Master of Engineering in Logistics and Supply Chain Management

RESEARCH JOURNAL

CLASS OF 2017

Summaries of select research projects by graduates of the MIT-Zaragoza Master of Engineering in Logistics and Supply Chain Management (ZLOG)

Linking Lead Time and Inventory in Pharma Businesses
Team: Ashish Thomas Augustine, Shwethika Adusumalli
Advisor: Dr. Spyridon Lekkakos

Adding Value through Collaboration: Big Data Analysis and Opportunities
Team: Greivin Rodríguez Calderón, Romina García Soriano, Beverly Osborn
Advisor: Dr. María Jesús Sáenz

Agility in Global Pharma Supply Networks
Team: Rodrigo Falcão Gomes, Sailesh Kolachana
Advisor: Dr. Rafael Díaz

Design of Effective and Efficient Distribution Network in Sub-Saharan Africa
Team: Syed Muhammad Talha Kamal, Rishi Prakash
Advisor: Dr. Spyridon Lekkakos

An "Internet of Things" Approach against the Bullwhip Effect
Team: Snehashish Sridhar, Rubén Sifuentes
Advisor: Dr. Rafael Díaz

ZLC | MIT GLOBAL SCALE NETWORK

Introduction

Welcome to the 2017 MIT Zaragoza Master of Engineering in Logistics and Supply Chain Management (ZLOG) Research Journal!

The five papers included in this journal were chosen from the eleven theses submitted by the ZLOG class of 2017 at the Zaragoza Logistics Center. The articles are written as executive summaries and are intended for a business, rather than an academic audience.

The purpose of the executive summaries is to give the reader a sense of the business problem being addressed, the methods used to analyze the problem, and the relevant results, conclusions and insights gained. The complete theses are, of course, much more detailed. We have also included a complete list of this year's ZLOG theses with short descriptions at the end of this journal.
The articles in this publication cover a wide range of interests, approaches, and industries. This variety of topics illustrates one of the hallmarks of the ZLOG program: the students' ability to focus their course work and research on topics that most interest them.

The ZLOG program is designed for early to mid-career supply chain professionals who want a more in-depth and focused education in supply chain management, transportation and logistics.

All projects are conducted in conjunction with the Zaragoza Academic Partner (ZAP) Program, an initiative to enhance applied research and closer industry-academia relationships in the field of supply chain management.

The ZAP Program gives ZLOG students the opportunity to work closely with industry professionals on actual supply chain problems, and gives companies an opportunity to interact with a student or student team along with a professor as expert thesis advisor who together bring new insights and approaches to a current supply chain project.

We hope you enjoy the articles. If you wish to discuss any other aspect of the ZLOG program or wish to find out how your company can interact with ZLOG students, please do not hesitate to contact me directly.

Happy reading!

Marta Romero
Director, Master of Engineering in Logistics and Supply Chain Management
Zaragoza Logistics Center
mromero@zlc.edu.es
www.zlc.edu.es

Linking Lead Time and Inventory in Pharma Businesses

By Ashish Thomas Augustine and Shwethika Adusumalli
Thesis Advisor: Dr. Spyridon Lekkakos

Summary:

The key focus of this thesis is to empirically investigate the relationship between lead time and inventory within the supply chain network of a global pharmaceutical firm. By means of statistical data analysis and case-based examination of the system under study, the impact of lead time and lead time variability on inventory is quantified, along with the identification of focus areas within the firm's network. This is followed by scenario-simulation to provide useful insights in terms of scope for inventory reduction by controlling lead time related parameters.

M.E. in Logistics & Supply Chain Management, MIT-Zaragoza International Logistics Program

Bachelor of Technology in Mechanical Engineering, VIT University, Vellore, India

M.E. in Logistics & Supply Chain Management, MIT-Zaragoza International Logistics Program

Bachelor of Technology in Chemical Engineering, VIT University, Vellore, India

KEY INSIGHTS

1. Theoretical relationship between lead time and inventory is demonstrated through statistical data analysis of the supply chain system.
2. Disparities between sites performing similar activities in comparable environments is brought to attention of the stakeholders through in-depth data analysis of the system.
3. Multi-stage inventory model simulation identifies which lead-time related parameters contribute in bringing considerable benefits in terms of inventory optimization.

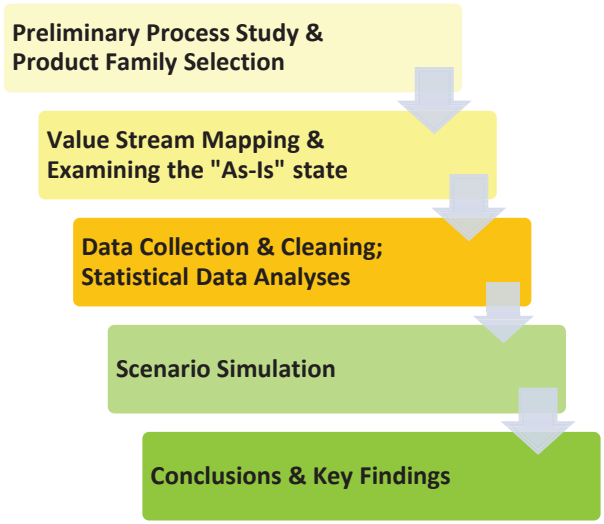
Introduction

With ever-increasing costs of developing new drugs, acquiring patents, and conforming to authority-regulations, pharmaceutical companies are seeking internal solutions for reducing their operational costs while maintaining service levels appropriate for an industry manufacturing life-saving medications. Like other companies in this sector, our sponsor is looking at cost reduction through several initiatives. One such initiative is using End to End Lead Time (E2E LT) as a strategic lever for streamlining and optimizing inventory. In the context of this thesis, we consider E2E LT as the time from the beginning of production of the first intermediate product up to the warehousing stage of the finished-goods.

Problem Definition

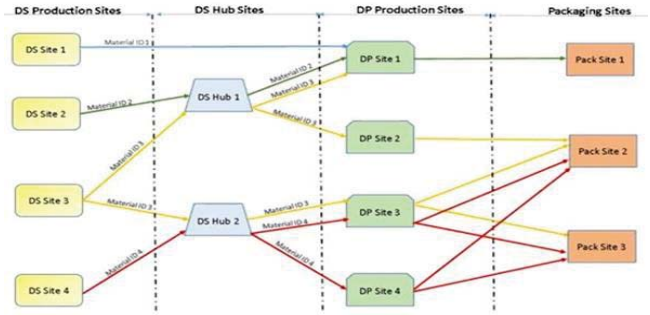
The primary objective of this thesis is to help the company establish data-driven evidence of a correlation between inventory and lead time within their supply chain system, and identify potential impact on inventory through reduction in lead time, while maintaining similar service levels.

Methodology



Supply Chain Framework

There are 3 main product forms/stages- Drug Substance (DS), Drug Product (DP) and Finished Goods (FG). Each stage has 6 sub-processes with its individual lead time. The sum of all lead times for each sub-process contribute to the E2ELT.

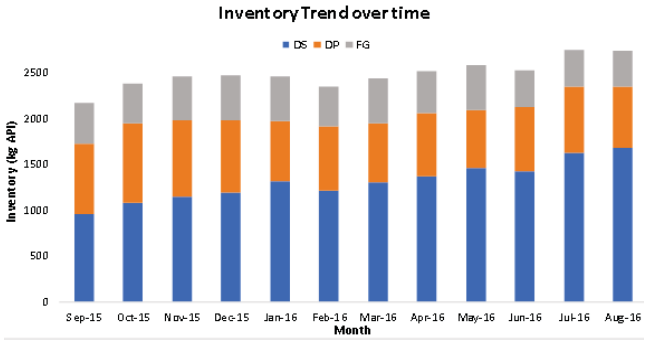


Data Analysis

Data analysis is based on data provided by the company, consisting of historical records of lead time and inventory over a one-year period. Both variables are first individually studied and then investigated for inter-relationships.

Analysis- Inventory

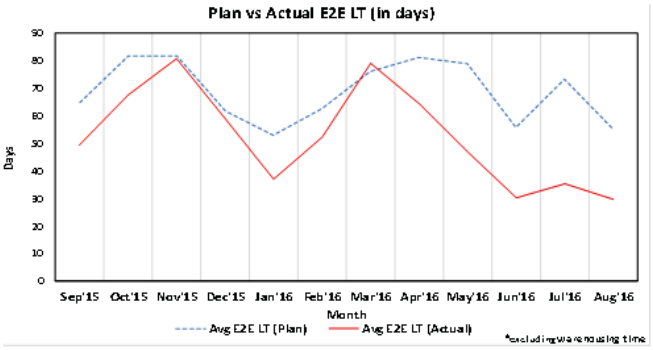
An analysis is performed on different types of inventory in the system. Overall inventory is gradually increasing over the time period studied, with DS inventory being the most significant. Also, there is evidence of slight amplification of inventory variability due to the bull-whip effect as one moves upstream.



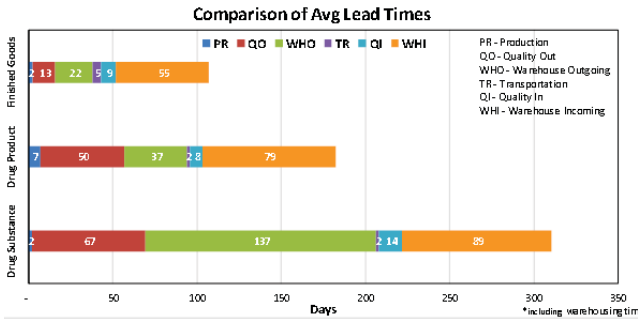
	Stage		
	DS	DP	FG
Average (kg API)	1319	719	451
Std. Deviation (kg API)	205	73	35
Variability %	16%	10%	8%

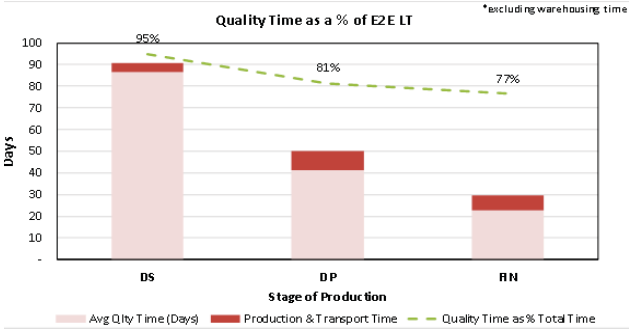
Analysis- Lead Time

The actual lead times are found to be performing better than the benchmark plan values.



Further, lead times in DS product stage are found to be much higher than those in DP and FG stages while quality lead times are the largest contributors.





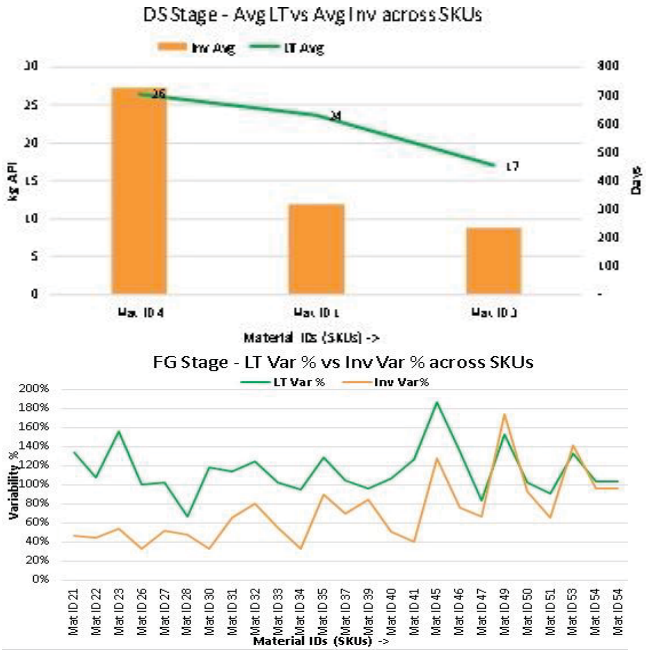
Finally, the extent of LT variability is found to be high within the stages. As expected, these patterns are similar to those observed in their respective inventories with a slight lag observed in certain cases

Analysis- between Inventory & Lead Time

Next, we explore the interdependencies between inventory and lead time in a multi-stage supply chain system, considering the different SKUs.

Analysis across SKUs

A comparative study between average LT and average inventory for all SKUs (Material IDs) is conducted across all stages of product forms. Some level of correlation is observed across the DS and FG stages.



Multiple cases of nodes with similar lead times are examined and the level of LT variability and inventory variability do exhibit similar characteristics. However, the inventory held across sites with similar lead times varies significantly. This probably is due to differences in demand and other operational environment characteristics.

Mat ID	Source	Dest.	LT	LT Var	Inv Var	DOC
ID 3	DS Site3	DS Hub2	29	119%	125%	61
ID 1	DS Site1	DP Site1	29	85%	51%	77
ID 3	DS Site3	DS Hub1	30	76%	101%	59

Statistical Correlation

Collating together the average LT and inventory data of all SKUs, statistical correlation coefficients are derived as per the following tables.

Correlation between Avg LT and Avg Inv

	Avg LT	Avg Inv
Avg LT	1	
Avg Inv	0.33	1

Correlation between LT Variation and Inv Variation

	LT Var	Inv Var
LT Var	1	
Inv Var	0.47	1

Correlation between Avg Inv & LT Variation

	Avg Inv	LT Var
Avg Inv	1	
LT Var	0.43	1

Regression Analysis

Using the same aggregated data, multiple regression analyses are conducted. In each case, acceptable levels of R square are obtained and the explanatory variable is found to be statistically significant.

Regression between Avg LT and Avg Inv

R Square 0.11

Adjusted R Square 0.10

	Coeff.	Std. Error	t Stat	P-value
Intercept	-12.25	7.52	-1.63	0.11
X Var (Avg LT)	2.34	0.53	4.40	0.00

Regression between LT Variation and Inv Variation

R Square 0.22

Adjusted R Square 0.22

	Coeff.	Std. Error	t Stat	P-value
Intercept	-7.99	2.71	-2.94	0.00
X Var (LT Var)	1.22	0.18	6.80	0.00

Regression between Avg Inv & LT Variation

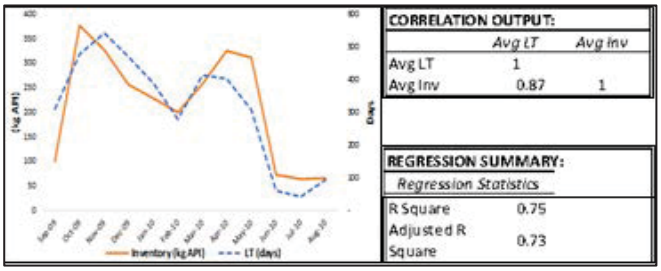
R Square 0.19

Adjusted R Square 0.18

	Coeff.	Std. Error	t Stat	P-value
Intercept	(20.18)	7.21	(2.80)	0.01
X Var (LT Var)	2.89	0.48	6.04	0.00

Analysis over Time

Next, we investigate the existence of similar correlation over a function of time for each SKU. Based on the material flow network of the selected product family, several cases of node-combinations are studied. Within the DS and DP inventory forms, 6 out of 9 cases and 7 out of 10 cases respectively, showed correlation patterns. A representative case is shown below:



Statistical Correlation

Collating together lead time and inventory data of all cases (combinations of nodes) as discussed above, a dataset was built to perform correlation analysis. The result is tabulated below.

Correlation between Avg LT and Avg Inv

	Avg LT	Avg Inv
Avg LT	1	
Avg Inv	0.67	1

Regression Analysis

With the same dataset as that used for statistical correlation conducted above, a regression analysis, with LT as the explanatory variable and inventory as the dependent variable, is carried out.

Regression between Avg LT and Avg Inv

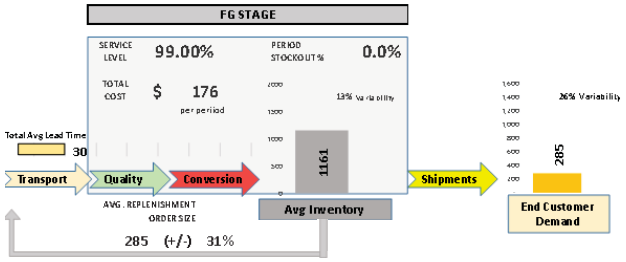
R Square 0.44

Adjusted R Square 0.44

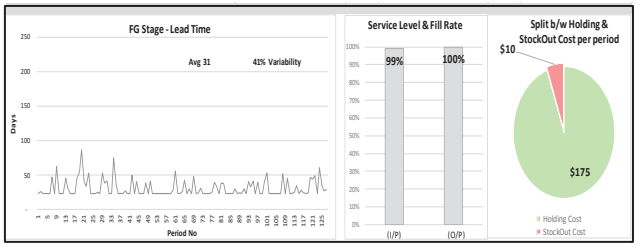
	Coeff.	Std. Error	t Stat	P-value
Intercept	5.82	9.9	0.59	0.56
X Var (LT)	0.54	0.04	13.85	0.00

Simulation

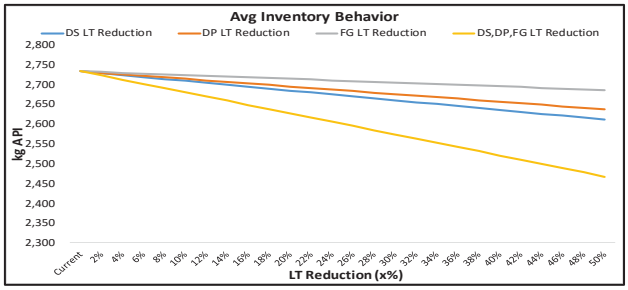
Finally, a simulation model is developed for helping stakeholders identify potential opportunities for inventory optimization. A simplistic multi-stage system is modelled and simulated trials are run to predict system behavior when LT characteristics are modified. The assumptions considered in the simulation model are derived from the available data set and from a survey we deployed among the company's planners. A snapshot of one of the modelled stages of the simulated pharma supply chain is shown below.

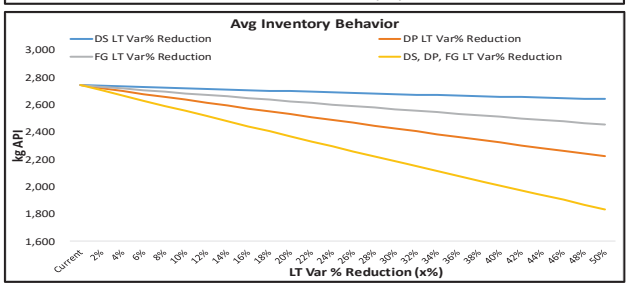


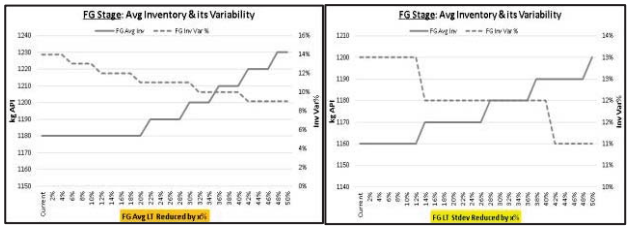
The interface of the simulation model provides capabilities to monitor specific trends. A dashboard is provided to view results and trends of each trial run. An example is shown below.



Several insights are derived from the simulation. Reducing the average DS LT and variability of DP LT are found to deliver the most benefit. However, controlling LT behavior of only one stage in isolation, may have undesirable effects on average inventory, if the inventory policy is not revised accordingly.







Conclusions and Recommendations

Having demonstrated and quantified the inter-variable relationship between LT and inventory, we believe lead times should be a key focus area of improvement, specifically those in the DS stage. This could serve as an important lever to facilitate better management of DS inventory, that is currently the largest share of total inventory. At an intra-stage level, the respective quality lead times could be a starting point for lead time reduction since inventory in quality inspection form is quite significant.

Furthermore, on comparing the variability of lead times across similar sites, it was observed that certain sites exhibited lower averages and better controls over their lead times (processes). Unless this is attributable to other favorable factors, we believe a benchmarking study would help determine best practices and then replicate them as applicable.

Finally, although controlling lead times of individual stages would result in inventory reduction, the cumulative benefit of reducing lead times of all stages is far higher than that generated individually. It is thus, advisable, to focus on a collective effort to optimize the E2E LT altogether and ensure inventory policy revision, as applicable. More importantly, it is imperative that planners of each stage be coordinated, so that changes in a particular stage are appropriately prepared for by other stages, to prevent undesirable effects in the system. Furthermore, it is important to state that benefits of reducing lead times within the system are tangible, but a centralized and collaborative planning system, augmented by higher controls over lead times, would provide even higher benefits in terms of inventory optimization.

Cited Sources

Bagchi, U., Hayya, J., & Chu, C. (1986). The Effect of Lead-Time Variability: The Case of Independent Demand, Journal of Operations Management, 6(2); P. 159-177.

Bautista K. & Girsch T. (2012). Impact of End-to-End Lead Time on Service Level and Working Capital in a Pharmaceutical Company. Zaragoza Logistics Center.

Chopra S. & Meindl P. (2010). Supply Chain Management, Strategy Planning and Operation (Bd. Edition 4). New Jersey: Prentice Hall International.

Adding Value through Collaboration: Big Data Analysis and Opportunities

By Greivin Rodríguez Calderón, Romina García Soriano, Beverly Osborn.
Thesis Advisor: Dr. María Jesús Sáenz

Summary: This thesis identifies opportunities for large companies to create added value by analyzing the logistics-relevant big data stored in their enterprise resource planning systems. All analysis is based solely on data provided by the sponsor, a global chemical company which currently makes many logistics decisions within each business unit. We propose ways to analyze and act on the firm-wide data that can lead to reductions in costs and improvements in service levels.

Greivin Rodriguez, graduated from the MIT-ZLOG. Prior to ZLOG, Rodríguez worked for more than eight years in different companies in the logistics field, including as a Logistics Engineer for Canon-Germany where he finished his MBA in Logistics and Leadership.

Romina Garcia Soriano graduated from MIT-ZLOG. Garcia Soriano has degrees in industrial engineering from the UPV and the ETHZ. Specialized in supply chain management, she has been working in the automotive and energy sectors in various countries.

Beverly Osborn graduated from MIT-ZLOG. Osborn has experience working in the private sector and the United Nations in sourcing, supplier performance management and negotiations. She has worked in petroleum and construction. She will start a PhD this year.

KEY INSIGHTS

1. Before identifying opportunities from big data analysis, it is necessary to develop an understanding of the information through data mapping. The data analyzed here comes from a company with more than 100 plants producing more than 50,000 materials shipped to more than 25000 locations.
2. Big Data analysis can be a valuable tool for use in continuous improvement and decision making. Order consolidation can eliminate 25% of orders and shipment consolidation can reduce shipments by 21%. Potential backhaul routes carry 27% of shipments.
3. Creating an organizational culture that makes decisions based on data analysis requires people with analytical and leadership skills. Close collaboration between stakeholders and appropriate technological tools are needed.
4. More globally, this work also defines a repeatable methodology for using a large dataset to develop clear managerial insights.

Introduction

This thesis identifies opportunities for large companies to create added value by analyzing the logistics-relevant data already stored in their enterprise resource planning (ERP) systems.

According to the report “The Current and Future State of Digital Supply Chain Transformation” published by GT Nexus in 2016, “organizations have struggled for decades to gain access to and analyze their extended supply chain data for decision making.”

Firms should analyze their big data in order to profit from the insights available, enabling them to make better decisions and surpass current targets (Wang et al., 2016). All analysis are based on data provided by the thesis sponsor, a global chemical company. In the past, logistics decisions have been primarily made within each business unit (BU), making it likely that opportunities to realize additional value through collaboration exist. The company was seeking specific opportunities for how this value could be created, how much potential benefit and effort corresponds to each opportunity and recommendations for realizing the value creation identified.

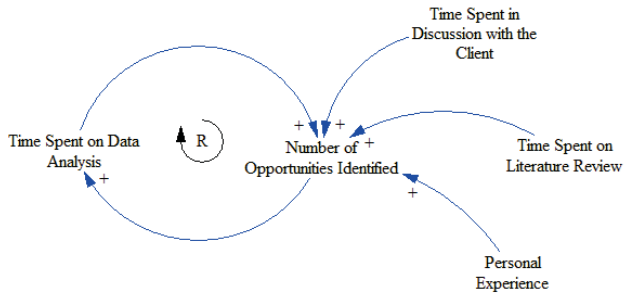
As an indication of scale and complexity, logistics flows move from more than a dozen European countries to approximately 150 destination countries. More than 100 plants produce more than 50,000 materials, sell them to more than 15,000 customers, and ship them to more than 25,000 locations. Transportation modes include air, sea, road (both bulk and packed), rail, and pipeline.

Methodology

Data relating to customer orders, deliveries, and inventory levels was provided by the company. The Client requested a general project that can be applied in a variety of contexts (i.e., specific operating constraints and current processes were disregarded).

The first stage of the project was dedicated to developing a deeper understanding of the Client's objectives and expectations. Next, it was necessary to develop an understanding of the information available in the dataset. This was done by mapping relationships between the tables (for cross-referencing) and by using regression analysis to observe the relationships between potential explanatory variables and freight costs. The process is described below.

Figure 1 - Opportunity identification

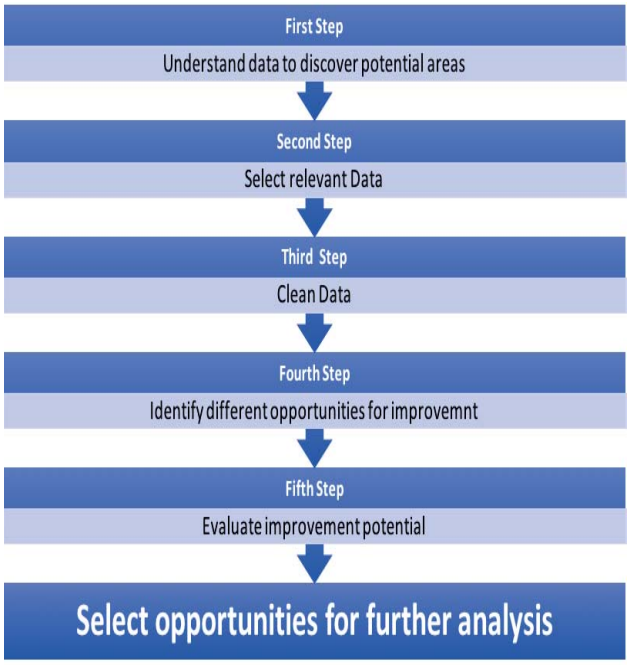


The next major task was to generate a variety of potential applications for the Client's provided data set. We expected many of the opportunities for potential applications for the dataset to come from the literature review. In practice, potential opportunities were also generated in meetings with the Client and during data analysis activities.

The next stage of the project was to select a subset of opportunities worthy of deeper analysis. The Client requested that this decision should be made based on effort and benefit. We interpreted effort to mean both the effort required for our initial analysis, including the feasibility of gaining valuable insights from the dataset provided (i.e., with no additional information being required), and the effort required by the Client to implement the associated changes and realize the value of the analysis. Estimated potential benefits include expected cost impacts, expected effects on lead time, and expected effects on the customer experience.

The opportunities selected for further analysis were discussed and agreed with the Client. Methods vary for analyzing each of these opportunities, and are therefore discussed briefly within the findings. The decision flow diagram is below.

Figure 2 - As-is approach



Results

We identified the following potential applications for the provided dataset: identifying backhaul routes; driving improvements in carrier performance; reducing the number of orders processed through order consolidation; managing differences in customer service levels by customer priority level; optimizing the assignment of orders to plants; increasing multi-BU shipments; driving reductions in raw materials costs; generating product recommendations for customers; identifying binding capacity constraints; and identifying opportunities for direct shipping.

Figure 3 - Opportunities identified

These potential opportunities were compared in terms of the required effort level and the expected benefits. A subset of these opportunities was selected for quantitative analysis, namely: identifying backhaul routes; driving improvements in carrier performance; and reducing the number of orders processed through order consolidation. These three options were selected for further analysis due to having the best ratio of short-term benefits to effort required for analysis and implementation.

Recommendations

Transport routes with frequent shipments in both directions were identified. Shipments on each unidirectional route are concentrated with one (or few) carriers, but different carriers are used in each direction. We recommend preferentially assigning both route legs to the same carrier to reduce transportation costs. The routes that can most benefit from including backhaul considerations in carrier selection are routes with frequent shipments in both directions. This is because the cost savings from backhaul are realized when a truck with available capacity will be travelling the required route regardless of whether shipments are assigned to it (e.g., a truck returning to its hub) while a shipment along that route is required. This situation will happen most frequently on routes with frequent shipments in both directions, i.e., routes that are both busy and balanced. Shipments between Spain and Italy and between Germany and Switzerland are both frequent and balanced. We therefore consider these two bidirectional routes to have strong potential benefit from the incorporation of backhaul considerations in carrier selection decisions.

Carrier performance differences were found in the following metrics: mean cost forecast accuracy, mean actual freight costs, proportion of deliveries on the requested date, proportion of deliveries on the confirmed date, mean days late (based on requested date). No difference was observed in mean days late (based on confirmed data). We recommend using the observed differences in carrier selection decisions and for carrier performance management.

We assess that order and shipment consolidation represent a great opportunity for the firm to reduce treatment time for sales orders and shipments, respectively, by 25% and 21% by eliminating duplications. Sales order management could be optimized the most in divisions C12, F10, K11. Shipment management could be optimized the most in divisions B10, F10, G10, H10, and K11.

In addition to these analytical recommendations, we also provide recommendations on collaboration and data management to support successful implementation of these initiatives.

It is critically important to “zoom-in” to the right level when using data analysis to drive decisions; we frequently observed different statistical relationships depending on how aggregated the data analyzed was. We also recommend that the Client ensure that all required information is available to the relevant decision makers, whether firm-wide data or BU-only data. The Client should also verify that strong horizontal communication channels are in place where required.

Data analysis requires the use of appropriate software and hardware. Our recommendation is not for the Client to acquire the latest technology, but rather to find what is useful, what is necessary, and what satisfies the needs of the company.

Many modern companies face a significant challenge in managing big data. Big data analytics requires excellent analytical skills, but over and above that, it also requires leadership, team work, and the willingness and openness to generate benefits from horizontal collaboration. Besides setting clear benchmarks and asking the right questions, key leaders need to be capable of identifying opportunities, understanding how the market behaves, and thinking creatively so that they can propose a convincing vision, persuade team members of its value, and work collaboratively towards its execution.

Cited Sources

GT Nexus (2016). The Current and Future State of Digital Supply Chain Transformation. Retrieved from http://www.supplychain247.com/paper/the_current_and_future_state_of_digital_supply_chain_transformation. Consultation date 12.13.2016.

Wang, G., Gunasekaran, A., Ngai, E., Papadopoulos, T. (2016). Big Data analytics in logistics and supply chain management: Certain investigations for research and applications. *Int. J. Production Economics*. (17)6: 98-110.

Agility in Global Pharma Supply Networks

By Rodrigo Falcão Gomes, Sailesh Kolachana
Thesis Advisor: Dr. Rafael Díaz

Summary: The key focus of this thesis is to develop a framework pointing out the "what", "how", "who", and "why" of the success factors responsible for driving agility and adaptability effectively in a pharma supply chain network. Logistics flexibility, one of the key domains of agility, was placed as the focus and its behaviour was studied under the influence of various uncertainty environments using a scenario based approach. The robustness of each scenario simulated was verified using ANOVA test.

Rodrigo F. Gomes (Brazil)

M.Eng. in Logistics and Supply Chain Management
Postgraduate in Business Management
Postgraduate in Logistics Management
Bachelor in Business Administration

Sailesh Kolachana (India)

M.Eng. in Logistics and Supply Chain Management
Master of Technology in Engineering Design
Bachelor in Technology in Engineering Design

KEY INSIGHTS

1. Agility in supply chain embraces two main factors: a proper response to an anticipated or unexpected change in due time; and taking advantage of those changes as opportunities.
2. During times of uncertainty some logistics decisions work better than others by keeping service levels robust.
3. The adequate application of methodologies and tools established in the academic field can support managers in their decision-making processes in the business world.

Introduction

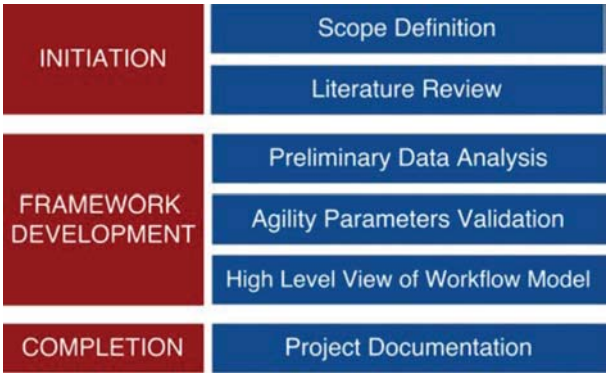
Companies from different industries have been facing increasing supply chain challenges due to the turbulence and volatility of demand in global markets (Seebacher and Winkler, 2015; Collin and Lorenzin, 2006; Christopher, 2000). Product variety expansion, shorter life cycles, globalization, outsourcing, competition and technological leaps are some examples that increase complexity and turn supply chain management into a challenging task (Lee, 2002).

Seeking to manage risks proactively, the ability to quickly adapt the supply network to unexpected changes and meet customers' demands without incurring significant costs, has become an on-going concern among operations managers. An agile supply chain comprises being fast and flexible (Collin and Lorenzin, 2006) and, according to Swafford et al. (2006), agility has become an essential element in an organization's competitive strategy.

The pharmaceutical industry is a very uncompromising supply chain, as it is highly regulated and directly influences health and safety (Mehralian *et al.*, 2015). It is also one of the industries that usually have a vast inventory with several Stock Keeping Units (SKUs), thus increasing in product complexity (Oey and Nitihardjo, 2016).

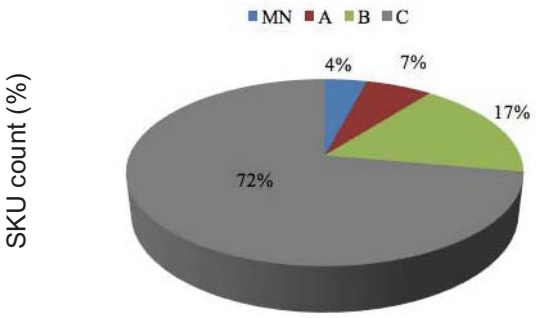
Methodology

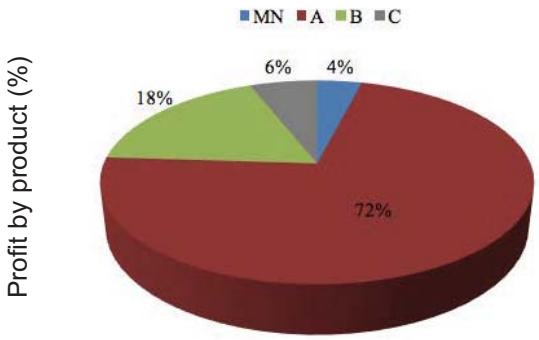
This section presents the research methodology undertaken to carry out the project. The figure illustrates the research methodology flowchart, and the preliminary data analysis, agility parameters validation and high level view of workflow model stages mentioned in the diagram are detailed in sequence.



Preliminary data analysis

According to the information received from the company, four products are predominant, here named Products "A", "B", "C", and Medically Necessary items ("MN"). Each of the product segments has differentiated service level targets based on the overall strategy. Forecast accuracy and bias are measured by market and by item category. Observing the expected service levels, it is possible to realize that products MN, A, and B expect an increase in service levels whereas C does not. Product C has the highest proportion of SKU count. However, the company's increasing focus lies on products MN and A, especially on their service levels. Product C has high investments built into its massive 10000 SKU count, which currently run at a 96% service level. The onus lies in making C lighter on capacity and inventory and making it more agile – in turn improving the service levels of products A and MN.





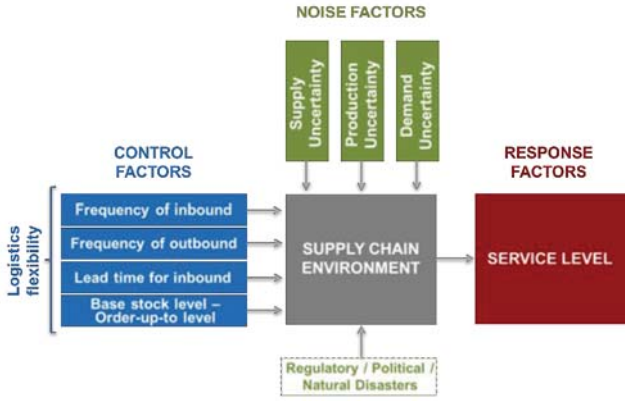
Agility parameters validation

The agility parameters validations were defined based on the literature – mainly on the basis provided by Swafford *et al.* (2006) – and validated with the industrial sponsor and academic advisor. The parameters considered are presented as follows:

- Sourcing flexibility
- Manufacturing flexibility
- Logistics flexibility
- IT flexibility
- Product development flexibility

High level view of workflow model

As per the requirements of the sponsor, a focus was placed on logistics flexibility. At a high level view of the workflow model, a deeper analysis through a simulation that describes the impact of logistics flexibility on service level, across various levels of demand and supply uncertainties (raw material and production disruptions), was undertaken at this point using a network-modelling tool (Arena software).



Pharma environment to be simulated

The real world pharmaceutical environment is typically composed of four broad vertical layers – the supplier, the production plant, the logistics center and the market logistics. These layers are composed of different players – such as suppliers, manufacturers, distributors, health insurance companies, hospitals, and so on.

Taguchi analysis methodology

An L9 Taguchi Orthogonal Array framework is implemented for the design of experiments. The controls observed are the variables around logistics flexibility, and from which the service level of Product 1, the service level of Product 2, and the truck utilization are derived as an output.

The same Taguchi framework is replicated for two levels of demand uncertainty, which can vary as much as 100% to 300% (Ellison *et al.*, 1997). Similarly, as observed from literature, minor supply disruptions and production disruptions can be negligible and can vary to as high as 25% (Friedli *et al.*, 2013), with the exception in the case of natural disasters. Thus, the framework is replicated for two levels of increased demand uncertainty, two levels of increased supply disruption, and two levels of increased production disruption. Hence, the framework is run a total of 7 times, each with 50 replications to ensure enough smoothing of the results. The results of the replications were subject to an ANOVA (Analysis of Variance) test to understand if they can correlate to obtain a significant p-value.

Analysis of variance test

Since each scenario was run for 50 replications, an ANOVA (Analysis of Variance) test was carried out between the baseline and each among 8 other scenarios within one L9 orthogonal array that manipulated the control factors. The noise factors, on the other hand, were varied on two or three levels on a stepwise basis.

As seen in this comparison, various p-values are obtained, with most being lesser than 0.01, thus being significant at a 99% confidence level. However, a few factors, i.e. some of the stepwise variations of noise factors, are significant at a 5% significance level, 10% significance level or insignificant.

Results

The results of the Taguchi analysis lead to the impact of the logistics flexibility control factors on service levels of Product 1 in the face of demand uncertainty, supply disruptions and production disruptions, while Product 2 remains as another product that shares supply and production capacity with Product 1.

Success Factors

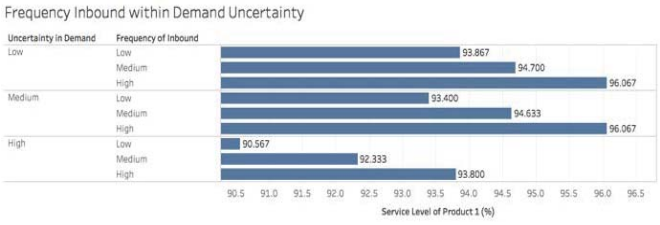
Frequency of logistics: The decisions around the frequency with which the logistics manager controls the inbound (rate at which replenishments are taking place) and the outbound (rate at which deliveries are taking place) can cause different service level variations (payoff), depending on the levels of disruption and the levels of uncertainty.

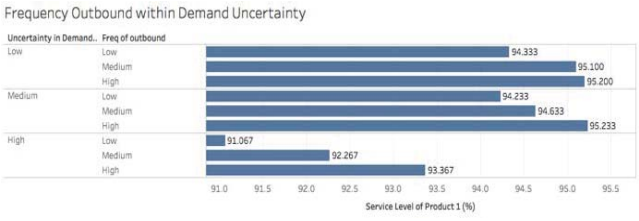
Lead time of replenishment: The decisions around lead time of replenishment in the logistics/distribution center can cause different service level variations (payoff), depending on the levels of disruption and uncertainty. The logistics team can choose to ship by air or truck, or in some cases, has to procure from a secondary location that has a longer lead time.

Order-up-to level at distribution center: The order-up-to level in the logistics/distribution center can also impact the service level. Many pharmaceutical companies work on the order-up-to model for their inventory policies (Pharmaceutical Manufacturing, 2012). Hence, a high order-up-to level can come with large safety stock that can hedge for uncertainty, but this study will help describe by how much, depending on the levels of uncertainty and disruption.

Cause of success

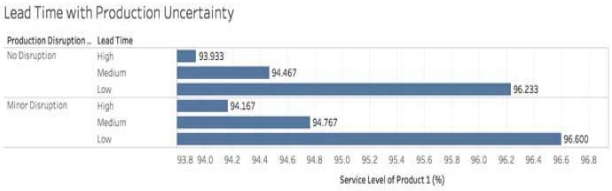
Increasing the frequency of inbound and outbound by two levels, as per the usual variation cited in literature (Friedli *et al.*, 2013) increases the service levels significantly and positively. Also, it is observed, that increase of demand uncertainty causes a decrease of service level on average. When the demand uncertainty levels are at the low level, increasing the frequency of inbound and outbound from low to high increases the service levels by 1-2%. However, it is to be observed that in periods of high demand uncertainty, when demand can swing up to 300% (Ellison *et al.*, 1997) in excess, it is observed that the increases in frequency of inbound and outbound from low to high can cause a service level increase (payoff) of as much as 4%. When demand is highly uncertain, having faster replenishments and deliveries helps manage the higher demands better, thus leading to better service levels.





With a production disruption in place, having low lead times proves an important logistics decision, with service level increases. It is also observed that the increase in service level (payoff) due to changing the lead time from high to low during minor production disruption is slightly higher than the increase in

service level (payoff) from changing the lead time from high to low during no production disruption.



Those responsible for success

This thesis is written keeping in focus the scope of the logistics operations (operation across the plant to the logistics center and the logistics center to the market logistics). The transportation team would be responsible for choosing the modes of transport and the routes that would impact the lead time. The transportation team would also be responsible for the control of the frequency of the replenishments and the deliveries to and from the logistics center. The inventory manager would be responsible for choosing the order-up-to level. However, when high demand uncertainty occurs, or worse, when supply disruptions occur, the coordination between the teams usually falls apart and the tactical decisions need to be replaced by more strategic ones by keeping in mind the big picture about the costs and the service levels. In such scenarios, a big picture understanding would be helpful to the high level management, to understand what must be done around logistics decisions depending on whether the disruption is in supply, production or demand.

Conclusions

The Taguchi orthogonal array methodology was used to understand how multiple control factors are individually impacting the response factor without running it for all the combinations of the control factors. The Taguchi framework ran 9 scenarios, and each Taguchi framework was run a total of seven times (various uncertainties). Each scenario was run with 50 replications to ensure enough smoothing of the results that occurred due to variations. The results of the scenarios were, then, submitted to an ANOVA (Analysis of Variance) test in order to understand if they can correlate with the baseline to obtain a significant p-value. After performing the scenarios and comparisons, various p-values were obtained, with most being lesser than 0.01, showing that the difference between treatments is statistically and highly significant, at a 99% confidence level.

When decisions are taken around logistics flexibility, the environment, that is, the uncertainty level of the demand and disruptions in supply have to be gauged. When, the uncertainty happens downstream, it is recommended to quickly and frequently move resources downstream. However, when the disruption happens upstream, being agile usually means creating flexibility by fixing bottlenecks, regrouping resources and collaborating across teams. The results section shows that, in the face of disruptions and uncertainties, the right logistics decisions were able to increase the service levels of Product 1 by 2-3% at the same time keeping Product 2 service levels robust, that is, not affecting its service levels beyond 2% variation.

Cited Sources

Ellison, S.F., Cockburn, I., Griliches, Z. and Hausman, J. (1997) Characteristics of demand for pharmaceutical products: an examination of four cephalosporins, *RAND Journal of Economics*, 28(3), pp. 426-446.

Friedli, T., Basu, P., Bellm, D. and Werani, J. (2013) *Leading Pharmaceutical Operational Excellence: Outstanding Practices and Cases*. Springer, Berlin Heidelberg, pp. 37-40.

Lee, H.L. (2002) Aligning Supply Chain Strategies with Product Uncertainties, *California Management Review*, 44(3), pp. 105-119.

Design of Effective and Efficient Distribution Network in Sub-Saharan Africa

By Syed Muhammad Talha Kamal and Rishi Prakash
Thesis Advisor: Dr. Spyridon Lekkakos

Summary:
The aim of this thesis is to develop a distribution strategy which will enable the Sponsor Company Vetapharm in reducing the distribution costs and thereby increasing the affordability of its products for small holder farmers in East Africa especially Tanzania.

M.E. in Logistics & Supply Chain Management, MIT-Zaragoza International Logistics Program

Bachelor of Science in Economics, Lahore University of Management Sciences, Lahore, Pakistan

M.E. in Logistics & Supply Chain Management, MIT-Zaragoza International Logistics Program

MBA (Marketing and Operations) FORE School of Management, New Delhi, India

Bachelor of Engineering in Civil Engineering, RTM Nagpur University, Nagpur, India

Key Insights

1. Very wide geographical spread of small farmers and lack of access to quality animal health care products leading to low productivity of small farmers
2. Multiple intermediaries in the Supply Chain of Vetapharm in Tanzania leading to multiple mark ups and increase in product cost for small farmers.
3. Proposal to develop and implement a mobile based App anchoring on the spread of Internet and mobile communication in Tanzania.
4. The proposed App might lead to a "order timing pooling" leading to a reduction in distribution costs and a subsequent increase in affordability by small farmers

Introduction

Our sponsor company, Vetapharm, is a global leader in veterinary medicine and animal healthcare. Vetapharm aims to provide farmers in East Africa, i.e., Kenya, Uganda and Tanzania with better quality pharmaceutical products for their animals and farms. By doing so, Vetapharm hopes to bring a significant improvement in the economic prosperity of the East African farmers as well as its own bottom-line. However, there are several challenges in terms of delivery of the product to the end customer that need to be dealt with before the East African Market can be tapped. The very first hurdle is that there are multiple intermediaries in the supply chain leading to multiple markups and consequent increase in product cost for small farmers. Second is the very wide geographical spread of small farmers and lack of access to quality animal health care products leading to low productivity of small farmers.

Country in Focus: Tanzania

At the beginning of the study, we were focusing on three East African countries (Kenya, Uganda and Tanzania), countries in which Vetapharm aims to enter/expand. As we studied the basic demographics, economies, growth potential and agricultural industry of these countries in greater detail, we found several similarities. After discussing the above findings with Vetapharm, it was decided to focus our research on just one country, namely Tanzania. The primary reason for our selection is that – amongst the three East African countries mentioned above – Tanzania is the country where Vetapharm is encountering the highest number of problems in distributing its products.

Problem Definition and Methodology

The objective of this thesis project is to develop distribution strategies that will enable Vetapharm to improve its sales growth by improving access to small holder farmers in East Africa. Due to the vast geographical spread of end customers, the existing veterinary distribution networks of the company's main distributors in East Africa involve multiple levels of intermediaries. This strategy creates a number of problems for Vetapharm, with the most important being the difficulty in reducing the delivered product cost for the end customer on account of multiple mark ups in the supply chain. The potential strategy for the research could be the development of solutions that are targeted towards reducing the number of intermediaries and hence the number of mark ups in the supply chain

Literature Review

From our literature review we noted that the livestock and poultry industry in the East African region is dispersed and highly fragmented. Our study also revealed that some of the key features of the livestock and poultry industry in Africa are as follows:

a) Lack of access to quality veterinary medicines and animal health care

b) Limited understanding and adoption of basic animal husbandry practices and preventive animal health measures

c) Concerns related to the right pack size for delivery to the final customer, especially the small farmers

As-Is Distribution Framework

In the current distribution set up of Vetapharm in Tanzania, a product has to go through at least three levels of intermediaries before it reaches the final consumer (i.e., the small holder farmers). In many cases, though, due to the geographical dispersal of end customers the number of intermediaries can be much higher than three.

Surveys

We conducted two surveys, one for customers and one for retailers in order to get an insight into the distribution network of Vetapharm in Tanzania. Our surveys had the following limitations

a) Surveys were administered by a third party, so we did not have control over the methodology of the survey

b) The number of responses was not as large as initially planned.

c) The surveys have been administered in the most developed areas in Tanzania as such the survey results represent the best case scenario of the distribution network in Tanzania

Key Insights from the Survey

a) Retailer Profile: We observed that the retailers surveyed here prefer quantity discounts and better payment terms over other benefits. We may say that the primary motivation of the retail shop owner is to increase his profits/monetary gains.

b) Product Price and Pack Size: We noted that Vetapharm's products are priced at the higher end as compared to the competition. Also, in certain product categories like fly control, Vetapharm products are the most popular products in the survey population.

c) Customer Profile: We observed that customers surveyed here value quality and availability of the product as the most important factors. Also, they buy products based on advice of the veterinary doctors or based on the reputation of the product.

d) Productivity: As per the survey results the productivity of the small farmers was much lower than the productivity of the large farmers.

e) Spread of the market: We noticed that more than 60% of the small farmers in the survey sample buy products from retail outlets within a 5 km radius. From this we can say that at least in the region where surveys were conducted, there might be a large number of small retail outlets spread all over the area.

f) Spread of ICT: We noted that 100% of the customer survey respondents and 98% of the retailer survey respondents own a mobile phone and have access to internet services. This gave us a major insight into the spread of the ICT in Tanzania.

Structured Interview of Lead Distributor

The key inputs and insights from the interview are as follows:

a) The mark up from the distributor to the stockist/agro vet shop is 15%. However, the distributor has no control on the mark up from the stockist to the retailers.

b) Vetaphram products are premium products and are priced higher in the market in all product categories.

c) The lead distributor is currently using the ICT technology in Tanzania for advertising its products.

Leveraging the ICT

From the interviews, internet research, and surveys we see that the ICT technology is spreading in East Africa, especially Tanzania. This creates opportunities for leveraging the ICT technology to develop solutions that might enable some streamlining of the current distribution system in Tanzania. Our search for ideas within the ZLC network brought us upon a unique solution, called Miti Health App, which is currently in the implementation phase in Kenya. Miti Health App is an application that is improving the pharmaceutical distribution network in Kenya.

Our proposed solution is inspired by the Miti Health App and shares several of its characteristics.

AniHealth App

AniHealth App, our proposed solution, will function in the following manner:

a) The distributor, stockist and the retailer each will have a unique registration number allocated based on their Country, Zone, Area, and Village.

b) As the retailer sells a particular product, the sales of the product will be recorded in the App. Subsequently, at the end of a period, the App will give the retailer the demand forecast of the product for the next period, along with an order quantity recommendation based on the desired service level. This will help the retailer by making the inventory management system more systematic and methodical.

d) Further upstream in the supply chain, the AniHealth App will help the distributors to improve the coordination with the retailers with the help of an inventory management system embedded in the App. This embedded inventory management system will enable the distributor using the AniHealth App to set up the App to collate and pool the orders of the retailers of a particular geographical region over a pre defined period of time.

Benefits of AniHealth App

The AniHealth app will address the following pain points:

a) Disintermediation in the Supply Chain: By collating the demand from a number of retail outlets over time and over an area the AniHealth App will allow retailers to reach farmers in far flung areas. This will help in disintermediation.

b) Lower Product Cost: The benefit of lesser number of mark ups may be passed onto the small holder farmers in the form of a lower product cost.

c) Analytical Support: The AniHealth App will provide basic level of analytical support for the retailers like forecasting demand and generating sales reports.

d) Reduction in stock out and lost sales: With better sales forecasts, the product availability and the customer service levels will improve.

e) Improve Two-way communication: The retailer acts as a doctor and provides advice to the farmers on which products to use and is a very important intermediary in the supply chain in Tanzania. The AniHealth App will help in bringing a more systematic and methodical approach to the demand and other information flow from the retailers to the distributors.

Discussion with Vetapharm

Vetapharm confirmed that the solution was workable and could help in increasing the coordination in the supply chain. Also, they stated that it would help reduce the costs of distribution by collating the demand from an area and increasing inventory visibility.

Concerns Regarding AniHealth App

There are a number of questions that need to be resolved before this idea of AniHealth App can be turned into a solution. These questions are:

a) First concern is with respect to keeping the AniHealth as product neutral or keeping it as a product specific App. The latter option will provide economies of scale in the value chain.

b) The second is with respect to the security of the information which will be stored by the AniHealth App. We suggest that a trustee be appointed by mutual acceptance of all the stakeholders for information security.

c) The source for the funding for the development and implementation of the AniHealth App still remains to be decided.

d) Last but not the least it is still not clear that how many layers of intermediaries the AniHealth App will be able to remove. This might vary from region to region depending on the geography of the region and the spread of the retail outlets among others.

Limitations

First, the available literature and research material with regard to animal healthcare in developing countries as Tanzania is limited and of questionable reliability. Second, being in a market-entry phase and

using a third party distributor in Tanzania, Vetapharm has limited visibility and lacks an in-depth understanding of the distribution network of its products in the Tanzanian market. Third, the lead distributor of Vetapharm products in Tanzania also did not have a complete visibility of the supply chain beyond the level of stockists to the level of retailers and Agro Vet shops. Fourth, the surveys we designed for gaining valuable insights on the profiles of retailers and end customers were administered by a third party. Regarding the survey results, apart from the small size of responses, there are some findings of questionable credibility

Recommendations

Our main recommendations for our sponsor company are the following:

a) Development and implementation of AniHealth App is still an idea and not a solution per se to improve Vetapharm's distribution strategy in East Africa. Many questions need to be answered and a consensus to be reached for those questions within Vetapharm.

b) The development, launch, and spread of the AniHealth App need to be properly managed. We also suggest that a beta version of the AniHealth App may first be launched and feedback on the performance of the App recorded. Based on the feedback, the App is updated and subsequently launched in a phase wise manner.

c) Vetapharm may like to focus on holding several training and educational programs for the farmers on the proper methods of usage, storage, and finally disposal of expired veterinary products.

d) A further study might be needed for investigating the potential of increasing the scope of AniHealth App product-wise and competition-wise.

e) Vetapharm may like to engage NGO's and development organizations to help with the implementation and funding of AniHealth App. Development organizations are doing lots of work in Africa, have a huge knowledge base, and can provide significant insights, resources and guidance for the successful implementation of this App.

f) Vetapharm may also like to engage competitors as we recommend the AniHealth App be product neutral. The App should be used for all the products that the retailer stocks as it would result in significant economies of scale in distribution.

An “Internet of Things” Approach against the Bullwhip Effect

By: Snehashish Sridhar and Rubén Sifuentes

Thesis Advisor: Dr Rafael Diaz

Summary

Significant research has been done on the causes of the Bullwhip Effect in supply chain networks. Studies have also been committed to understanding the Internet of Things (IoT) and the potential impacts it will have in the supply chain sphere. This thesis evaluates the possibilities of combining the two spheres, to find opportunities for Bullwhip Effect mitigation using Internet of Things technologies. Our analysis was done through simulation of a “Beer Game” supply chain within an Arena software environment, and addition of IoT tools.

Snehashish Sridhar, Master of Engineering in Logistics and Supply Chain Management, Zaragoza Logistics Center, 2017

B.S. Industrial & Systems Engineering, Georgia Institute of Technology, 2016

Rubén Sifuentes, Master of Engineering in Logistics and Supply Chain Management, Zaragoza Logistics Center, 2017

B.S. Industrial Engineering, Pontificia Universidad Católica del Perú, 2003

KEY INSIGHTS

1- The Bullwhip Effect is an extremely complicated and multifaceted problem affecting the performance of modern day supply chains.

2- The Beer Game is an interactive game that replicates a supply chain and is an adequate visual approach to analyze the interactions among the echelons along the supply chain.

3- Simulation is a powerful analytic tool through which the Beer Game can be replicated to analyze the different results in performance within a supply chain as specific Internet of Things tools are used to mitigate the Bullwhip Effect.

4- Since all improvements generate costs, it is critical to define the appropriate trade-off between the costs of tool implementation versus the savings reached in the supply chain.

Introduction

At its core, the Bullwhip Effect is caused by a lack of communication between different echelons within a supply chain. This lack of communication, in combination with short-sighted behaviors such as shortage gaming and price gauging, leads to increased inventory levels, lower customer service levels, and higher supply chain costs for everyone.

Since the Internet of Things has become an increasingly efficient tool in industrial applications, our sponsor company wants to explore its potential in providing new supply chain solutions.

The scope of the thesis is to analyze the limits of IoT technology in the industrial sphere, and to understand how it can be implemented to provide visibility into the factors leading to the Bullwhip Effect. To this end, our two key research questions are as follows:

1. How is the Internet of Things helping companies to reduce the Bullwhip Effect on a multinational supply chain scale?

2. Could this reduction be enhanced by further emerging technologies, such as 3D printing?

Our main goal has been to provide our sponsor company with a scalable plan against the Bullwhip Effect., that will present its impact on the reduction of the Bullwhip Effect in a tangible manner.

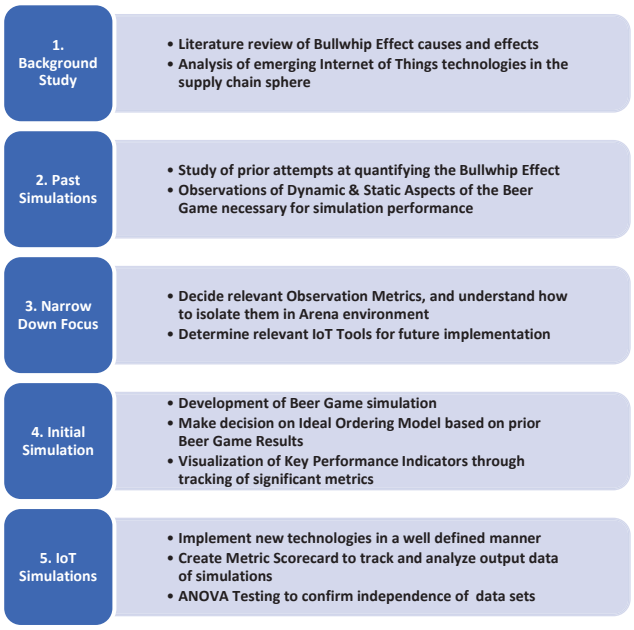
Therefore, this thesis has two main contributions:

1. Advancing research on the factors that contribute to the Bullwhip Effect in multiple Industries.

2. Development of a mitigation strategy to control the Bullwhip Effect, involving IoT technology.

Methodology

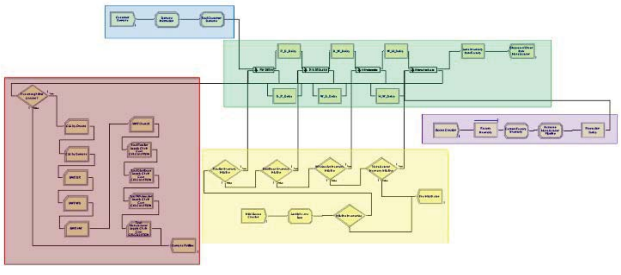
The methodology involved five steps required to set up our initial study and provide the context towards the final analysis.



From prior simulations, we reviewed how to design a basic framework for measuring the Bullwhip Effect per echelon, implementable without any external data, which could be automatically adjusted when parameters changed.

Baseline Simulation

The simulation setup is as follows:



Our baseline simulation involves 4 major echelons, with their interaction details listed below:

Echelon	Receives Orders from	Sends Orders to
Retailer	Customer	Distributor
Distributor	Retailer	Wholesaler
Wholesaler	Distributor	Manufacturer
Manufacturer	Wholesaler	Factory

The simulation begins with an initialization period (*yellow*), in which all echelons receive inventory such that there is not an immediate backorder queue.

The simulation refers to “turns” within the Beer Game as hours within the simulation environment clock. Every turn, several steps occur as follows:

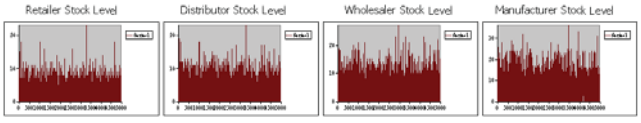
1. A customer order is released into the system (*blue*). At this point, it is assigned a value based on a predetermined distribution, and sent to the retailer for fulfillment.

2. The retailer will fulfill the order as much as possible, and will send an order to the distributor. This chain continues until the manufacturer places an order with the factory. After a lead time of 2 turns, they will receive the order (*green*).

3. All units of goods are pre-produced by the simulation before initialization, stored, and released when called for (*purple*). Only then do they enter the system to be sent to the manufacturer. The manufacturer’s order will assist them in increasing their inventory, which will be useful in fulfilling further orders. This path of order fulfillment continues until the retailer, who fulfills the original customer order.

A Winter’s forecasting model has been determined as appropriate to define the amount of inventory that an echelon needs to order to act in a similar fashion as an average player would in the Beer Game.

Our system includes 4 set of graphs to track major KPIs and to confirm that there is no abnormal behavior, such as a lack of units to fulfill demand or abnormally high inventory demands. For example, the stock level charts display the current inventory level at each echelon. They can be seen below:



To measure simulation performance, we considered the following metrics:

- Customer Service Level for Orders (CSL_O): percentage of orders that can be fulfilled completely at the time of order.
- Customer Service Level for Units (CSL_U): percentage of units of demand fulfilled.
- Total Supply Chain Cost, which considers echelon backorder and holding costs
- The Bullwhip Effect (BWE) Factor: a measure of the change in order size variability per echelon:

The initial simulation was run for 5000 turns, with the basic setup as described above. It was then repeated 100 times for a minimization of variability.

In the baseline figure, the CSL_U is 0.668, while the CSL_O is 0.396. The standard deviation is less than 5% (in both cases), indicating consistency in results.

From the initial simulation, there is an initial total cost of $25,065.22, with a standard deviation of $3,297.89, or 13.15%. This value indicates a high level of randomness in the way each echelon is responds to the Bullwhip Effect. The breakdown of cost is:

	Holding	Backorder	Total
Retailer	$ 9,074.10	$2,722.23	$11,796.33
Distributor	$ 3,501.87	$1,050.56	$ 4,552.43
Wholesaler	$ 3,172.05	$ 951.61	$ 4,123.66
Manufacturer	$ 3,532.92	$1,059.88	$ 4,592.80
Total	**$19,280.94**	**$5,784.28**	**$25,065.22**

The BWE Factor, between all combinations of echelons, is greater than 1, and the BWE Factor for the system is 3.32. This result proves that the model does in fact exhibit the Bullwhip Effect. Thus, it is viable for testing of IoT tools to combat this issue.

Updated Simulations

The next step is to implement relevant technologies within this environment to observe changes to specific KPI's. For this study, the IoT tools chosen are:

- Complete End-to-End Visibility, which allows for tracking of in-transit and stationary goods at any point in one's own supply chain
- Backorder Visibility, useful to share information about overall inventory position, providing a better view of upcoming demand.
- 3D Printing, which provides inventory to downstream members quickly when inventory is low or nonexistent. They do so by building the unit internally, shortening the supply chain and leading to much lower lead times.

For each echelon, observations are made about the current pipeline inventory level, inventory level, and backorder level and then this information is scaled against the overall average of each indicator for the duration of the simulation, which is also calculated and updated every turn, providing a "scale factor" for each indicator that is used for order calculations.

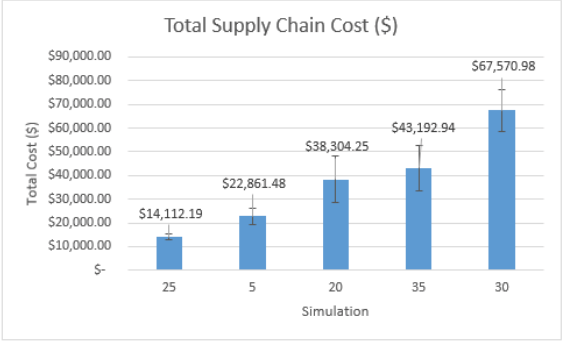
Meanwhile, during order processing, scale factors from all other echelons are considered to give each echelon a picture of the state of the system. If all scale factors are above 1, it can be assumed that there is an increase in some specific inventory level. Otherwise, a deficit can be presumed by the echelon.

Furthermore, each echelon can compare its own backorder level with the average backorder level throughout the simulation. When the current backorder level is greater than average backorder level by a prefixed degree, an appropriate amount of 3D printed goods is released to fulfill incoming orders, without altering the backorder level.

Prior to analysis, an ANOVA test was done to confirm that each population of results, or observations, was statistically independent, with no covariance between them. As is evident from the table below, all populations were statistically independent at a 95% probability.

KPI	Average	Minimum	Maximum
CSL_U	4.14E-43	4.54E-207	1.62E-41
CSL_O	4.31E-17	7.21E-96	1.68E-15
BWE	8.09E-06	4.63E-186	3.15E-04
SCTC	1.21E-03	4.63E-186	3.16E-02

The following scenarios were found to have the lowest total supply chain cost:



From the graphic above, Scenario 25 has the minimum total cost. In this scenario, the IoT tools used were the pipeline and backorder visibility. Despite this, the Bullwhip Effect factor is 9.70, very high in relation to the baseline scenario (3.33) and

such a scenario is far from optimal despite the low cost. The reason for this increase in BWE can be directly attributed to order variability in Scenario 25.

Meanwhile, in Scenario 5, the total cost is $22,861, the second-best value, and the BWE Factor is 3.15, lower than the baseline. This scenario only has backorder visibility, and still maintained a low BWE Factor. Therefore, Scenario 5 is the best case if there is a significant tradeoff between Total Cost and the Bullwhip Effect.

The conclusion is that two similar scenarios occurred, but the one with an additional IoT tool had increased variability and BWE. This is because in Scenario 25, echelons are receiving instructions about the general layout of the system from one tool, and this conflicts with instructions from other tools, leading to deviation from expected results.

Related to the BWE, we observed that only one scenario tested resulted in a BWE Factor lower than the baseline scenario. What can be concluded is that using multiple IoT tools with relatively open instructions as to how to respond to them led to greater variability in order sizes. Thus, Scenario 5, which only uses a backorder visibility, is still the most viable option from observed simulation scenarios.

Scenario 6 has a BWE Factor only 20% greater than the baseline, but the cost is significantly higher. This is evidence of the ability of 3D printing to minimize the Bullwhip Effect, while assisting in providing for customer demand needs when no other option is available. The higher cost is also important to observe.

Regarding CSL_U and CSL_O, Scenario 34 features the second highest CSL for units at 97.8%, as well as the highest CSL for orders at 95.1%, compared to the Baseline. What is notable about 8 out of the top 10 scenarios in CSL, is that they all observe the pipeline visibility, the inventory visibility, and the 3D printing tool set to varying degrees of sensitivity. This is evidence to suggest the validity that a 3D printing and IoT tools will be effective in assuring and maintaining high CSL's.

Regardless of additional tools present, Supply Chain Cost rose significantly with the addition of 3D printing tools, as seen in the table below.

Simulation	Average Total Supply Chain Cost	
With 3D printing	$	61,622.79
Without 3D Printing	$	194,658.89

The primary reason for this is that the threshold for use of 3D printing, for an echelon, is placed too low. Future work will be required to examine the effects of setting a greater threshold, such that it will serve as a last resort to increase CSL, rather than a constant immediate solution. The secondary reason is that there are not enough restrictions placed on the use of IoT tools in general, and on responses to the outputs of those tools by simulation echelons. The merits of these tools are proven in the decreased BWE and increased CSL's in specific scenarios, but unconsidered scenarios may lead to questions about these conclusions.

Conclusions

As businesses expand in a global manner, spreading different stages of their supply chain along time zones, it becomes a major challenge to maintain and improve coordination between stages. To reduce the factors that generate the Bullwhip Effect, objectives must be aligned to overcome barriers.

In pursuit of conclusions, 40 simulations based around the Beer Game were created, due to its mutability. Also included were increasing complexities implemented through research of emerging Internet of Things technologies. The resulting simulations were analyzed, in regards to the defined metrics.

From these results, we drew conclusions about the validity of these technologies in preventing the Bullwhip Effect and improving supply chain coordination, in terms of costs incurred and savings achieved. It is up to the supply chain manager to decide the appropriate trade-off between implementation costs and potential savings through the achievement of operational targets.

Cited Sources

Lee, Hau L., V. Padmanabhan, and Seungjin Whang. "The Bullwhip Effect in Supply Chains." *MIT Sloan Management Review*. MIT Sloan, 15 Apr. 1997. Web. 14 Jan. 2017.

Sterman, JD. "Operational and behavioral causes of supply chain instability". 2006. In *The bullwhip effect in supply chains*, Edited by: Carranza, O and Villegas, F. UK: Palgrave McMillan.

ZLOG CLASS OF 2017

THESIS PROJECTS

Digital Experience Research for Freight Forwarders
Team: Marcos Benedí, Cristina Escribano, Andrés Rosas
Advisor: Dr. Luca Urciuoli

This thesis undertakes the context of how new technologies and digitalization are revolutionizing relationship between companies and their customers. The thesis deepens in how companies must adopt digitalization as a value-added service to firstly remain ahead of competition, and secondly due to their impact on customer satisfaction and loyalty.

Predictive analytics for improving supply reliability
Team: Lakshmanan Chinnanchetty, Maria Canellas Arcarazo
Advisor: Dr. Davide Luzzini

This thesis aims to develop the understanding of predictive analytics by conducting a pilot project focused on predicting failures in customer service well in advance. The thesis is mainly focused on mitigating non fulfilment of targets of customer service level, in terms of the metric Line Item Fill Rate (LIFR) and backorders.

Uberization of Supply Chains
Team: Pierre Sfeir, Farshid Izadi
Advisor: Dr. Susana Val

This thesis titled "Uberization of Supply Chains" studies the roots, background and paradigms of sharing economy in logistics and supply chain. We also propose a stepwise process to define a better business model for any logistic provider company facing disruption through Uberization in the market.

Safety Stock Optimization for a UK Brewery
Team: Yikun Li, Josep Zambrano
Advisor: Dr. Alejandro Serrano, Dr. Spyridon Lekkakos

This thesis tackles the question of which is the minimum safety stock level that optimizes the company performance in terms of costs, maintaining the customer service level (CSL) as high as required. It adapts some of the existing standard models to a real-world problem with specific assumptions.

A New System for Temperature-Controlled Transportation
Team: Ifeanyi Peter Obijiaku, Parodi Manuel
Advisor: Dr. Luca Urciouli

This project focused on understanding the markets that a novel cold chain technology – Chill-X can address. Chill-X is temperature controlled solution that is made up of two components - the cube and the thermo shield. Ice is stored in the cube and the thermo shield is used to distribute the ice evenly across the cargo to ensure cooling. In addressing this problem, we combined both primary and secondary data sources. We segmented the markets, by temperature and geography, in order to identify addressable markets. We further conducted interviews with companies within the markets identified to understand their pain points, suitability of the technology, and possible constraints to the success of this technology.

Determining the Optimal Distribution Network

Team: José Ramon Gené Garrigós, Ritesh Ranjan, Victor Mansur Ghetti
Advisor: Dr. Mustafa Çagri Gürbüz

This thesis determines optimal dispatch weight and time for air and ocean shipments to minimize global transportation cost and improve on time delivery service level. Because order arrival in the system is stochastic, we have used simulation to mimic reality and then optimize the network.

Linking Lead Time and Inventory in Pharma Businesses

Team: Ashish Thomas Augustine and Shwethika Adusumalli
Advisor: Dr. Spyridon Lekkakos

The key focus of this thesis is to empirically investigate the relationship between lead time and inventory within the supply chain network of a global pharmaceutical firm. By means of statistical data analysis and case-based examination of the system under study, the impact of lead time and lead time variability on inventory is quantified, along with the identification of focus areas within the firm's network. This is followed by scenario- simulation to provide useful insights in terms of scope for inventory reduction by controlling lead time related parameters.

Adding Value through Collaboration: Big Data Analysis and Opportunities

Team: Greivin Rodríguez Calderón, Romina García Soriano, Beverly Osborn
Advisor: Dr. María Jesús Sáenz

This thesis identifies opportunities for large companies to create added value by analyzing the logistics-relevant big data stored in their enterprise resource planning systems. All analysis is based solely on data provided by the sponsor, a global chemical company which currently makes many logistics decisions within each business unit. We propose ways to analyze and act on the firm-wide data that can lead to reductions in costs and improvements in service levels.

Agility in Global Pharma Supply Networks

Team: Rodrigo Falcão Gomes, Sailesh Kolachana
Advisor: Dr. Rafael Díaz

The key focus of this thesis is to develop a framework pointing out the "what", "how", "who", and "why" of the success factors responsible for driving agility and adaptability effectively in a pharma supply chain network. Logistics flexibility, one of the key domains of agility, was placed as the focus and its behaviour was studied under the influence of various uncertainty environments using a scenario based approach. The robustness of each scenario simulated was verified using ANOVA test.

Design of Effective and Efficient Distribution Network in Sub-Saharan Africa

Team: Syed Muhammad Talha Kamal, Rishi Prakash
Advisor: Dr. Spyridon Lekkakos

The aim of this thesis is to develop a distribution strategy which will enable the Sponsor Company Vetapharm in reducing the distribution costs and thereby increasing the affordability of its products for small holder farmers in East Africa especially Tanzania.

An "Internet of Things" Approach against the Bullwhip Effect

Team: Snehashish Sridhar and Rubén Sifuentes
Advisor: Dr. Rafael Díaz

Significant research has been done on the causes of the Bullwhip Effect in supply chain networks. Studies have also been committed to understanding the Internet of Things (IoT) and the potential impacts it will have in the supply chain sphere. This thesis evaluates the possibilities of combining the two spheres, to find opportunities for Bullwhip Effect mitigation using Internet of Things technologies. Our analysis was done through simulation of a "Beer Game" supply chain within an Arena software environment, and addition of IoT tools.

www.zlc.edu.es/zlog

MIT Center for Transportation & Logistics

PLAZA
PLATAFORMA LOGÍSTICA DE ZARAGOZA PLAZA S.A.

Universidad Zaragoza
1542

FONDO SOCIAL EUROPEO
"Construyendo Europa desde Aragón"

iberCaja

GOBIERNO DE ARAGON