# DECISION MODEL IN SUPPLY CHAIN SIMULATION GAME, EXPERIMENTAL STUDY IN THAILAND

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***ABSTRACT***

*This study describes on decision making model for supply chain management by a favor simulation-based named "beer game" (including four supply chain units; manufacturer, distributor, wholesaler and retailer within 40 cycles simulated order placement). This study is also concentrated on analyzing factor that influencing to the "bullwhip effect" under criteria on accumulated value of cost reduction and inventory level. This's under instruction for supply chain units to collaborated inventory plan and computerized simulation ordering via "beer game" during cycle 11 to end game of 40. It is applied to usually require demonstration information flow. The study finding on the total cost tends to increase according to the index of the bullwhip effect and bullwhip effect will tend to occur when there is a shortage at manufacturers. The collaborated information on consumer demand and the amount of outstanding products is benefit to the supply chain to drive decision making process to replenishment order and trend to reduce, mitigate and retard this effect several for discrete-event oriented models. Future work offers apply simulation model for a multi-criteria towards robustness performances indicators of entire supply chain.*

***Keywords:*** Supply Chain Simulation, Beer Game, Uncertainty Environment, Decision Making Model on Business Planning

***INTRODUCTION***

Simulation modeling is nowadays a well-known tool for many applications in various fields of study, especially as tool for decision making [1, 2]under multi-criteria and scenarios of fuzzy and uncertainty environment [3, 4]. Simulation also practiced as a tool for education STEM workshop and learning by practicing and continual. It has also been, providing approaches to design realistic case within controllable factors and multi criteria. One remarkable area of application is production management since simulation can provides learning scenarios or how-to approaches; there still have statistics on simulation fail due to validity and reliability; neither from the processes nor results [5-7]. The popular one on simulation of supply chain is beer game, developed by [8], represent as a role-play simulation game that lets participants experience typical coordination problems of traditional supply chains, on information sharing and collaboration non exist. In general, this supply chain represents any non-coordinated system where problems arise due to lack of systemic thinking. It purposes for testing strategies to coordinate action of supply chain units complied with criteria of efficiency. In a study of decision-making in the supply chain the availability of information at the point of sale, delivery time or lead time and demand patterns are analyzed in terms of efficiency of the supply chain. Event of information sharing from customer to entirely supply chain was found to be helpful or

harmful; on the other hand, it was found that a shorter response time helps to improve the efficiency of the chain, regardless of the behavior of demand. These events and decisions are seen in the form of patterns of demand behavior and system structures.

In this article focus on impact of sharing information on the financial performance of the chain [3, 9-11] so measurements on logistics costs; accumulated value of cost reduction [8] which are representative of the financial performance of the chain also with the efficiency of supply chain; inventory level trial on beer game application. This research objectives (1) Study supply chain decision making factor by apply experimental design focus on multi criteria; stock level and accumulate value of cost and (2) Study factors affecting bullwhip effect.

## *LITERATURE REVIEW*

### *Decision making model on supply chain*

[8]developed industrial dynamics conceptual model, which later extended and renamed system dynamics; a nonlinear model of a supply chain using first-order differential equations without sensitivity and cost-based analysis. Many discrete-event simulation packages available today provide a more advanced simulation capability. However, such bullwhip can easily be incorporated into a discrete event simulation model (DES). DES has two characteristics: (1) representing individual events, e.g., an individual customer order; (2) incorporated uncertainties, e.g., fluctuation on demand and customer orders each point of time. Most of systems dynamics models are non-stochastic, but the behavior often becomes indecipherable cause of nonlinear feedback. DES provides more accurate simulation capabilities against above described techniques and so it has been considered an important method in supply chain modeling[2, 6, 12-15].

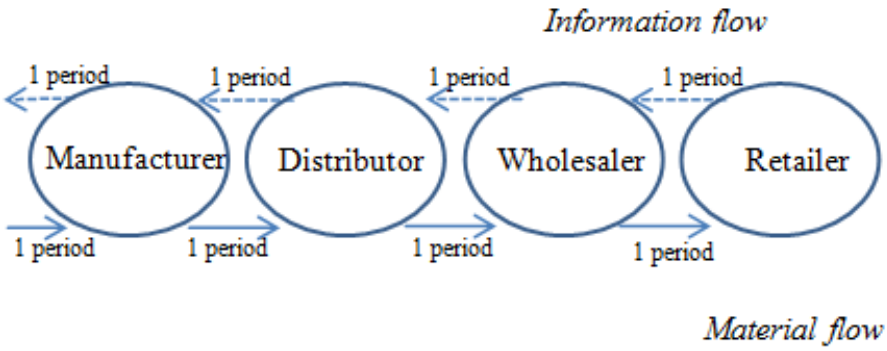


**Figure 1**: Supply chain, lead time in for run beer game traditional

This experiment of study is shown as Figure 1 depicts the material and information flows in the supply chain. The figure also specifies the two kinds of delays at each unit of supply chain simulation-based; material and information. This information delay is due to the administrative steps in processing an order. The demands in different periods are independent, identically distributed, normal random variables. This experiment was set 10 ordering periods without information sharing from randomized trials (randomized pick from 5, 10, 20, 25) then the result is 10 cycles. Instruction of this game was set since starting units ordering with 2 internal criteria; 1st none shortage stock and second maximum order limited with 100 each.

From cycle 1 to cycle 10, after completed 10th cycle with non-sharing information then 11th cycle was started under sharing and network order prediction. The normal distribution is discretized and truncated at zero to avoid negative demand values.

The study of decision making model in supply chain dynamics is explored using the comprehensive overview of decision theory. As far as awareness, decision theory has not been adopted in supply chain dynamics. So approach on supply chain simulation-based is available automated connected, managed information flows and linked transactions for specific functions in each supply chain unit for effectiveness decision making [16-21]

The previous literature reviews of supply chain decision making, an approach is taken to address both the theoretical foundation offered and also to identify how well references to make decision in supply chain dynamics, literature fit with particular decision theory typologies and other related concepts of the supply chain dynamics. One of common approach on multi criteria decision analysis (MCDA) is a widely applied decision making method and can be used for improving the quality of decisions, they mostly produce conflicting results [10, 15, 22, 23]but another hand it is worth noticing that decision maker may reach different decisions even when applying the same weights of criteria and the same criteria evaluations of variants. The study area then focuses on if the approach of multi criteria decision making model with two criteria on supply chain dynamics can be alternatives of decision model for supply chain then experiment of simulation can provide for basic generic model of decision in supply chain units with scenario of accessing for entire stock movement shown improvement.

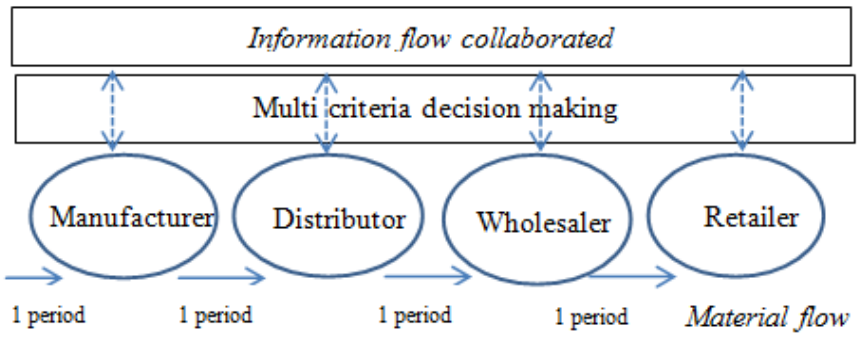


**Figure 2**: Centered supply chain

The area for experiment setting then provided with accessing stock level and cost in whole units of chain were developed over a system dynamics model. For this challenge study evaluation, under the criteria of two supply chain performance indexes; used for criteria on this study included supply chain productivity on inventory level and financial effectiveness on accumulated value of cost reduction.

### *THE BULLWHIP EFFECT AND BEHAVIORAL FACTOR*

The bullwhip effect is the failure to account for inventory in the supply line and time it takes to receive an order. With the guidance for demand patern of [7] measures bullwhips effect on model consisting of one supplier and two retailers with the correlation coefficient between the two error terms, and the variances of the error terms on the bullwhip effect; minimum mean square error (MMSE) forecasting method and the base stock policy then conducted to illustrate the behavior of the bullwhip effect with respect to demand processes; two- stage supply chain. The two factors of bullwhip are: (1) operational factors and (2) behavioral factors. The operational factors of bullwhip categorized mainly following: (1) demand forecasting [4, 22, 24-26]); (2) order batching [9, 26, 27]; (3) lead time [9, 24]; (4) inventory policy [8, 9, 13, 24]; (5) replenishment policy [9, 24, 28] also

pointed out another cause from the interaction of two rational supply chain units can also be a cause of bullwhip effect.

The behavioral factor include the following: (1) neglecting time delays in making ordering [29, 30]; (2) lack of learning and/or training on optimization and lean supply chain effectiveness [31, 32]; (3) reject state of empty stock [29-31]. The importance of data sharing [18] is the key to develop enhance profitability on forecasting. The root of all the causes is lack of coordination among the supply chain units and tolerance on human activities common process.

Then study develop the experiment under simplify first order supply chain and next test set the mission for under 2 control conditions: no backlog in each unit of chain and deduct accumulate value of cost. The area for experiment setting under attempt to minimize impact of the bullwhip effect provided in simulation program

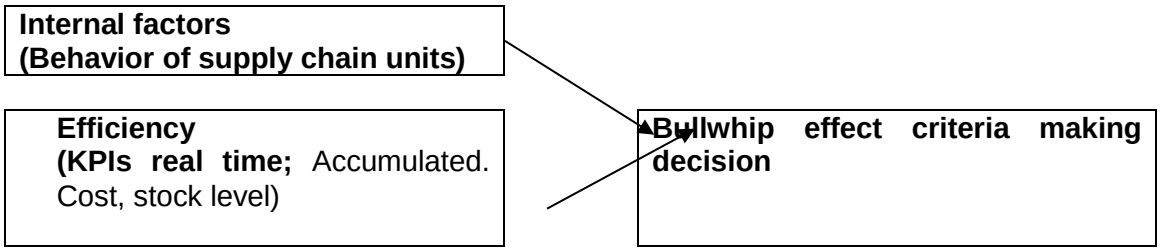


**Figure 3:** Theoretical framework of the study shows the relationship between factors affecting of on making decisions

***RESEARCH METHODOLOGY***

Research sampling is applied purposive selection on 132 control participants with teenagers (18-22 years old), basic knowledge on application for simulation-based, first time trial and could complete experiment loop and describe by qualitative analysis.

Then research is designed from experiment and survey method sequential

(1) Design with quasi experiment and trial on implemented simulation game. Set up the scenario on simulation and instruction for participants as following, experiment 1: Free individual ordering (1st to 10th) and then experiment 2 Control for setting sharing stock level within whole supply chain units as figure 2. (11th to 40th).

(2) Survey with open-end questionnaire. The questionnaire was designed to study internal factor and development.

The instruction of beer game simulates initiate for supply chain that consists of four stages (retailer, wholesaler, distributer and factory) [33] and widely developed for online simulation supply chain business game. The task of each supply chain is to produce and deliver units of beer: the factory produces and the other three stages deliver the beer units until it reaches the external customer demand at the downstream end of the supply chain. The aim of each player is quite simply: fulfilling the incoming orders of beer. The retailer receives an externally predetermined customer demand and places orders with the wholesaler; the wholesaler sends orders to the distributor, who orders from the factory; the factory finally produces. Describe step by step as for game; each round the following steps have to be carried out by the players: 1) receive incoming orders, 2) receive incoming deliveries, 3) balanced play sheets (outstanding deliveries and inventory), 4) send out deliveries, and then 5) make decision on the amount to be ordered. The simple rule of this game commence with players have to fulfill every orders and keep track of backlog (backorder), and then inventory and backlog incur cost so primary aim is to keep costs lowest (each item in stock costs £0.50 per week, while each item on backlog costs £1.00 per week) with least stock reaching optimization. Hence, orders flow in the upstream

direction, while deliveries flow in the downstream requires two rounds until they are finally delivered to the next stage. In the structural setup of the game this is represented by two shipping delay fields located between the supply chain stages as well as at the production.

The experiment is played using four online players. The aspects of supply chain are simplified in the traditional game are introduced in 10 cycles and next from cycle no. 11 to no. 40 in 2 control conditions with simulation-based case study. Sample is set with quasi experiments that were in same knowledge of stock management. The 33 groups of participants in this experiment activity were achieving in general good results after designing decision making rules by means of simulation. And apply descriptive statistic analyst for experimental results.

Last session was called the debriefing session; the data collected during the in-class game play is being presented and discussed. The discussion and survey collected on open-ended question for content analysis and described on factor that effect to results of simulation for behavior factors as following: (1) How to complete the mission under two controllable conditions and what are the key success. (2) Describe on benefit and challenge of simulation game based.

### *RESEARCH RESULTS*

This study bases on cause of variability through the perfectly understandable and rational desire by the different links in the supply chain order-stock management sensibly. The bullwhip effect can be happened if demand change and are moving slowly with large lot size through the chain that caused lags in information or insufficient sharing of accurate stock information typically. The negative value effects on supply chain units' performance is represented as excess stocks, quality problems and keeping stock cost as example. To study supply chain decision making model by apply multi criteria on stock level and accumulate value of cost, the conclusion with descriptive of making decision with centralized stock management suggest that supply chain units cannot reduce the bullwhip effect by sharing stock level and balancing ordering each link of units clearly within simulated 40 order cycles. So, decision maker should learn by trail of the basic pull demand models; and trial in different forecasting methods instead of uniform demand pattern.

This study identifies factor affects the bullwhip effect and its consequences, supply chains seek to improve their information systems and shown final results of supply chain unit accumulative cost and stock level figure 4. This helps to reduce the bullwhip effect to prevent distortion in the information and amplification in demand, thereby contributing to improving the financial performance of the chain.


| Supply chain mode | Accumulated cost (£) | Stock level |
|---|---|---|
| Retailer | 7,910 | -16 - 50 |
| Wholesaler | 4,680 | -4 - 51 |
| Distributor | 7,675 | -5 - 80 |
| Manufacturer | 6,950 | -15 - 80 |

**Figure 4**: The cumulative value of the inventory and accumulated cost

Figure 4 shows result on inventory fluctuation that include period of negative inventory (backlog, 16) and positive inventory (overstock, 80) as cumulative on level of stock and level of orders. Obviously in weeks 15-20, players move into back order then fill quickly.

Accumulated value of cost reduction represents impact of sharing information on the financial performance of the chain and efficiency of supply chain on inventory level as shown in table 1 from 33 gaming groups, optimal solution shown results on total accumulated cost with £27,215 as shown in Figure 4. Stock level is demonstrated between -16 to 80 (min-max).

In each of the links and the chain showed in the different scenarios of access to information. Unlike the previous experiment, this is achieved more easily to observe the impact of information on the entire chain; the accumulated value of the inventory decreases for all nodes in the chain, except for the retails. The retails has the same behavior as the indicators above, while the wholesaler has the lowest unconformities having none certain stock forecasting or having it anywhere in the manufacturer; it is in the manufacturer's interest that the information of fluctuated demand has it the wholesaler.

This study shows the significant of internal factors included inventory and lead time policy and efficiency that measured by variance.

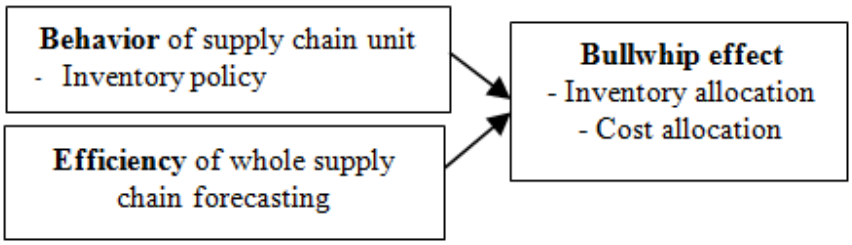


**Figure 5:** A model of decision factors affected to bullwhip effect

The model as figure 5 defines factors affecting bullwhip effect from qualitative (open-ended question and group focus) suggest that quantifying the bullwhip effect and investigating its behavior are helpful in the allocation of efforts for mitigating the influence of the bullwhip effect in each unit of supply chains. This paper can be continuous in several directions that are likely to enhance understanding of how demand signals are transmitted along the supply chain system. First, inventory policies can be studied. The simple order-up-to inventory policy can be misleading when an obvious fixed ordering cost exists. And develop for deployment on inventory policy such as callback system, can be studied. In this study on the bullwhip effect for the general regulation would have more practical significance and reachable. Second, more factors can be used for evaluating efficiency of forecasting. The bullwhip effect as the only factor is as to estimate various forecasting methods. Decision maker may pay more attention to the level of proper inventory cost in practice, so researches on the impact of parameters for the inventory cost should be interesting further; hierarchy decision making.

The simulation result demonstrates that the behavioral adjustment with different extent results in different supply chain performance criteria. The impact of two factors is very different. The decision makers should try to avoid the more adjustments to the scarcity of upstream unit. Bullwhip effect values are calculated and analyzed under different forecast behavior parameters and not been increased with forecast behavior to uncertain demand, also not effected to supply chain performance. That is decision makers can decrease order variance by adjusting order quantity for dealing with uncertain demand but has to pay more attention when forecast to increase the order quantity for dealing with inadequate

supply. The latent of forecast behavior also includes perceives on uncertainty of demand as cause and effect relationship therefor better ordering decisions making.

The efficiency of supply chain forecasting may be observed from previous study that conventional forecasting methods do not reduce negative impact in demand process or general classic technique of forecasting suggested higher stock value. Therefore each cycle of simulation required previous shared data to predict future demand and to improve forecasting accuracy with trend or future demand and reserved one period before-hand forecasting and calculate the accuracy from observed values with predicted values enhance profitability and efficiency.

## *DISCUSSION AND CONCLUSION*

Recommend the decision-making on the various links in a supply chain, with the support of a simulation model using system dynamics. Firstly design the experiment of simulation, analyzed a model of the “beer game” under different conditions of demand, delivery time and access to information for practice ([33]). That suggests next approach for single retailer or the total order, the decrease of lead-time and the increase of demand forecasting precision can reduce level of bullwhip effect actually. Secondly the study suggests developing the game for the logical and systematic thinking in experiment of simulation design [21] and validating the model to multistage [17, 34, 35].

Regarding this experimental design, the inventory level and accumulated value of cost reduction, the workouts assent with baseline. Concept to reduce the inventory level showed, the indicators were improved regardless of the integrated single supply chain units’ demand, while the aggregate value of the inventory reduces the nonconformity. It should be noted that set of study was conducted with the results obtained through description of simulations process and assumption for experiments, as in the target-base study. The ability to validate our findings experimentally with real decision makers is left open. Similarly, subsequent studies that measure profitability based on accumulated value of cost reduction could come about more generalizable results on empirical data more advantage for simulation on business case and widely used in field of resource management.

The opportunity of applying business simulation is to continue set what-if-else situation. It had merged to guide the creation of simulation game to improve communication in complex policy decision under uncertainty environments. Experience from simulation and game are outlined to illustrate the progression of discipline for supply chain policy and context.

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## *REFERENCES*

1. Ancarani, A., C. Di Mauro, and D. D'Urso, *A human experiment on inventory decisions under supply uncertainty.* International Journal of Production Economics, 2013. **142**(1): p. 61-73.DOI: https://doi.org/10.1016/j.ijpe.2012.09.001.
2. Cimino, A., F. Longo, and G. Mirabelli, *A general simulation framework for supply chain modeling: state of the art and case study.* arXiv preprint arXiv:1004.3271, 2010.
3. Cleophas, C. *Designing serious games for revenue management training and strategy development*. IEEE.DOI: https://doi.org/10.1109/WSC.2012.6465154.
4. Costantino, F., et al. *A simulation based game approach for teaching operations management topics*. IEEE.DOI: https://doi.org/10.1109/WSC.2012.6465028.

5. Banks, C.M. and J.A. Sokolowski, *Modeling and simulation fundamentals: theoretical underpinnings and practical domains*. 2010: John Wiley & Sons.DOI: https://doi.org/10.1002/9780470590621.
6. Clark, R. and D. Krahl. *Roadmap to success: Your first simulation model*. IEEE.DOI: https://doi.org/10.1109/WSC.2011.6147865.
7. Sirikasemsuk, K. and H.T. Luong, *Measure of bullwhip effect in supply chains with first-order bivariate vector autoregression time-series demand model.* Computers & Operations Research, 2017. **78**: p. 59-79.DOI: https://doi.org/10.1016/j.cor.2016.08.005.
8. Forrester, J.W., *Industrial dynamics.* Journal of the Operational Research Society, 1997. **48**(10): p. 1037-1041.DOI: https://doi.org/10.1057/palgrave.jors.2600946.
9. Chen, L., W. Luo, and K. Shang, *Measuring the bullwhip effect: Discrepancy and alignment between information and material flows.* Manufacturing & Service Operations Management, 2017. **19**(1): p. 36-51.DOI: https://doi.org/10.1287/msom.2016.0590.
10. Sari, K., *On the benefits of CPFR and VMI: A comparative simulation study.* International journal of production economics, 2008. **113**(2): p. 575-586.DOI: https://doi.org/10.1016/j.ijpe.2007.10.021.
11. Soosay, C.A. and P. Hyland, *A decade of supply chain collaboration and directions for future research.* Supply Chain Management: An International Journal, 20(6), 613-630. , 2015.DOI: https://doi.org/10.1108/SCM-06-2015-0217.
12. Anthony, A., H. Walker, and M. Naim, *Decision theory in sustainable supply chain management: a literature review. Supply Chain Management: An International Journal, 19(5/6), 504-522.* 2014.DOI: https://doi.org/10.1108/SCM-01-2014-0007.
13. Bandyopadhyay, S. and R. Bhattacharya, *A generalized measure of bullwhip effect in supply chain with ARMA demand process under various replenishment policies.* The International Journal of Advanced Manufacturing Technology, 2013. **68**(5): p. 963-979.DOI: https://doi.org/10.1007/s00170-013-4888-y.
14. Danese, P., *Collaboration forms, information and communication technologies, and coordination mechanisms in CPFR.* International Journal of Production Research, 2006. **44**(16): p. 3207-3226.DOI: https://doi.org/10.1080/00207540600557991.
15. Farvid, M. and K. Rosling, *The discounted (R, Q) inventory model—The Shrewd Accountant's Heuristic.* International Journal of Production Economics, 2014. **149**: p. 17-27.DOI: https://doi.org/10.1016/j.ijpe.2013.02.010.
16. Helen, W.A.A.M.N., *Decision theory in sustainable supply chain management: a literature review. Supply Chain Management: An International Journal, 19(5/6), 504–522.* . 2014.DOI: https://doi.org/10.1108/SCM-01-2014-0007.
17. Jermsittiparsert, K. and S. Rungsrisawat, *The supply chain management and information sharing as antecedents of operational performance: A case of SMEs.* Humanities & Social Sciences Reviews, 2019. **7**(2): p. 495-502.DOI: https://doi.org/10.18510/hssr.2019.7258.
18. Thaiprayoon, K., T. Sriyakul, and K. Jermsittiparsert, *Information sharing in OBOR projects to ensure better performance: mediating role of dynamic manufacturing capability.* International Journal of Supply Chain Management, 2019. **8**(5): p. 769.
19. Torres, O.C. and A.B. Maltz, *Understanding the Financial Consequences of the Bullwhip Effect in a Multi-Echelon Supply Chain.* Journal of Business Logistics, 2010. **31**(1): p. 23-41.DOI: https://doi.org/10.1002/j.2158-1592.2010.tb00126.x.
20. Triana, A.C., S.L. Lasprilla, and F.A. Arenas, *Supply chain decision making: A system dynamics approach.* Sistemas & Telemática, 2016. **14**(37): p. 73-86.DOI: https://doi.org/10.18046/syt.v14i37.2243.
21. Wątróbski, J., et al., *Generalised framework for multi-criteria method selection.* Omega, 2019. **86**: p. 107-124.DOI: https://doi.org/10.1016/j.omega.2018.07.004.
22. Jaipuria, S. and S.S. Mahapatra, *An improved demand forecasting method to reduce bullwhip effect in supply chains.* Expert Systems with Applications, 2014. **41**(5): p. 2395-2408.DOI: https://doi.org/10.1016/j.eswa.2013.09.038.
23. Romo, F., H.F. Daza, and F.A. Arenas, *Systemic Analysis of service and financial risks in a supply chain.* Sistemas & Telemática, 2013. **11**(25): p. 105-119.DOI: https://doi.org/10.18046/syt.v11i25.1562.
24. Garcia, C.A., et al., *Inventory control for the supply chain: An adaptive control approach based on the identification of the lead-time.* Omega, 2012. **40**(3): p. 314-327.DOI: https://doi.org/10.1016/j.omega.2011.07.003.
25. Parmigiani, G. and L. Inoue, *Decision theory: Principles and approaches, pp. 381.* 2009: John Wiley & Sons.DOI: https://doi.org/10.1002/9780470746684.

26. Zotteri, G., *An empirical investigation on causes and effects of the Bullwhip-effect: Evidence from the personal care sector*. International Journal of Production Economics, 2013. **143**(2): p. 489-498.DOI: https://doi.org/10.1016/j.ijpe.2012.06.006.
27. Ivanov, D., S.J. Mason, and R. Hartl, *Supply chain dynamics, control and disruption management*. 2016, Taylor & Francis. p. 1-7.
28. Chaharsooghi, S.K., H. Faramarzi, and J. Heydari. *A simulation study on the impact of forecasting methods on the bullwhip effect in the supply chain*. IEEE.DOI: https://doi.org/10.1109/IEEM.2008.4738197.
29. Kaasgari, M.A., D.M. Imani, and M. Mahmoodjanloo, *Optimizing a vendor managed inventory (VMI) supply chain for perishable products by considering discount: Two calibrated meta-heuristic algorithms.* Computers & Industrial Engineering, 2017. **103**: p. 227-241.DOI: https://doi.org/10.1016/j.cie.2016.11.013.
30. Minner, S. and S. Transchel, *Order variability in perishable product supply chains.* European Journal of Operational Research, 2017. **260**(1): p. 93-107.DOI: https://doi.org/10.1016/j.ejor.2016.12.016.
31. Cao, B.-B., Z.-D. Xiao, and J.-N. Sun, *A study of the bullwhip effect in supply-and demand-driven supply chain.* Journal of Industrial and Production Engineering, 2017. **34**(2): p. 124-134.DOI: https://doi.org/10.1080/21681015.2016.1239659.
32. Raghunathan, S., C.S. Tang, and X. Yue, *Analysis of the bullwhip effect in a multiproduct setting with interdependent demands.* Operations Research, 2017. **65**(2): p. 424-432.DOI: https://doi.org/10.1287/opre.2016.1571.
33. Goodwin, J.S. and S.G. Franklin, *The beer distribution game: using simulation to teach systems thinking.* Journal of Management Development, 13(8), 7-15., 1994.DOI: https://doi.org/10.1108/02621719410071937.
34. Kleindorfer, G.B., L. O'Neill, and R. Ganeshan, *Validation in simulation: Various positions in the philosophy of science.* Management Science, 1998. **44**(8): p. 1087-1099.DOI: https://doi.org/10.1287/mnsc.44.8.1087.
35. Somjai, S. and K. Jermsittiparsert, *Mediating Impact of Information Sharing in the Relationship of Supply Chain Capabilities and Business Performance among the Firms of Thailand.* International Journal of Supply Chain Management, 2019. **8**(4): p. 357-368.