Coordinating supply and demand applied Bass diffusion modelling

Nguyen Thi Bich Tram1\*

1 Ho Chi Minh City Open University, Ho Chi Minh City, Vietnam

\*Corresponding author: tram.ntb@ou.edu.vn

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| **ARTICLE INFO** | **ABSTRACT** |
| **DOI:**10.46223/HCMCOUJS. econ.en.12.2.2148.2022Received: January 10th, 2022Revised: January 26th, 2022Accepted: February 08th, 2022*Keywords:* Bass diffusion model; marketing efforts; multi-method modelling; supply chain management; S&OP  | Demand management concerns what customers need and want, while supply management focuses on producing products/services to fulfill demand. It is challenging in coordinating demand and supply from both sides. Multi-method modeling, which is an interesting combination between system dynamics and agent-based models, is adapted to address this issue through the Bass diffusion model to replicate a non-competitive supply chain, including a retailer, a wholesaler, and a factory in this study. The research findings show that there is a bullwhip effect on the supply chain due to sudden changes in demand impacted by marketing efforts, namely advertising, words of mouth, and electronic words of mouth. It is recommended that in the process of sales and operations planning, businesses should implement, measure, and estimate marketing effectiveness corresponding with supply capabilities. Additionally, through the study, the strengths and weaknesses of the multi-method simulation in facilitating business research reflect through multiple scenarios running with cost and time efficiency, as well as the validity of the study findings associated with modelers’ decisions on the model’s level of simplicity and elaboration. |

# 1. Introduction

Business problems are usually dynamic, complicated, and interrelated by several factors and processes. In order to solve those problems, all possibilities are used to resemble the complexities of business systems. However, traditional approaches such as statistics, analytic calculations, and linear programming are restricted in analyzing multiple interdependent processes operating simultaneously (Harrison, Lin, Carroll, & Carley, 2007). Each method could only capture one aspect of complex business problems. Simulation modeling has emerged as an advanced way of solving problems through mathematical relationships, which can be computed using numerical methods (Axelrod, 1997). In simulation modeling, the system uses its own “virtual” data to overcome the empirical problem of data availability and make more realistic assumptions rather than compromising with analytically convenient ones (Levinthal & Marengo, 2016).

There are three main types of simulation models based on the abstraction level, including System Dynamics (SD) with a high abstraction level, a discrete event with medium and medium-low abstraction level, and an agent-based model as the most flexible abstraction (Borshchev, 2013; T. T. B. Nguyen, 2022). Due to the nature of business problems, dynamic, complicated, and interrelated issues cannot be conformed entirely to only one modeling paradigm. Usually, leaving part of the problem outside the scope of the model is the way researchers choose to overcome this restriction when applying a traditional single-method tool. This is a critical limitation in capturing the interaction of business systems. As a result, there is the fourth type of simulation model, which combines all these types into one model, is called multi-method modeling. This method is widely applied to capture business interactions thanks to its well-known advantages, namely an infinite number of possible architectures, time and cost-saving, and flexible controlling the experimental conditions (Law, 2014).

Likewise, a combination of SD and agent-based models could capture an endogenous point of view and the behaviours of adaptive actors who make up a business system and influence another through their interactions at the same time. In particular, the SD model applies a causally closed structure known as the feedback loops or circular causality that defines its behaviour by identifying stocks or accumulations that affect them. In terms of mathematics, an system dynamics model is a system of differential equations. An agent-based model is created to get a deeper insight into systems that are not well-captured by traditional modeling approaches, namely SD and discrete events. Combining SD and agent-based models is very useful with regard to the extensive usage of graphical editors and scripts to illustrate the divergent behaviour of agents in a model (Borshchev, 2013). In other words, a more straightforward alternative system is being performed and allows to make decisions by running the model and observing the effect to solve business problems. Especially in the case, the system is heterogeneous, different components from different models will be best described. As a result, there is many research applying multi-method simulation to solve critical issues related to business and management (Chandrasekaran, Linderman, Sting, & Benner, 2016; Mota, Filho, Osiro, Ganga, & Mendes, 2021; Tong, Lai, Zhu, Zhao, Chen, & Cheng, 2018)

While balancing demand and supply is a very important task in sales and operations planning within any organization, which requires a massive amount of collaborative work among that company’s departments such as marketing and sales, distribution and logistics, operations, finance, and product development. These processes are designed with the aim of achieving the optimal balance between demand and supply through the production plan in line with the business plan over time. However, the link betweendemand and supply is still unknown, especially how marketing effectiveness from advertisements, WOM, and eWOM affects customers’ demand in a dynamic environment consisting of both demand and supply sides. Usually, previous research is limited to only one field, marketing or supply chain management, respectively (e.g., Chan & Chan, 2005; L. T. C. Nguyen, Tran, Moslehpour, & Do, 2019; B. Zhang, Fu, Huang, Wang, Xu, & Zhang, 2018). The link between marketing efforts, sales, and manufacturing in the supply chain is poorly understood, affecting the coordination of the critical business activities in marketing and sales with the operations and supply chain activities.

Hence, the purpose of this paper is to provide an analysis of applied multi-method modeling to link marketing and supply chain management in the same model, as an illustration, to examine various scenarios of how the supply side reacts to changes in demand due to marketing efforts. Through this study, the advantages and disadvantages of the multi-method model are reflected and analyzed in the context of a non-competitive market. The findings of this study indicate that the bullwhip effect of the supply chain could be easily shown due to changes in demand by marketing efforts, namely advertising, words of mouth, and electronic words of mouth. Additionally, marketing effectiveness should be implemented, measured, and estimated correspondingly with supply constraints in the process of sales and operations planning. The simulation results show that if the firm wants to increase marketing effort, and significantly increase the effectiveness of advertising, WOM or eWOM, over 200% is the threshold of increasing ratio due to restricted supply capacities.

# 2. Theoretical foundations

## 2.1. Modelling methodology

Simulation modeling is an experimenting process in a controlled virtual environment to replicate the working of a system (Law, 2014). The case of a dynamic market, including many supply chain sectors, is highly characterized by chain reaction. Therefore, simulation modeling facilitates researchers to design and evaluate the performance of a complex supply chain and its agents’ behaviour. In this study, a developing process of five key steps, as illustrated in Figure 1 proposed by Juan and Fonseca (2012) is applied to clarify necessary components of a dynamic market involving both demand and supply sides in the same model.

**Figure 1.** The process of model development

Source: Juan and Fonseca (2012)

This process is accompanied by five crucial components of a model, according to Juan and Fonseca (2012). First, the model’s objective is the most important component of a model that helps form the conceptual model. Each model is designed for a specific purpose and enables simulators to create an appropriate simplification of reality. An unclear model’s objectives can result in an overcomplicated model. In this study, the model’s objective is to examine how the supply side reacts to changes in demand due to the different impacts of marketing efforts. Second, the inputs and outputs of the model provide the content of the model. The inputs are the experimental factors that are continuously altered in order to try and achieve the modeling objectives. The outputs are the statistics that inform modelers whether the modeling objectives are being achieved and, if not, why they are not being achieved. In this work, inputs are mathematical equations and constants related to all proposed variables in the model, and outputs result from changing demand and supply chain inventory levels for different scenarios.

Third, the content of the model is formed by the inputs and outputs of the model. In detail, the model must be able to receive the inputs, and it must provide the outputs. The model content can be reflected in two dimensions which are the scope and the level of detail. In simple words, the model’s scope is the breadth of the real system included in the model. The level of detail is the detail to be included for each component in the model’s scope and how to model it. Fourth, assumptions are made either when there are uncertainties or beliefs about the real world being modeled. Last but not least, simplifications are incorporated into the model to enable more rapid model development, usage and improve transparency. Assumptions represent a facet of limited knowledge or presumptions, while simplifications illustrate a facet of the desire to create simpler models. The assumptions and simplifications of the proposed model are specified in Section 3.

## 2.2. Bass diffusion model

Bass diffusion model, which consists of a simple differential equation presenting a rationale of how current adopters and potential adopters of a new product interact, was developed by Bass in 1969. The premise of the original model is that the probability of adoption of a new product at time T could be weeks, months, or years depending on available data.

$\frac{f(T)}{1-F(T)}=p+qF(T)$ (1)

Where: F(T) is the installed base fraction, f(T) is the change of the installed base fraction, p is the coefficient of innovation, q is the coefficient of imitation (Bass, 1969) in the general function. Later, Bass’s model was found that fits the data for almost all product introductions, notwithstanding a wide range of managerial decision variables such as pricing and advertising. This means that decision variables can shift the Bass curve in time but that the shape of the curve is always similar. The generalized Bass model adding x(T) is a function of percentage change in price, or other “marketing effort” variables was developed by Bass, Krishnan, and Jain (1994):

$\frac{f(T)}{1-F(T)}=\left[p+qF\left(T\right)\right]x(T)$ (2)

x(T) can serve to shift the hazard function upward or downward. Hence, p and q are different and distinct functions of “marketing effort” in the generalization. In a real application, according to Bass et al. (1994), in any model with decision variables, three pieces of information will be required, including values of the diffusion parameters (p and q), an estimate of the market potential, and estimates of the response coefficients for the decision variables. The model has been widely used in forecasting, especially new products sales forecasting and product planning up to now. Especially, there are no data available with which to estimate parameters.

## 2.3. Balancing demand and supply

﻿For decades, controversy over how best to determine “marketing effort” such as advertising, Word-Of-Mouth (WOM), and electronic (eWOM) effectiveness has continued unabated as firms struggle to justify expenditures for those of the most extensive line items in the marketing budget (Hogan, Lemon, & Libai, 2004). ﻿It is agreeable among managers, marketing researchers, and sociologists that customer interactions through advertising, WOM, and eWOM can significantly impact consumer response to product demand. From these demands, how firms supply and fulfill consumers’ demands is required effort in sales and operations planning. Sales and Operations Planning (S&OP) is a process that helps firms provide better customer service, lower inventory, shorten customer lead times, stabilize production rates, and give top management a handle on the business (Jacobs & Chase, 2018). S&OP is a critical business process to match customer demand with supply capabilities in the medium term through aggregate planning, by providing an instrument for the vertical alignment of business strategy and operational planning and the horizontal alignment of demand and supply plans (Wagner, Ullrich, & Transchel, 2014).

As an essential role in supply chain management, S&OP integrates organizational units along a supply chain to fulfill customer demand and improve competitiveness as a whole (Tuomikangas & Kaipia, 2014). The organizational perspective covers cross-functional intracompany and supply chain coordination, while the planning/process perspective covers the coordination of material, financial, and information flows (Lim, Alpan, & Penz, 2014). It requires a massive amount of coordination and collaboration between marketing and sales, distribution and logistics, operations, finance, and product development within and across organizations. According to the literature review by Tuomikangas and Kaipia (2014), there are various coordination-related challenges in S&OP such as sub-optimal decisions, difficulties in reaching the desired level of integration within the organization, trading off the risk between unmet demand and excess supply, managing uncertainties in demand, and so on. For example, the operation and logistics departments usually are in charge of managing the supply side, and the sale and marketing department takes over managing the demand side. One side wants to sell as many as possible while the other side cannot fulfill requirements. Additionally, globalization, market uncertainty, and increasing supply chain complexity raise further challenges for S&OP in coordinating supply and demand. These challenges can benefit from various methodological approaches, namely simulation, case studies, and empirical research. Among them, ﻿simulation modeling with multiple perspectives is suitable to deal with the complexity of the S&OP phenomenon under multiple scenarios and assumptions to reflect real life.

# 3. The proposed model

## 3.1. Conceptual modeling

In this paper, a multi-method model containing an agent-based model linked to a System Dynamics (SD) model is conducted to resemble a new product’s supply chain and sales in a consumer market in the absence of competition. This study is constructed grounding on many modeling features of the works in the books of Borshchev (2013) and Law (2014), which are used to examine Bass diffusion for a product on the market considering both supply and demand sides at the same time concerning changes in marketing efforts. In this model, the supply chain and the market are represented on the supply and demand sides, as seen in Figure 2.

In detail, on the supply side, the SD aspect reflects the change in the external conditions for an established and ongoing process. The product is sold via a simple model of a primary supply chain consisting of a retailer, a wholesaler, and a factory. Each active component, which is the agent, maintains a specific inventory management policy. The supply chain also contains its own SD models of manufacturing. ﻿The supply chain model in this paper is a pull-based system, which means the production is driven by the actual customers’ demand rather than by the forecast.

While on the market, the bass diffusion model is used to replicate the process of adopting and discarding this product. On the demand side, the Bass diffusion model is applied in SD approach to simulate the market using the equations of Bass et al. (1994). The product is being sold to consumers who are sensitive to advertising, WOM, and eWOM. The link between the market and the supply chain is assumpted as the following. The SD model exposes its demand stock to the retailer, and the retailer transfers consumers from the demand stock to (actual) Users stock when it is able to satisfy the consumers’ needs.

**Figure 2.** The conceptual model

Source: The author

## 3.2. Defining model characteristics

### 3.2.1. Demand side

There are three stages in the market in the SD model of Bass product diffusion to simplify the demand side. The SD aspect in this study is used to model the change in conditions for an established and ongoing process of Bass diffusion in adopting and discarding products affecting demand variation. The same architecture is used to model manufacturing processes of the factory, where continuous-time equations best describe part of the process on the supply side. In detail, Potential users stage (stock) indicates when people have a need and want for the product. Demand stage reflects when potential users are being affected by “marketing effect”, and Users stage demonstrates when they actually buy the product. Potential users will become Demand by Adoption rate following Bass diffusion model. Demand is satisfied by Supply becoming Users, and Users will demand new products after they discard old products, as illustrated in Figure 3.



**Figure 3.** Demand and supply model

Source: The author

We have x potential users in the market and y users (x,y $ϵ R^{+}$). Potential users create demand through adoption rate equation as fA = f(Ad, WOM, EWOM)/total market, fAd modifies the advertising effectiveness by the number of potential users and advertising effect rate $r\_{i}^{A}$, fWOM is calculated by contact rate $r\_{i}^{C}$, the fraction of the market $δ$ and numbers of potential users and users, fEWOM is calculated through its relationship with WOM by $γ(t)$ following the suggestion from the studies of Hogan et al. (2004); H. Zhang, Yuan, and Song (2020) ($r\_{i}^{A}, r\_{i}^{C},δ, γ(t) ϵ R^{+}$). Thus, the adoption rate equation can be expressed as follows:

 $f\_{A}= \frac{\sum\_{i}^{n}(f\_{Ad, }f\_{WOM},γ(t)f\_{WOM})}{x+y }$ (3)

 $or f\_{A}= \frac{xr\_{i}^{A}+ xyr\_{i}^{C}δ(1+γ\left(t\right))}{x+y}$ (4)

Discard rate is calculated by product lifetime z (z $ϵ R^{+}$) per number of users, discard rate denotes: $f\_{D}= \frac{z}{x}$

### 3.2.2. Supply side

On the supply side, an agent-based supply chain consisting of a retailer, a wholesaler, and a manufacturer is implemented grounding on the model of inventory system by Law (2014). Each month, each supply chain company reviews its inventory level and decides how many items to order from its supplier. When an order is placed, it is distributed immediately (0 lead times). Each company uses a stationary (s, S) policy to decide how much to order:

$X(t)= \left\{\begin{array}{c}S(t)-I(t) if I(t)<s\\0 if I(t)\geq s\end{array}\right.$ (5)

where *I(t)* is the inventory level at time *t* and *I(t)* $\geq 0$, *s,S* $ϵ R^{+}$.

The goods flow of the supply chain is as follows. At time *t*, the retailer receives orders from Demand on the market, it checks its inventory, and satisfies immediately if *I* $\geq D$. If *D > I*, the excess of demand over supply is backlogged *B* and satisfied by future deliveries, so the backlog is equal to demand minus inventory. The wholesaler’s behavior is the same as the retailer, it receives orders from the retailer and checks its inventory. If the order can be shipped, it will remove the order from the queue. $β$ is a random variable of delivery that is distributed within *[a, b]* day (*a,b* $ϵ R^{+}$). It updates the inventory level equal to the current inventory level plus expected shipments minus backlog. If the order cannot be shipped, it will order following the rule (5) to the manufacturer. The manufacturer has the same manner as the wholesaler plus its own system dynamics model to manufacture with manufacturing rate $r\_{i}^{M}$per day ($r\_{i}^{M}$ $ϵ R^{+}$).

## 3.3. Running the model

The significant benefit of developing simulation is that we can run as many scenarios as we desire, opposite experiments. It is impossible to do the same with experiments that need to be carried out in the real system due to high cost, consuming time, and restricted control of the experimental conditions. In this study, multiple scenarios are run to compare the differences in WOM and eWOM effectiveness on demand and how each supply chain sector reacts in terms of its inventory levels. In detail, WOM $f\_{WOM} $and eWOM effectiveness$ $ $γ\left(t\right),f\_{WOM}$ are adjusted in a wide range while the rest variables remain the same. Initial input data are displayed in Table 1. The model is coded using Java programming language and run using Personal Learning Edition developed by © the AnyLogic company, which is widely used for multi-method modeling for both industrial and academic research (software available at https://www.anylogic.com/). Through five scenarios, the whole supply chain is running with a stable inventory policy, and the initial inventory level at each sector is equal to a constant. Only $γ(t)$ is changed in a range [1,4] to illustrate the level of WOM and eWOM effectiveness increases from normal (only WOM, no eWOM) to a higher level (including eWOM) by multiplying up to fourfold as seen in Table 1.

Table 1

Input data of the model in five scenarios

|  |  |
| --- | --- |
| **Variables** | **Scenario** |
| **1** | **2** | **3** | **4** | **5** |
| Potential users *x* | 100,000  | 100,000 | 100,000 | 100,000 | 100,000 |
| Advertising effect rate $r\_{i}^{A}$ | 1.1% | 1.1% | 1.1% | 1.1% | 1.1% |
| $$γ(t)$$ | 0 | 1 | 1.5 | 2 | 4 |
| Contact rate $r\_{i}^{C}$ | 10 person per day | 10 person per day | 10 person per day | 10 person per day | 10 person per day |
| Product life time *z* | 60 days | 60 days | 60 days | 60 days | 60 days |
| Fraction of the market $δ$ | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% |
| Initial inventory of each sector | 70 units | 70 units | 70 units | 70 units | 70 units |
| Inventory policy (s,S) | (2,000, 4,000) | (2,000, 4,000) | (2,000, 4,000) | (2,000, 4,000) | (2,000, 4,000) |
| $$Delivery β$$ | [0.5,1] | [0.5,1] | [0.5,1] | [0.5,1] | [0.5,1] |
| Manufacturing rate $r\_{i}^{M}$ | 4,800 units per day | 4,800 units per day | 4,800 units per day | 4,800 units per day | 4,800 units per day |

Source: Data analysis result of the research

The results of justified demand on each sector’s inventory level within a period of 200 days are illustrated in Figure 4. The simulation modeling results show that in scenarios 1 and 2, when increasing the level of WOM and eWOM effectiveness from only WOM, no eWOM to the combination of WOM and eWOM as $γ(t)$ equals 1. The changes in demand in both scenarios are the same. Hence, there are no significant differences between scenarios 1 and 2. The clear impacts of marketing efforts on demands start to show when $γ(t) $surges within (1,4] in scenarios 3, 4, and 5. The inventory levels of each sector in the supply chain change dramatically, especially the inventory level of the wholesaler and the factory suffer the most since they approach and reach nil level several times in these scenarios.

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**Figure 4.** The inventory levels of each sector in multiple scenarios

Source: The author

# 4. Discussion

The previous sections have provided the concept model and the simulation to analyze product Bass diffusion in the non-competitive market considering both supply and demand sides at the same time regarding changes in marketing efforts. From the results of simulating different effectiveness levels of WOM and eWOM, there are dramatic changes in demand under diversified marketing efforts. A more vigorous marketing effort affects demand to increase faster than usual. However, whether firms should allocate massive resources to marketing efforts to take advantage of this result generates a lot of interesting discussions below.

As seen in Figure 4, changing demand in the market leads to a dramatic change in the behaviours of the retailer, the wholesaler, and the factory. Although in this simulation model, the unit of model analysis is restricted to the unit of goods through demand and inventory level of each sector in the supply chain, we could see how increasing demand impacts the capacity of the supply chain in Figure 4. The more demand increases, the more goods each sector supplies. The retailer receives orders directly from customers. Therefore, it suffers the slightest changes in the inventory level through five scenarios.

On the contrary, the wholesaler and the factory show a clear trend of volatility in their inventories due to fluctuation in demand. At some points, when the demand reaches a peak, the wholesaler and the factory are unable to fulfil orders due to empty inventories (*I* = 0) and limited manufacturing capacity under assumptions of this model. These assumptions reflect productional constraints, and it is not easy for firms to expand their production scale within a short time. Frequent adjustments to the production plans usually lead to increases in production and inventory/shortage costs, reduced productivity, lower customer service levels, and a general state of confusion on the shop floor (Demirel, Özelkan, & Lim, 2018).

In supply chain management, it is acknowledged that the benefits of buffers, including inventory, capacity, and time, have a non-linear impact on the supply chain’s resilience (Schmitt & Singh, 2012). When these buffers reach nil, it posts many risks related to supply disruption, which could last a lengthy period and require considerable time for each chain sector to recover. In this study, the supply system does not have flexibility built into it via inventory policy throughout the system. As a result, disruptions can have a more prolonged, worse impact than a scenario when some inventory flexibility is available (T. T. B. Nguyen, 2021). Most of the time, firms try to minimize inventory as an essential and money-saving endeavour. It should not be undertaken without considering that it has a direct bearing on increasing both demand-side risks in this case. ﻿It is cautious that ﻿disruptions may be local in nature when they strike a system; the impact could be globalized and spread both upstream and downstream instantaneously (Schmitt & Singh, 2012).

From the perspective of marketing, when the speed of goods supply cannot keep up with the rate of change in demand, it is evident that marketing efforts become useless in this case. Any business adjustment is related to cost, and marketing effort is no exception. Although “marketing is an investment, not a cost” according to Sir Martin Sorrell, when we invest in something, we still care about Return On Investment (ROI). Marketing effectiveness is the optimization of marketing resources to achieve better results for both short- and long-term strategic marketing objectives (Bui, 2022; Milichovský & Šimberová, 2015). Marketing effectiveness requires much visibility into the results that assist organizations to prioritize better their efforts, the quality, and the precision of marketing resources. To this end, marketers could consider different approach to optimise the organisational resources, such as applying advanced technologies to satisfy customers (Mogaji, Soetan, & Kieu, 2020).

As a result, the findings of this study suggest that marketing effectiveness should be implemented, measured, and estimated accordingly to the supply capacities of the company, which are related to production rate, inventory facilities, distribution, and logistics abilities. Integrating marketing effort and supply processes can support firms to prioritize and ensure fulfillment grounded on a shared generation, dissemination, interpretation, and application of real-time customer demand as well as ongoing supply capacity constraints (Esper, Ellinger, Stank, Flint, & Moon, 2010). Extensive integration between the demand-side and supply-side streams of information establishes a strong foundation of value creation through intra-organizational function management in S&OP.

Taken together, the findings of the study contribute to practical implications in marketing, S&OP activities, and supply chain management for firms by suggesting the threshold of increasing marketing effort for firms. In practice, nil inventory is not recommended. Therefore, increasing marketing effort too much is not practical in terms of cost and the ability to fulfill demand. From the results of this simulation modeling, 200% is the threshold of increasing ratio due to restrictions in the supply capacities. Coordination in S&OP and supply chain is emphasized in the study of T. T. B. Nguyen (2021) since productional constraint poses many challenges for firms to expand their production scales within a short time due to soaring inventory/shortage costs, reduced productivity, lower customer service levels.

Regarding the research methodology, multi-method modeling is used and analyzed to modify the advantages and disadvantages of this method for business studies as the main research contribution of the study. This study is an illustrated example of using multi-method modelling in researching to solve a practical issue related to coordination of marketing, S&OP, and supply chain management. There are several obvious advantages and disadvantages why simulation is preferable to such research. First, multi-method simulation has captured dynamic interactions among supply chain sectors triggered by marketing efforts. In detail, many scenarios are analysed through many alterations to see the differences of each scenario and its behaviours. It is easy to make changes immediately at no cost and without interruption to the real-world system’s operation with a simulation. Second, when comparing alternatives, controlling the conditions under which the experiments are performed is extremely helpful. Then, direct comparisons are easier to make. Also, with a simulation model, the conditions under which an experiment is performed can be repeated many times as researchers want.

Nevertheless, the findings of the paper may be somewhat limited by the level of model complexity. Usually, a simulation model is constructed by combining simplicity and elaboration (Harrison et al., 2007). This model could be more realistic by adding many variables such as analysis units (not only demand and inventory level) and competition in the market (more than two agents of retailer, wholesaler, and factory). However, adding too many variables in the same model also makes it too difficult to code, calculate and understand what happens and drives the results in the model at a highly complicated level. Finally, the value of simulation findings lies in the validity of the simulation model. In this research, the author attempts to assess the model’s behaviour over a range of conditions under technically demanding and susceptible to errors in a technological environment. Thus, generated data by simulations do not entirely represent real observations.

# 5. Conclusion

The main goal of the current study is to apply multi-method modeling in solving business problems related to coordinating supply and demand. Multiple perspectives of simulation modeling show its advantages, disadvantages, and suitabilities in addressing the complexity of the S&OP phenomenon under multiple scenarios and assumptions to reflect the difficulties of coordinating demand and supply. In this study, a dynamic market is captured and analyzed by Bass diffusion model in adopting and discarding products under the impact of marketing efforts as well as demand fulfillment of a non-competitive supply chain.

The findings indicate that on the supply side, the bullwhip effect of the supply chain could be easily shown in inventory due to changes in demand. The retailer is at a closer distance from customers; negative consequences on its inventory level are the least compared to those of the wholesaler and the manufacturer. The evidence from this study suggests that companies should pay attention to rapidly growing demand because changing demand within a short time induces supply disruption.

Additionally, one of the issues that emerge from these findings is that marketing efforts need to synchronize with the company’s supply capacities. Otherwise, marketing efforts are not effective in terms of allocating their marketing resources. The study also suggests that marketing effectiveness should be implemented, measured, and estimated correspondingly with supply constraints in the process of S&OP. Taken together, these findings highlight the importance of a strong foundation in value creation through intra-organizational function management of S&OP based on the installation of extensive integration in matching demand and supply.

This study is an example to illustrate that simulation modeling is flexible and suitable for business researchers. Nevertheless, the readers should bear in mind that the study is based on multi-method simulation. There are a few drawbacks in interpreting the results due to the assumptions and simplifications of the model. In this study, assumptions are made to explore the interactions of the dynamic market dealing with changing demand. Also, simplifications with reference to the unit of analysis and no competition in the market are incorporated in the model for rapid model development, ease of usage, and improved transparency.

Contrarily, increasing the model’s level of elaboration, such as including competition in the model, might correctly replicate the dynamic nature of a market. It is cautious that greater accuracy creates a greater complexity level of the model’s inputs and outputs. Also, the units of analysis, namely lead and delivery time for each order, revenue, and cost of each sector in the supply chain, could be added to elaborate the current model. The issue of replicating market reality is intriguing and could be usefully explored in further modeling works. Future works with the application of multi-method modeling and using mentioned approaches could be interesting to examine this method’s advantages, and disadvantages deal with the complexities of proposed systems in the business context.

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