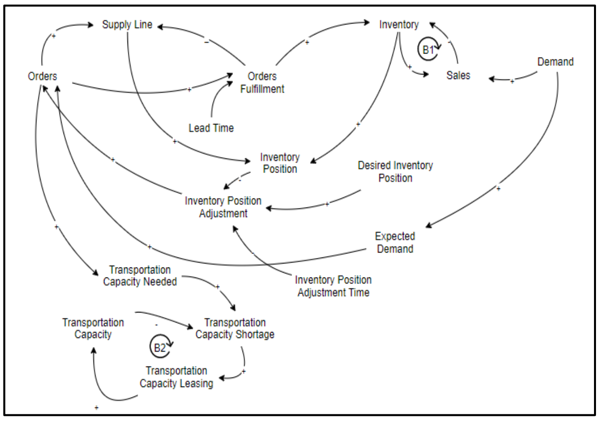

Figure 2. Preliminary Causal Loop Diagram by Georgiadis et al., (2005)

Regarding the proposed model, based on the preliminary CLD and combined with a direct interview with the Chief accounting of the hotel, therefore this study decided to include and revise several new variables for the proposed model. Several new variables such as Order Cost, Holding Cost, Lot Sizing, Order Frequency, Maximum Delivery, and Response Time are assumed as the most appropriate variable to describe the overall supply chain system in the case study company.

However, several variables underwent a nomenclature alteration to fit the actual conditions in the field. The Inventory variable is replaced with the Wet and Dry Inventory variable, and the Expected Demand variable is substituted for the Forecasted Demand variable. The Supply Line variable is developed into the On Order Inventory variable, while the Order Fulfilment variable is replaced with the On Hand Inventory variable. As a result, the final CLD of the study is illustrated in Figure 3.

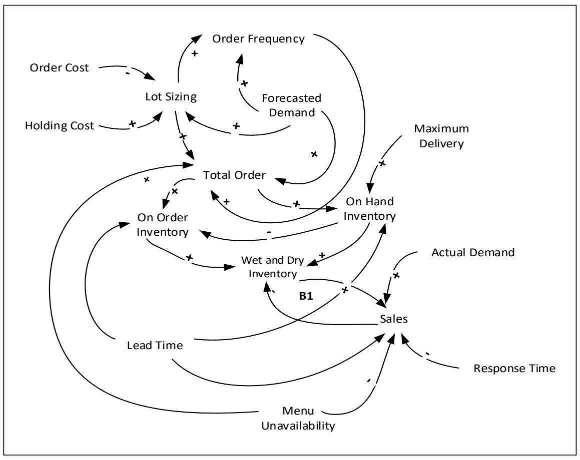

Figure 3. The Final CLD

Based on Figure 3 reveals that adding the Lot Sizing variable will positively affect the number of orders the company will receive. Economic Order Quantity (EOQ) assists the company in determining the number of order that is considered as economical for the company. In addition, The company's Total Order can then be determined based on the Lot Sizing value obtained by the Order Frequency. The order will only be placed based on the stock replenishment planning when the raw material stock if the inventory is deemed unable to meet the received request. The Forecasted Demand will positively influence the Total Order variable.

Furthermore, from the verification result and discussion with the case company, this result figured out that the additional variable that affects the company's sales is the Menu Unavailability variable. This additional variable describes that the total absence of a menu in the company inventory will result in the lost sale or the lost business. The loss of the menu stock is commonly caused by the uncertain number of demands far exceeding the company estimation. Hence, the depleted stock will be automatically added to the subsequent ingredient repurchase.

3.2 Stock and Flow Diagram (SFD)

Stock-flow diagram is a notation that visualizes the physical structure of the system. The visualization is often described as the stock and flow. In this terminology, stock represents the state and condition of the system, while the flow represents the changes influenced by the predicted nature of a system. In its development, SFD is designed from the final CLD that has been validated using *Powersim®* software. The diagram aims to describe the relationship between variables in a comparable unit quantitatively. Table 3 shows the equations that are used in the inventory and sales variable.

Table 3. Data Equation

Variable	Equation
Inventory	+dt*On Order+dt*On Hand - dt*Sales Initial: 0 item/order
Sales	ABS(MIN(Actual Demand/Lead Time;Inventory/Response Time)-Menu Unavailability/Lead Time)

Furthermore, the constructed SFD requires a validation process to ensure that every behavior and relation has a logical visualization. Hence, Figure 4 illustrates the validated SFD of the study.

The result of SFD from figure 4 explains the condition of the hotel supply chain system. In this diagram, Inventory is regarded as the primary variable or the objective function of the SFD model. The model focuses on the stabilization and the minimization of the extreme fluctuation level caused by the inventory rotation.

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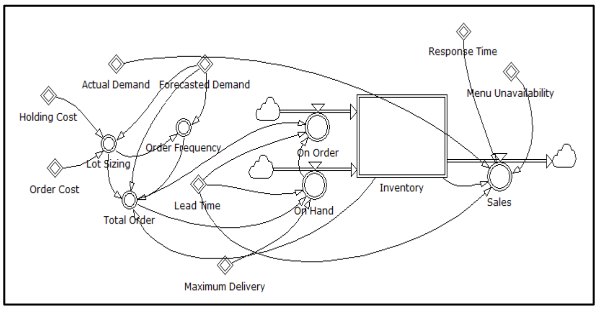

Figure 4. The Stock and Flow Diagram of Hotel food Supply chain

Additionally, the Inventory variable is influenced by the three other variables in the model, which include On Order and On Hand variable that act as the inflow, while Sale variable act as the outflow. This connection explains that the value of inventory variable as a stock can be increased by the inflow and can be decreased by the outflow.

3.3 Model Simulation

The validated simulation model aims to determine the value of existing variables, particularly the inventory and sales. Simulation on the existing condition will operate in daily rotation for two months. In order to clearly describe each variable effectively, the Inventory variable is divided into two sub-variables; inventory 1 consists of a wet food hotel ingredient variable, while inventory 2 consists of a dry food hotel ingredient variable. Figure 5 shows the result of the simulation process on the existing condition.

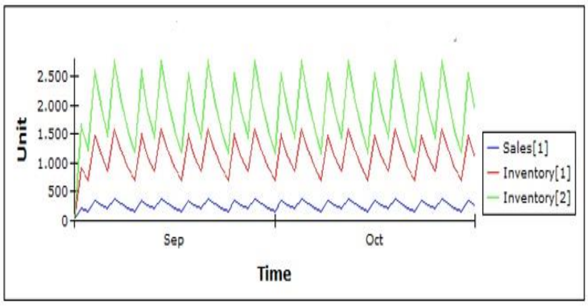

Figure 4. The simulation result on the existing condition

At this stage, we can observe an extreme fluctuation in every system's variable in the existing conditions. The capacity of Inventory 1 and Inventory 2 moved at an average capacity of 1,095.616 kg and 1,892.739 kg, while the number of Sales fluctuated in the range of 262 pax. Table 4 explains the detail of each variable in unit.

Table 4. The Simulation Result on the Existing Condition

Parameter	Inventory 1	Inventory 2	Sales
Mean	1,095.616	1,892.739	262.101
Standard Deviation	331.068	579.461	82.127
Standard Error	42.389	74.192	10.515

The standard deviation produced on the simulation proves that all the data are spread out over a broader range of its average value. In contrast, the standard error verifies the accuracy with which a sample distribution represents a population of the data. The variable of Sales is regarded as the benchmark of the decision policy to stabilize the fluctuation level of the Inventory variable.

3.4 Developing The Policy Scenario

The policy scenarios propose several models to adjust the control variable that influence the value of the primary variable. Based on the previously simulated result, it is known that the variable of Sales affects the inventory circulation. Therefore the scenario plans to stabilize the number of sales of the case study company.

The control variables in this study are the Responses time variable and Menu Unavailability variable. Response time is an elapsed time in a kitchen to complete a customer request. The standard time suggested by the World Tourism Organization (WTO) for a kitchen to complete an order is between 5 to 25 minutes. Therefore, the variable response time will be controlled by the recommended standard.

Regarding the Menu Unavailability variable, this variable states the number of non-available menus at the time of the request, which resulted in the loss of sale. The result from the interview reveals that the menu unavailability is often occurs due to the unpredictability of costumer demand trends, which resulted to the inaccurate stock reorder point. Hotel management claims that stock unavailability commonly occurs in at least one to eighteen weekly occurrences. Therefore, it suggested that the Menu Unavailability variable should be controlled using the field's data to achieve the optimum result. To explore a maximum possible result of the simulation, this research employs and tests five possible policy scenario, and each scenario is explained as follow:

A. Scenario 1

Scenario 1 simulates the Response Time variable as the only response control of the scenario. The variable has a minor condition controlled at 15 minutes standard order times. Meanwhile, the menu unavailability is regarded as the independent variable, so the impact of the Response time variable on the sale and the inventory can be observed more independently. The result of scenario 1 can be seen in Figure 6.

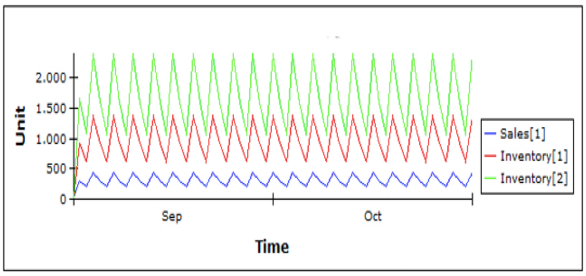

Figure 6. The Simulation result of Scenario 1

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B. Scenario 2

In scenario 2, the Response Time variable is still used as the control variable of the simulation, where the length of the kitchen's response time is increased to 25 minutes. The menu unavailability in this scenario is still regarded as the independent variable. Figure 7 reveals the result from the simulation in the scenario 2.

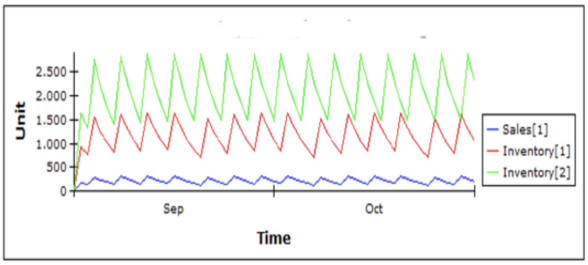

Figure 7. The Simulation result of Scenario 2

C. Scenario 3

The third scenario assumes that the Menu Unavailability variable is the controlled variable. The variable has an occurrence value of 18 per week, higher than the existing condition. Meanwhile, the Response time variable will be used as the independent variable. Figure 8 shows the result of the simulation in the scenario 3.

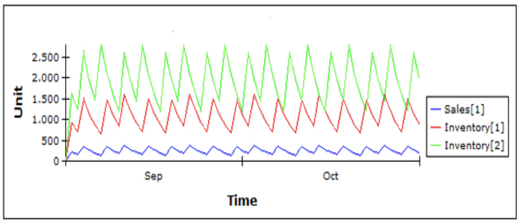

Figure 8. The Simulation Result of Scenario 3

D. Scenario 4

The fourth scenario assumes the reduction of the Menu Unavailability occurrences down to 10 occurrences per week, indicating a lower occurrence than the existing condition. Meanwhile, the other variable remains as the existing condition. Figure 9 shows the simulation result in the fourth scenario.

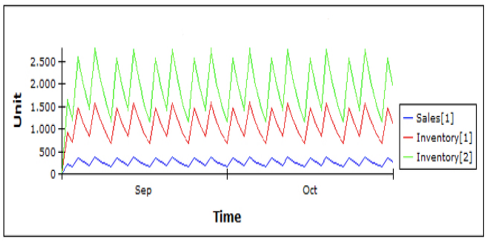

Figure 9. The Simulation Result of Scenario 4

E. Scenario 5

The last scenario regards both Response Time and Menu Unavailability variables as the control variable of the simulation. The scenario assumes that menu unavailability occurs in every 15 orders, while the customer order should be prepared at a maximum response time of 25 minutes. Figure 10 illustrate the result of the simulation in the scenario 5.

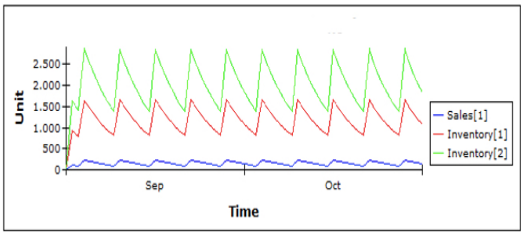

Figure 10. The Simulation result of Scenario 5

Therefore, Table 5 concludes the simulation result from the five developed scenarios in this study.

Table 5. Recapitulation Parameter for the Simulation Scenarios

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Mean	306.906	216.134	249.578	262.297	161.579
Standard Deviation	107.926	64.813	81.394	81.997	49.484
Standard Error	13.818	8.298	10.421	10.499	6.336

The recapitulation result in Table 5 explains that scenario 5 has the lowest standard Deviation (49.485) and Standard of error (6.336) among other scenarios in this study. The Standard deviation and Standard of error are regarded as the result parameter of the study. Both parameters determine the validity of the scenario result based on the number of scattered data points displayed at each level of standard deviation. The Standard of errors determines the sample's accuracy or the accuracy of multiple samples by analyzing deviation within the means [21].

Therefore, the result indicates that the fifth scenario is chosen as the best stimulus to control the simulation's response time and menu unavailability variables. Accordingly, the scenario suggests that optimizing the response time to a maximum of 25 minutes and optimizing the menu unavailability to 15 occurrences per week will result in a more stable inventory and sales level for the case study company.

4. Conclusion

The system dynamic modelling of the Hotel food supply chain reveals that the inventory level is significantly influenced by the total sales the company produces. To minimize the extreme fluctuation level of inventory and sales, this study simulates the case study's Response Time to customer orders and Menu Unavailability as the control variable of the simulation. Furthermore, this study constructs five possible simulation scenarios to observe the stability of inventory movement according to sales.

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Based on the five scenario simulations, the result suggests that controlling the response at a maximum of 25 minutes while maintaining the menu unavailability occurrence to a maximum of 15 occurrences a week will result in the most optimum objective function of the simulation. Scenario number five is therefore chosen as the most optimum scenario with a standard deviation of 49.484 and a standard of error of 6.336. Therefore, by applying the fifth simulation scenario to the model, the expected function model can be achieved because a balanced inventory turnover is closely correlated to the number of balanced sales the company produces.

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