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SIMULATION AS AN INTEGRAL PART OF THE SUPPLY CHAIN CURRICULUM

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ABSTRACT: *Logistics and Supply Chain Management courses have relied on traditional lectures and the famous beer game to enhance learning. Although this simulation game creates greater understanding for students to learn supply chain concepts, it fails to model non-linear situations like capacity constraints. A teaching method that integrates such constraints into the curriculum of the course is provided in this paper to help students understand the challenge of managing supply chains. An action learning approach was adopted which involved providing a procedure for exercises solved using an industrial software, Supply Chain Guru. Additionally, twenty postgraduate and ninety four undergraduate students selected by purposive sampling provided feedback on their experience of using computer modelling to understand the subject better. The results show that students can enthusiastically acquire supply chain knowledge by using computer models to learn supply chain simulation. This paper introduces a new teaching method of teaching SC simulation using Supply Chain Guru software which is severely lacking in the literature.*
KEYWORDS: logistics and supply chain management; supply chain simulation and modelling; supply chain guru

INTRODUCTION

In recent years, Logistics and Supply Chain Management (LSCM) has evolved from an operational to a strategic role in business management (Shams & Qing, 2014) due to its importance in creating a competitive advantage for numerous organizations (Maina & Mwangangi, 2020). Chen & Paulraj (2004) highlights that extensive research has been carried out in LSCM and other areas such as Purchasing and Supply Management, Logistics and Transportation, Marketing, Operations Management and Management Information Systems that have contributed immensly to this field. Moreover, there have been a rise in conferences and seminars, programmes for personal development and university courses for teaching LSCM subject (Larson, 2008). Sparling (2002) however arguments that there's a need for effective teaching tools despite the growing interest in the subject and Lau (2010) additionally asserts that the training and education is inadequate and suggests that more emphasis is required on the technical aspects of the field.

Maina & Mwangangi (2020) exemplifies that due to the rapid changes in consumer demand, technological swift and globalization, Supply Chains (SCs) have become complex entities to manage and in order to gain resilience in the SCs powerful technologies like simulation have been used which also act as key decision making tool, as they mimic real life situations (Mendoza & Mula, 2014). In the field of academia, teaching LSCM subject is very challenging due to its dynamic nature (Lancion, Forman, & Smith, 2001). Fawcett (2009) supplements that universities, professional associations and publication are making immense efforts in developing supply chain leaders but insists that faster progress has to be made in order to meet the future leadership challenge.

From a SC practitioners outlook, a good SCM curriculum is prerequisite in producing a valuable LSCM education programme which entail actual problem solving techniques (Rutner & Fawcett, 2005). Nevertheless Clayson & Haley (2005) criticise the designs of academic programs in comparison to the needs mentioned by practitioners in that they rely on theoretical models of coursework which students fail to understand and find it difficult to apply. More specifically in regards to LSCM, the curriculum should ensure the provision of fully intergrated modules that encompass practical skills required to produce successful graduates (Lau, 2015) who will fully comprehend how the performance of the entire SC is affected by the actions of a single firm (Webb, Thomas, & Liao-Troth, 2014).

LSCM teaching approaches have relied on experiential lectures, exercises and business case studies to pass over SC concepts to students (Gumus & Love, 2013; Lau, 2015). As the field continues to grow, spreadsheets analytical tools have been applied in the classroom as they are more practical to SC scenarios (Chou, Tan, & Yen, 2004). Adams, Flatto, & Gardner (2005) however mention that despite the fact that spreasheets are understandable, they're not really attention-getting as most students find them to be too complex and not visually appealing. Due to this limitation LSCM games are highly prefered as they are fun and encourage students to work as a team. Faria, Hutchinson, Wellington, & Gold (2009) after reviewing atleast 300 articles on business simulation games discovered that games are able to improve students abilities in making business decisions and formulating strategies required to solve complex business problems. In LSCM simulation like the beer game have gained preference as they have been reported to impact positively on students' self control, boosting their self esteem and developing their evaluation and organization skills required in the real business environment (Pasin & Giroux, 2011).

Huang, Chuan and Lin (2007) who used the beer distribution game to encounter the challenge of educating software engineers and new generation managers found out that 92% of the participants were in agreement that the game raised their awareness in issues affecting the SC and 82% declared that it acted as a motivational driver in dealing with issues affecting the SC. Additionally, Reyes (2007) after using it for teaching students for atleast three years illustrated that the game enabled students to deal with complexity and dynamics of parallel SCs by coming up with tactical and strategic solutions to the problems presented. Other simulation games in the LSCM literature include JIT simulation (Guneri, Kuzu, & Gumus, 2009). Despite the fact that the beer game is fun and easy to understand, Hussain, Khan and Sabair (2016) illustrate that it is limited to linear models and it cannot model non linear situations like capacity constraints. For non linear modelling, simulation softwares could be used to test different WhatIf scenarios.

Sweeney, Campbell and Mundy (2010) exemplify that LSCM commercial softwares differ from the academic games in that they offer a broader functionality and flexibility prerequisite for modelling diverse business processes faced by real world constraints. Likewise, Laforge and Busing (1998) explains that use of industrial softwares in the classroom assist students in making critical decisions affecting the supply chain which is vital for external validity. They insist that LSCM curriculum should intergrate the use of software tools in the subject to equip students with knowledge and skills of complex data structures that they will encounter in the real world. The popular softwares incorporated in LSCM education include ERP (Boykin & Martz, 2004), Class software for warehousing and Transportation and WMS. Simulation softwares used include Arena and Supply Chain Guru. Most literature draws towards the use of Arena software as evidenced by (Jove et al. 2014; Rodgers and Moraga 2011).

There are very few papers in the literature leaning towards the use of SCG to model SC scenarios. A recent article by Maina & Zhang (2019) used SCG to model facility locations decisions and their impact on their environment. This research paper therefore aims to use SCG in SC teaching in order to develop modelling skills for students. Perera and Rupasinghe (2015) state that although SCG software's licence is valid only for 90days, it's visually appealing, simple to use as it contain data grids making it easy to identify and rectify any mistakes. This makes it favourable for LSCM students.

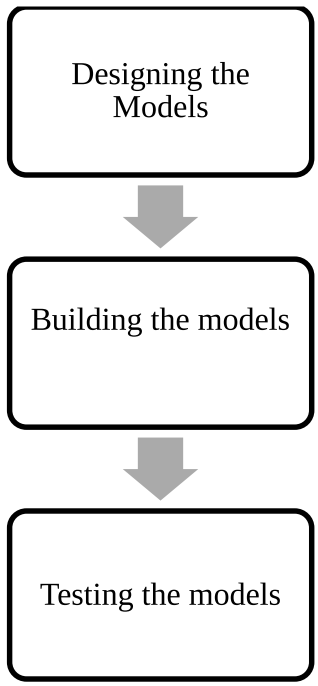
The research questions that need to be addressed are: What models can SC students build using SCG simulation software and how can they build them? ; and Why should simulation be an integral part of the SC curriculum? This paper introduces a new teaching method of teaching LSCM course using SCG where a step by step approach is outlined for better understanding by the students. Second, it reports on the inputs, processes and the outputs of the variables modelled by SCG to provide empirical evidence that can be used to support integration of simulation in the Supply Chain Curriculumn.

This work can be used as a checklist in academia and also in the industry for using simulation in improving Supply Chain education and Supply Chain operations respectively as the deliverables of this research will provide good practical and theoretical background operations to be used in the field of LSCM. This will not only simplify learning and raise more interest in the subject by students but it will also aid in eliminating the teaching challenge of the techicality of the subject thus leading to improved learning outcomes.

METHODOLOGY

Research Design

According to Creswell (2014) a research design aims at collecting, measuring and analysing data so as to draw conclusions about the initial research questions. This research adopted a mixed method approach as the first research question was of quantitative nature while the second research question was of qualitative nature. According to Creswell & Clark (2011) a mixed method research involves the use of both quantitative and qualitative methods of data collection and analysis in a single study. It's appropriate in validating, verifying, complementing, developing, initiating and expanding the research (Golicic & Davis, 2012). This research reviewed the literature from journals, conference papers and books to draw secondary data that helped in formulating a viable discussion. A commercial software, SCG, that enabled the delivery of a progressive tactic in building LSCM models to enhance action learning was used. A procedure of building the models was provided in form of a laboratory sheet to allow replications of the same study by researchers. The exercise in using SCG followed the following criteria:



The design of the experiments involved two aspects. One, specifying the factors to be investigated and two, selecting the performance measures to draw out viable conclusions. Surveys were also used to provide feedback and they followed the procedures outlined below.

Target Population

LSCM students were identified as the target population for the study as the key input of primary data and testing of the models. 94 undergraduate students in a Kenyan University and 20 postgraduate students in a UK university undertaking Procurement (/Logistics) and Supply Chain Management course were used to test the models and give feedback on their experience of using SCG simulation software to model SC activities.

Instruments, Data Collection and Data Analysis Procedure

The models were build by the authors and tested by the students in the classroom using the instructions given. After the testing, a follow up survey was conducted to investigate the experience that the students had with model building. Questionnaires were used for the survey which were sent through drop and pick method and google docs to the respondents. The questionnaire provided a good platform of getting relevant feedback about simulation and modelling from the respondents. A questionnaire was preferred for this study as it suggested potential reasons for certain relationships of simulation and its impact on learning as proposed by (Saunders, Lewis, & Thornhill, 2009). Data received from students feedback was analysed using SPSS software to gather relevant conclusions and recommendations.

FINDINGS

To answer the research question on what models and how can students build models using simulation SCG software? The authors developed various exercises that involved modelling push and pull systems, inventory and transportation systems. All these models were built using SCG simulation software and a sequential process on how this was done is provided (see list of appendix). The exercises are as provided below.

To understand the difference between push and pull systems
Push models are driven by forecasts as decisions on production and distribution rely on demand estimates while pull systems are based on current demand triggered by customers.
Exercise to help students understand the difference between push and pull models.
A UK company is operating in a long distribution network of one warehouse and two distribution centres. The company wants to know if they should operate under a push or pull system to improve their operations. Construct a push, pull network using the following information, and use the simulation analysis to advice the company accordingly.

Exercise 3.1 Design of Push and Pull Systems

a) Product - Cost – 100; Selling Price – 200
b) Facility Location

Facility	**Location**
Warehouse	London
DC 1	Teesport
DC 2	Birmingham

c) Demand

DC Location	Customer location	Weekly Demand
DC 1 (Teesport)	Dundee	100
	Edinburgh	600
	Glasgow	250
DC 2 (Birmingham)	Sheffield	400
	Manchester	750
	Liverpool	200

d) Reorder level and reorder quantities

Facility	Reorder level (R)	Reorder quantity (Q)	Initial Inventory
W_London	2000	6000	4000
DC1_Teesport	1000	3000	2000
DC2_ Birmingham	1500	4500	3000

Source: (Author, 2020)

Model Building

SCG arranges model data in major grids of sites, products, demand, sourcing, transportation and inventory. These features make it easier for students to use the software (Perera & Rupasinghe, 2015). The push and the pull models aimed at distributing product X from the warehouse located in London to the DCs in Teesport and Birmingham. Retailers from Dundee, Edinburgh and Glasgow got their supplies from Teesport DC while Birmingham supplied to Sheffield, Manchester and Liverpool as illustrated in the figure 1 below.

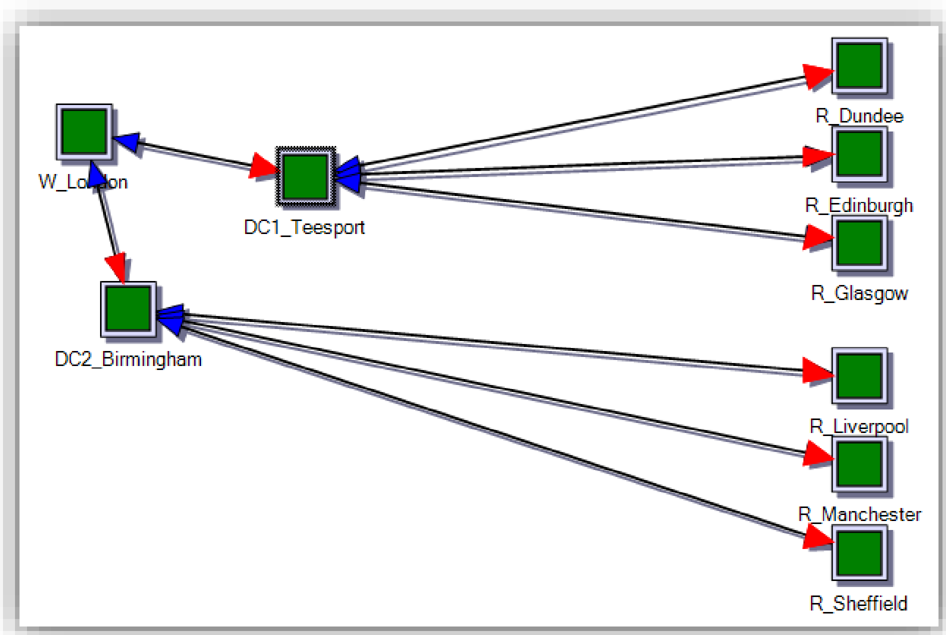


Figure 1 Distribution network for the push and pull model (SCG 2020)

Discussions

The two models used different inventory and sourcing policies. In the push model for instance, the sourcing policy used was make for the warehouse as they are responsible for making the product and source by transfer for the DCs as inventory is shipped to the distribution centre continuously awaiting customer orders. The pull models on the other hand adopted a make policy for the warehouses, which is like the push models, and a single sourcing policy for the DCs as the retailers did not have multiple choices. For the inventory policies: push models used demand flow policy as replenishment orders generated similar quantities as the exact demand of the products received at the specific sites. On the contrary, the inventory policy used for pull models was (R, Q) as the

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customers drove demand. After running a simulation for a period of four months, the results demonstrated that it is costly for the company to adopt a pull system than a push system as it exceeds the costs by $5102. Despite the high costs depicted in the pull system, this system is highly recommended for the company as it will generate more profits and revenues of $44819095 and $44860000 respectively while no profits and revenues will be generated in the push system. The result analysis of this experiment as similar to Pedrielli, Alferi and Matta (2015) empirical experiment that demonstrated that pull systems are more efficient for control strategy but better optimisation parameters should be generated to maximize their value.

To understand the difference in the periodic inventory systems

Companies use periodic inventory systems frequently to manage and control their inventory levels. Selection of the best inventory policy is however challenging due to random demand patterns and the urge for companies to maintain a high desired service level. The most common inventory policies used are (R, Q) where ordering a replenishment amount (Q) is done once inventory falls under a replenishment level (R) and (s, S) where a replenishment quantity is ordered to restore a target maximum (S) once on hand inventory falls below a point (s).

Exercise conducted to understand the difference between the two inventory policies

A multi-echelon company operating with one warehouse and three distribution centres based in the UK have asked you to advise them on the best inventory policy they should implement given the following information.

Exercise 3.2a): Design of s, S; R, Q inventory policies with Deterministic demand

I) Product - Cost- 150; Selling Price- 300

II) Existing Facilities

Facility	**Location**
Warehouse	London
DC1	Birmingham
DC2	Leeds
DC3	Glasgow

III) Demand

DC Location	**Customer Location**	**Weekly Demand**
DC1 (Birmingham)	Birmingham	2000
	Cardiff	1500
DC2 (Leeds)	Leeds	2500
	Liverpool	1000
	Manchester	2000
DC3 (Glasgow)	Glasgow	1800
	Edinburgh	3000
	Dundee	800

IV) Estimates of R and Q

Facility	Reorder level	Reorder quantity	Initial Inventory
W_London	15000	45000	45000
DC1_Birmingham	3500	10500	5000
DC2_Leeds	5500	16500	10000
DC3_Glasgow	5600	16800	10000

Source: (Author, 2020)

V) Lead Times: Warehouse – DC = 2 Days; DC – Retailers = 1 Day

Exercise 3.2b): Design of s, S; R, Q inventory policies with stochastic demand

I) Product- Cost- 100; Selling Price- 200

II) Existing Facilities

Facility	Location
Warehouse	London
DC1	Birmingham
DC2	Leeds
DC3	Glasgow

III) Demand

All demands are subject to $\pm$ 10 Variation

DC Location	Customer Location	Weekly Demand	New Max Variable DD	Min DD
DC1 (Birmingham)	Birmingham	1500	1650	1350
	Cardiff	1130	1243	1017
DC2 (Leeds)	Leeds	1900	2090	1710
	Liverpool	750	825	675
	Manchester	1500	1650	1350
DC3 (Glasgow)	Glasgow	1350	1485	1215
	Edinburgh	2250	2475	2025
	Dundee	600	660	540

IV) Estimates of R and Q

Facility	Reorder level	Reorder quantity	Initial Inventory
W_London	12500	37500	37500
DC1_Birmingham	2893	8679	3000
DC2_Leeds	4565	13695	5000
DC3_Glasgow	4620	13860	5000

Source: (Author 2020)

V) Lead Times: Warehouse – DC = 2 Days; DC – Retailers = 1 Day; Time between orders = 1 Week

Discussions
When building the model, a shelf life which is the maximum number of days that a product can satisfy the demand was included in the products table and this had an impact on costs and profits. Initially, when using the deterministic demand and the (s, S) policy without including the shelf life, the total cost of the network was $275,013 which rose to $281, 528 when a shelf life of 10 days was included and both the total profits and revenues generated dropped by 1% after including the shelf life. This is because shelf life provides a life span for a product and when the product expires it is removed from the inventory and placed in the scrap area.

For the deterministic demand, the (R,Q) policy exhibited over $ 2,000,000 more on profits and revenues and $14,382 more on costs than the (s,S) model. The average fill quantity rate and the average ready rate of the latter projected to 100% while that of (R,Q) seized at 95.98% and 99.86% respectively. For Stochastic demand, a ±10% variation was included to give the minimum, and maximum demand as highlighted in the exercise 3.2 (b) above. A triangular distribution was chosen to cover for the minimum, mode and maximum demand. Surprisingly, the simulation report on profits, revenues, costs and the service level was similar for both (s, S) and (R, Q) models. The results for the deterministic demand are similar to those of Wang and Xia (2016) whose empirical data demonstrated that (R,Q) policy exhibit better results for slow moving demand.

To understand the difference between LTL and FTL in achieving transport optimisation
Smaller shipments use less than truckload (LTL) transportation policy for the goods do not take up the total available space of the truck. This policy allows for transhipments into intermediate stops before reaching the final destination. Full truckload (FTL) on the other hand requires filling up of the trucks before shipping of goods and does not allow intermediate shipments.

Exercise to understand the difference between the two transportation policies
A UK company with one warehouse and two distribution centres want to know the best transportation policy to optimise their SC. Use the following information to compare LTL and FTL transportation policies and advise the company based on the simulation results.

Exercise 3.3 Design of LTL and FTL Transportation Policies
a) Product- Cost – 100; Selling Price – 200; Transportation times = 1 day- retailers; 2 days - DCs.
b) Facility Location

Facility	**Location**
Warehouse	London
DC 1	Birmingham
DC 2	Sheffield

c) Demand

DC Location	Customer location	Weekly Demand
DC 1 (Birmingham)	Bristol	980
	Coventry	640
	Wolverhampton	400
DC 2 (Sheffield)	Bradford	1020
	Wakefield	750
	Nottingham	560

d) Reorder level and reorder quantities estimates

Facility	Reorder level (R)	Reorder quantity (Q)	Initial Inventory
W_London	4350	13050	5000
DC1_ Birmingham	2020	6060	3000
DC2_ Sheffield	2330	6990	3000

Source: (Author, 2020)

Discussions

When building the transportation models, vehicles were preferred as road transport was the chosen mode of transportation. Trucks shipped goods from the warehouse to the DCs while vans transported the products to the retailers. The division of the total demand from the DCs by the fill quantities gave the total units of the trucks used. Similarly, the total demand of the retailers ordering from a specific DC divided by the fill quantity of the van resulted to the total number of vans required. For instance, the total demand of DCs from the warehouse amounted to 4350. The quantity capacity of the truck was 1000 but estimating a considerable quantity fills level of 800, the number of truck units used was 4350/800 to give six trucks. SCG calculated automatically the amount of CO2 released after selecting the type of truck and van. Both transportation policies used Heavy Goods Articulated trucks and Light Goods Diesel vans for shipments.

The UK government website and the internet Google Maps respectively provided relevant information on fuel costs approximations on the average cost of fuel per mile and the distance coverage between the cities taking time taken to travel the distance into account. The simulation results revealed that the LTL policy generated more revenues and profits as compared to the FTL policy. The earlier exceeded the latter by $120000 and $117,029 respectively. The total costs and the carbon footprint for the FTL network was however $2,971 and 0.78 lesser than the LTL network. The shipment transactions under the transportation simulation tab showed the flow units, flow weights and CO2 footprint for the networks. Therefore, companies in context need to make a trade-off of costs, profits and carbon when selecting the best transportation policy to adopt. If they aim at minimizing cost and becoming green, then the best policy is FTL. Alternatively, if they wish to maximize their profits and revenues, then LTL is the best policy.

Students Feedback

To answer the research question on why should simulation be an integral part of the SC curriculumn? Data gathered from students' feedback was used. Within a span of three weeks, fifteen postgraduate and seventy three undergradutes had responded to the questionnaire. This is a response rate of 75% and 78% respectively. Finchman (2008) illustrate that due to the higher expectations of response rates by editors, researchers should focus on getting atleast 60% response rate. All the postgraduate respondents illustrated that they had built models using SCG, and Class Software for warehousing. Additionally, 13% of the postgraduate respondents had experience with Auto CAD and Pro Engineering software. Surprisingly, none of the undergraduate students had experience in computer modelling. When asked why simulation should be integrated in the SC curriculum, the respondents indicated that modelling was as an effective tool for action learning because it provides a visual picture that creates better understanding of the subject as it is easier to understand what you can see making the subject interesting. Secondly, modelling is easy problem identification and solving tool which saves money and time before implementing real projects and finally is that it gives a real time experience and aid in creative thinking. Interestingly, all the respondents agreed that they would recommend the use of simulation and modelling in learning LSCM as different What If analysis to test different outcomes can be investigated. Additionally, it enables drawing out KPIs, which help in making better SC decisions.

Although majority of the students strongly agreed that it was easy to test the models and build new ones using the sequential steps provided, the analysis showed that the use of computer models in learning presented several challenges. The major ones presented by postgraduate students were complications of the software, which crush in between the duration of the project and licencing which allows only a short duration to use the software. Moreover, due to the numerous tabs and grids present, students are unable to make the best choice of parameters that will represent the system under study better. Undergraduates concern was on the complexity of the computer models that makes it difficult to understand, time limitations to learn how to build complex models and unavailability of portable software versions that can run on low space computers without glitches. Recommendations given to solve the above challenges were provision of more tutorials with demos to students showing the instructions of each process and possible discussions of the outcomes, liaising with vendors to provide prolonged licences for the software's intended for learning, and conducting constant research and development to make sure that the software's used for modelling are up to date due to the dynamic changes of SC issues. Computer modelling should also be introduced in the SC curriculum at the undergraduate level for increased exposure to action learning.

Discussions

The modelling results of push and pull models not only revealed that SCG uses pull strategies by default for modelling SCs but also illustrated that pull models generated more profits and revenues as compared to the push models. The latter however were more cost effective. This finding contrast most literature that pull systems are always superior to push systems. Greater possibilities of lost sales explain the low profits presented by push systems, as demand is not customer driven. Alternatively, the high costs in pull systems could possibly arise from high inventory carrying costs and transportation costs as in this system there's no storage of buffer inventory.

The modelling of EOQ involved a comparative study between (R, Q) and (s, S) inventory policies. Slow moving/ deterministic demand demonstrated a higher return on profits and revenues for (R,

Q) as compared to the (s, S) inventory policy. In spite of this, the (s, S) model presented a higher average fill quantity rate and saved on costs as compared to the (R, Q) model. There was no clear distinction between the two inventory policies when using stochastic demand as the results for profits, revenues and costs were similar in both scenarios. The higher profits revealed by (R, Q) model for deterministic demand can be a result of the nature of the policy, which allows a generation of a fixed replenishment quantity Q each time inventory falls below a certain point R. The high average fills quantity and the low costs associated with (s, S) model are because of the restoration of inventory to a target number, S every time the inventory falls below a minimum, s. Unlike the (R, Q), the (s, S) model account for how far the inventory is below the reorder level when generating a request for replenishment.

Transportation modelling involved a relative study of FTL and LTL policies. The simulation results revealed that even though LTL policy had a greater impact on profits and revenues as compared to the FTL policy, the latter was more cost and carbon effective. This is because for FTL policy, there were enough items to fill in the truck and hence its weight made it to be more cost effective. Different simulation results appear when using different weight dimensions. To test this, students can vary the freight dimensions and make comparisons.

CONCLUSIONS

With the use of industrial software's to enhance teaching of LSCM, the study concludes that simulation techniques greatly improve the understanding of the subject as they not only provide a visual outlook of the system under study but also offer a hands-on experience, which is prerequisite in preparing them to face real world challenges after they graduate. The objective of teaching is to pass knowledge to students in order to equip them with the necessary skills required to solve real life problems. The results revealed a big gap of lack of modelling skills and experience in undergraduate students of LSCM in Kenya. To achieve this objective, institutions of learning LSCM today should be agile enough to adjust and rebuild their curricula in real time to accommodate dynamic changes occurring every day. The feedback received from the students necessitates the need to integrate simulation in the SC curriculum.

The objectives under study establish that managers must consider a trade-off between costs, quality and revenues when choosing the best systems for their material flows, inventory and transportation policies for their companies. This reveals the importance of simulation in creating awareness in supply chain dynamics and efficiencies of companies. The key performance measures set by the company are however essential in developing supply chain models. Therefore, this study contributes to the learning theory as it provides empirical evidence of the performance implication of teaching modelling using industrial software’s (SupplyChainGuru) which is severely lacking in the literature.

The challenge faced during this research is software breakdowns which triggered reinstallations. Although this study provides substantial work, it was limited to very little literature available for teaching supply chain simulation with the use of computer models. Further area of research to fill in the gaps mentioned in this study is using modelling (SupplyChainGuru) to enhance learning on how to achieve safety stock optimization when modelling inventory, vehicle routing when modelling transportation and production flow constraints when modelling manufacturing processes. Additionally, directions for further investigation on this topic include, modelling of stochastic demand using (s, S) and (R, Q) models to investigate any differences as this study revealed similar impacts on costs and revenues for both models. Similarly, further research with a higher number of target populations will be required to give feedback on their experience with modelling to enhance action learning.

References

Adams, J., Flatto, J., & Gardner, L. (2005). Combining hands-on spreadsheet and discrete event simulation to teach supply chain management. *Simulations Conference Proceedings of the Winter*, (pp. 1702-1710).

Boykin, R. F., & Martz, W. B. (2004). The integration of ERP into a logistics curriculum: applying a systems approach. *Journal of Enterprise Information Management*, 45-55.

Chan, F. T., & Chan, H. K. (2005). Simulation modelling for comparative evaluation of supply chain management strategies. *The international Journal for Advanced Manufacturing*, 998-1006.

Chen, I. J., & Paulraj, A. (2004). Towards a theory of supply chain management: The constructs and measurements. *Journals of Operations Management*, 119-150.

Chou, D. C., Tan, X., & Yen, D. C. (2004). Web technology and supply chain management . *Information Management and Computer Security*, 338-349.

Clayson, D. E., & Haley, D. A. (2005). Marketing models in education : Students as customers, products or partners. *Journal of Marketing Education Review*, 1-10.

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative and Mixed Methods Approach.* Sage Publications.

Creswell, J., & Clark, V. (2011). *Designing and conducting mixed methods researchh.* Thousand Oaks, CA: Sage.

Faria, A. J., Hutchinson, D., Wellington, W. J., & Gold, S. (2009). Developments in Business Gaming. *Simulation & Gaming*, 464-487.

Fawcett, S. E. (2009). An update on the state of supply chain education. *Supply Chain Management Review*.

Fincham, J. E. (2008). Response Rates and Responsiveness for Surveys, Standards and the Journals. *American Journal of Pharmaceutical Education*, 43.

Golicic, S., & Davis, D. (2012). Implementing mixed methods research in supply chain management. *International Journal of Physical Distribution and Logistics Management*, 726-41.

Gumus, M., & Love, E. C. (2013). Supply chain sourcing game . *Journal of Innovative Education*, 3-12.

Guneri, A., Kuzu, A., & Gumus, A. (2009). Flexible Kanbas to enhance volume flexibility in a JIT environment: a simulation based comparison via ANNs. *International Journal of Production Research*.

Huang, S.-T., Chuan, M., & Lin, W.-H. (2007). Management and Education of the case based complex e-business systems based ob agent centric ontology and simulation games. *IEEE*, (pp. 379-382).

Hussain, M., Khan, M., & Sabir, H. (2016). Analysis of capacity constraints on the backlog bullwhip effect in the two-tier Supply Chain: a Taguchi Approach. *Internatinal Journal of Logistics Research and Applications*, 41-61.

Jove, J. F., Petit, A. G., Casas, P. F., & Joseph, C. (2014). Teaching system modelling and simulation through petri nets and arena. *Winter SimulationConference*, (pp. 3662-3673). Savannah, USA.

Karimi-Nasab, M. (2013). An inventory control model with stochastic review interval and special sale offer. *European Journal of Operational Research, 227*(1), 81-87.

Laforge, R. L., & Busing, M. E. (1998). The use of industrial software to create experiental learning activities in operation management courses. *Production and Operations Management*, 325-334.

Lancion, R., Forman, H., & Smith, M. F. (2001). Logistics and Supply chain education: Roadblocks and challenges. *International Journal of Physical Distribution and Logistics*, 733-745.

Larson, P. D. (2008). Accrediation program design: a survey of supply chain professionals. *Journal of Enterprise Information Management*, 377-392.

Lau, A. K. (2010). Training needs of purchasing and supply management personnel in Hong Kong. *Journal of European Industrial Training*, 400-415.

Lau, A. K. (2015). Teaching supply chain management using a modified beer game: an action learning approach. *International Journal of Logistics Research and Applications*, 62-81.

Maina, J., & Mwangangi, P. (2020). A critical review of simulation applications in supply chain management. *Journal of Logistics Management*, 1-6.

Maina, J., & Zhang, L. (2019). Facility Location and its impact on the environment: Using a centralized and decentralized approach, a case study. *European Journal of Logistics, Purchasing and Supply Chain Management*, 14-24.

Mangan, J., & Christopher, M. (2005). Management development and supply chain manager of the future. *The International Journal of Logistics Management*, 178-191.

Mendoza, J. D., & Mula, J. (2014). Using system dynamics to evaluate the tradeoff among supply chain aggregate production planning policies. *International Journal of Operations and Production Management*, 1055-1079.

Pasin, F., & Giroux, H. (2011). The impact of a simulation game on operations management education. *Computers & Education*, 1240-1254.

Pedrielli, G., Alferi, A., & Matta, A. (2015). Integrated Simulation-optimisation of pull control systems. *International Journal of Production Research*, 4317-4336.

Perera, T., & Rupasinghe, T. (2015). Teaching Supply Chain Simulation- from beginners to professionals. *Winter Simulation Conference* (pp. 3548-3556). IEEE.

Reyes, P. M. (2007). Parallel interaction Supply Chain Game: An Extension of the Beer Game. *Journal of Innovative Education*, 413-421.

Rodgers, D. M., & Moraga, R. J. (2011). The trouble with thinking the arena: learning to use simulation software. *Bulletin of Science, Technology & Society*, 144-152.

Rutner, S. M., & Fawcett, S. E. (2005). The state of supply chain education. *Supply Chain Management Review*, 55-60.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Students.* Harlow: Pearson Education Limited.

Shams, R., & Qing, N. (2014). Graduate students perceptions of supply chain skills for supply chain managers. *Benchmarking*, 276-299.

Sparling, D. (2002). Simulations and supply chains; strategies for teaching supply chain management. *An International Journal for Supply Chain Management*, 334-342.

Sweeney, D., Campbell, J., & Mundy, R. (2010). Teaching supply chain and logisics management through commercial software. *The International Journal of Logistics Management*, 293-308.

Tsou, C.-S. (2009). Evolutionary Pareto optimizers for continuous review stochastic inventory systems. *European Journal of Operational Research, 195*, 364-371.

Wang, F., & Xia, L. X. (2016). Evaluation and selection of periodic inventory review policy for irregular demand: A case study. *IEEE*, 275-279.

Webb, S. G., Thomas, S. P., & Liao-Troth, S. (2014). Teaching Supply Chain Management Complexities: A SCPR model based classroom simulation. *Journal of Innovative Education*, 181-198.

Zee, V. d., & Vorst, V. d. (2005). A modelling framework for supply chain simulation: Opportunities for improved decision making. *Decision science*, 65.

List of appendices

Appendix I: Sequential steps of building push and pull models using SCG

Instructions

1. Click on the model data. S*tart by the left-hand side of the grids to ensure keying in all the data before running the simulation.*
2. Adjust the date depending on how long you expect the simulation to run. *Change the date from four months to twelve months and observe the impact it has on the simulation results.*
3. Fill in the details of the name of the facility and its location in terms of the city and the country in the sites tab. *Adjust the type of location as either the existing or a potential or customer depending on the data given.*
4. Click on the tools > Geo coding guru > Batch code guru > start icon to input the latitude and longitude of the site locations keyed in step (3).
5. Return to the model data. On the products tab, insert the product name and its value and selling price. *Adjust the value and the selling price and observe the simulation results on costs and revenues.*
6. Click on the demand tab and input the demand data of all the retailers and key in the occurrences and time between orders. *Vary the demand patterns and make observations.*
7. On the sourcing policies tab, select the best sourcing policy based on the data provided. *In cases where customers are sourcing from multiple DCs, adjust the sourcing policy like multiple sources (most inventory/fastest path) and make observations*. Also, select a number in form of days or weeks under the source lead-time options to indicate the time it takes to get an item from the warehouse to the customer.
8. Adjust the transportation policy intended to be used to ship items to the customer's destinations under the transportation tab. *Vary different policies and make observations.*

9. Click on the inventory tab and choose the policy to use while keying in the reorder point and reorder quantity and initial inventory data. *Vary the figures of R and Q and initial inventory and observe their impact on the average inventory and the inventory carrying costs.*

10. Click on the simulation tab > play > options> general options> number of replications>apply. *Adjust the number of replications and observe the results.*

Instructions on how to model the other two exercises above are available upon request.