Using Spatial Simulation Modeling to Improve Warehouse- Logistics Operations Management

Emery, L. & Al Bazi, A.

Original citation:
Emery , L & Al Bazi, A 2013, 'Using Spatial Simulation Modeling to Improve Warehouse- Logistics Operations Management', International Review of Economics & Strategic Business Process Management, vol. 1, pp. 47-53.

ISSN 1737-9288

Publisher: IPCO

International Conference on Control, Engineering & Information Technology (CEIT'13)
Economics & Strategic Management of Business Process - Vol.1, pp. 47-53, 2013

Using Spatial Simulation Modeling to Improve Warehouse- Logistics Operations Management

Ammar Al-Bazi[1], Lynn Emery[2]

[1] *Faculty of Computing and Engineering*
Coventry University
Coventry, UK
ammar.albazi@coventry.ac.uk

[2] *Huf Hülsbeck & Fürst Ltd.*
Tipton, UK

***Abstract*— the purpose of this work is to investigate the application of spatial simulation technology in the area of warehouse-logistics operations management. A computerised simulation model is developed, with the use of specialist software known as Arena, aims at identifying areas of improvement in regards to warehouse-logistics management. In particular the simulation model focused on improving the storage location of goods, the picking of goods and the allocation of resources of warehouse management as these are believed to be potential weaknesses of logistics operations.**

Multiple tools and techniques are adopted for the collection of data including interviews and onsite visits; of which benefited greatly from the use of a stop watch approach. Logical identification techniques including flowchart is utilised following the collection of data. "As-Is" simulation model is developed to measure the current operations performance followed by multiple "What-If" experiments for further improvements. Sheldon Clayton Logistics Group is considered as a case study.

***Keywords*— Spatial Simulation Modeling, Warehouse Logistics, Resource Allocation, Layout Modeling.**

I. INTRODUCTION

[11] defined logistics as a process which supports managerial operations in regards to the supply chain. However [15] provided greater depth and suggested that logistics is the process of directing multiple activities including the planning, execution and the control of goods and/or people with the intent of achieving specific business objectives.

With the recent increase of competition and financial pressure it is thought that logistics has been heavily centralised within industry in the hope of improving inventory management, sustainability and customer service [2]. Consequently, logistics is now thought to be recognised as a highly essential strategic activity which can help establish a competitive advantage if managed and maintained effectively [14].

Warehouse management is thought to be an essential activity within the logistics industry and is commonly formed by the combination of warehousing and materials handling including process of storing goods.

The process of storing goods along with picking and packing them can often difficult to management and implement effectively, consequently they are often seen as ultimate focuses of warehouse management. Moreover, such activities are believed to positively affect the rate of success and efficiency within a business when managed correctly.

Warehouse Management was chosen to be focused upon within this study as it is thought to be seen as a very significant and vast operation within the logistics industry. Furthermore, the efficiency of the operation is thought to be critical for companies when wanting to capture a competitive advantage, yet problems are persistent with this field. This project has been centralised around warehouse management in order to demonstrate the ease of which such problems can be solved, to allow for maintain competiveness, when suitable tools and techniques are utilised.

Simulation technology has been used in solving a number of problems related to logistics industry such as: logistic operations [12], warehouse management [4]. For transportation of goods, there are a number of issues/ problems that affect the efficient transportation of goods [1]. Changes in the supply chain processes for a large logistics operation were proposed. Impact of these proposed changes was analysed using simulation [5]. [9] analyzed process of logistics collaborative operation and provided a new way to solve allocation of resources of collaborative operation. A simulation model is established for a typical storage outbound collaborative operation. [6] developed a detailed simulation model of their dispatch operations from the warehouse to the various customers in the Gauteng region. [16] reviewed optimisation methods for simulation models to quickly and effectively execute analysis and planning tasks related to production and logistics systems. [13] developed a simulation model of loading and unloading operations of the port logistics park. The final objective is to work out the optimal loading and unloading logistics system. [8] concentrated on simulating transportation and warehousing issues, and different approaches have been used in different publications. [3] discussed re-planning or reorganising of the layout of the warehouse logistics by resoning goods according to their weight based on the priority principle. The research suggests that the improved layout plan of warehouse logistics saves the total cost and drastically enhance the storage efficiency.

In this research, there are multiple complications which arise within warehouse management, many of which also affect warehouse-logistics operations performance and efficiency. However the picking of goods, the storage of goods and resource utilisation was the chosen fields on interest for this project as these areas are thought to be the most problematic, yet critical within the logistics industry.

II. RESEARCH PROBLEM

The problem of this research is summarised as follow: In transportation of cargo logistic operation, lorries arrive on site their load can only be unloaded if adequate resources are available. These resources, for example, can include people or equipments such as forklift trucks and/ or trolleys. Inadequate amounts of these resources can result in longer process times and decreased efficiency, whereas zero resource availability will result in extreme delays and process times as the required task cannot be completed.

Consequently, the complication in regards to resource utilisation often regards defining the optimum number of resources so that they are not over utilised or underutilised. This impediment also occurs when goods need to picked and loaded back onto a lorry for delivery. It should also be noted that identifying the optimum number of resources will not only improve company efficiency, it will also ensure companies receive good value for money, as their resources will be used to their potential. Nevertheless, identifying the optimum number of resources is a rather challenging task as a number of constraints must be accounted for including demand levels, resource output, reliability, time schedules and affordability. Due to such difficulties it is often the case that company demand is greater than their capabilities, therefore they are applying excessive utilisation rates to their employees of which can in turn create poor customer service.

Following the delivery of goods, employee resources are required to effectively store the goods to allow for easy access and retrieval. Many logistics companies are confident in the way in which they store goods; however the research suggests that company efficiency is often affected due to poor methods of storage. Depending upon the size of the warehouse and its demand, the method of storage will vary. Some warehouses will store their goods randomly, whereas others will store it systematically. For example, some will store their goods by customer name, or destination, whereas others store the goods via product, due date or even one a first in first out basis. The storage method adopted is significantly important as it can affect the speed of retrieval and the efficiency of picking when required. Poor storage techniques can create an array of problems especially when goods which are required first are stored at the bottom of the pile. Not only does this create added work for the employees when the goods are to be picked, it increases process time and decreases efficiency. Consequently identifying the optimum method of storage is essential within the logistic companies; however this can be a somewhat tiring and difficult task due to the many techniques and constraints imposed within warehouses.

As touched upon, the storage method adopted can also affect the efficiency of picking goods. For example, good which are easily accessible and stored systematically can often be picked with less effort compared to goods which are stored unsystematically.

The physical location of the stored goods can also impact the picking time as the distance from the picking station to the loading bay can vary; therefore finding the optimum storage location is an important challenge to conquer when wanting to improve operational efficiency. Furthermore, the route travelled to pick the goods will undoubtedly vary depending on the storage location and layout of a warehouse. A route which forces and individual to weave in and out of isles in order to pick goods is far more inefficient, not only will it take up more time to but also more effort compared to a route which allows direct collection. Therefore companies which adopt highly complicated routes are likely to be far more unproductive compared to those which have identified an optimum route. Identifying an optimum picking route will not only decrease picking time, it will also increase companies demand capabilities as time and effort will be freed to allow for more work and therefore highlights its significance.

To summarise problems surrounding warehouse picking, storage and resource utilisation are common but yet are thought to be difficult to solve. A lack of efficiency within all three of these are'As Is' thought to affect company, performance output and effieicny and therefore attempts to ressolve such challenges must be focused upon.

The aim of the project is to develop a spatial simulation model to improve management of warehouse-logistics operations and transportation and unloading of cargo logistic operation in particular.

In order to achieve the above aim effectively the following objectives where composed and centralised throughout the project.

1. To review previous studies in the area of warehouse management and it's faced problems along with the tools and techniques used to solve these problems.
2. To collect data required to model the current workflow.
3. To identify logic of the current situation
4. To develop a spatial simulation model in order to imitate the current course of action.

The following research methods where exploited as they were thought to be the most effective.

1. A literature review which reviewed previously faced problems and used tools and techniques within the field of warehouse management.
2. A selection of tools and techniques including onsite visits, observations, interviews and a stop watch approach where utilised to capture data required to develop simulation models.
3. Logical techniques including flowchart is used to identify logic of the current workflow.
4. The simulation software Arena was used to develop the simulation model via a discrete event methodology

The project deliverables, of which are the planned outcomes of the objectives listed below:

- A comprehensive review which analyses problems encountered within the field of warehouse management and tools and techniques previously utilised to improve warehouse management within the logistics sector.
- A collection of data which relates to warehouse management operations.
- A number of logical diagrams including flowcharts.
- Simulation model which imitates the current situation and potential recommended scenarios.

III. DISCRETE EVENT SIMULATION METHODOLOGY

Discrete Event simulation is a methodology which relies heavily on modelling a system which is based upon time and state variables. To be more specific the methodology regards the modelling of state variables that change specifically at set points in time [7].

A number of simulation methodologies such as Agent-based modelling, system dynamics, three-phase and Monte Carlo have been compared. Based on this comparison, it has been concluded that discrete event simulation is more applicable as this methodology is ideal when wanting to model a network of queues [10]. Furthermore it is thought that this methodology will provide credible and reliable modeling and improvements to Sheldon Clayton.

IV. CASE STUDY

Sheldon Clayton Logistics group, a company which has been trading for approximately 30 years, operates air, ocean and sea fright management, logistics and warehousing within the West Midlands as well as Northampton and Scotland. The company's central site, which amasses a total floor space of 12.5 acres is located within Birmingham, the heart of England, and therefore is thought to provide a huge competitive advantage for the company. In addition to haulage, Sheldon Clayton offer storage solutions to its customers whatever their requirements are, be it short term or a complete outsourcing solution. The products available for storage are diverse and range from food to bathroom and kitchen utilities.

On a daily basis an array of goods is delivered to Sheldon Clayton Logistics Company, these goods vary in both quantity and type. For example delivered goods range from popcorn, white goods and metal steel rods. Once, delivered personnel (workers) at Sheldon sort and systematically store the delivered goods in preparation for their upcoming departure. The duration of which freight is stored at the warehouse, following delivery depends on company scheduling.

However, it is common for goods to depart within 24 hours from its arrival. In addition it should be noted that the number of lorries arrive at the warehouse to drop off or collect freight varies daily and is heavily dependent on customer demand and daily scheduling. The figure below represents a conceptual model which helps to introduce the current logistical operations at Sheldon Clayton Logistics (see Fig.1).

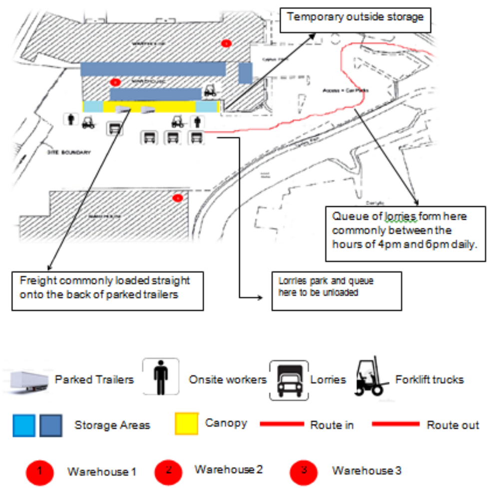

Fig. 1. The logistics operations at Sheldon Clayton

Lorries which, arrive on site, to drop off freight, enter the warehouse site and they park and queue adjacent to the warehouse and its canopy in order for the lorry to be unloaded as fig.1 shows. Once parked, the driver of the lorry collects a manifest from the warehouse office. This manifest is a paper document which informs the driver where the goods he/she has just collected is to be stored within the warehouse. Freight at the Sheldon Clayton are stored by their final location, therefore goods dropped off which have a final destination named Birmingham are stored in a designated location in the warehouse termed Birmingham, for example.

However it should be noted that goods which are to be collected and delivered to their final destination on the same day as they are dropped off are commonly loaded straight onto the back of a parked trailer throughout the day, instead of storing them in a storage bay, as this saves both time and energy. The parked trailers are also identified by their final destination. For example a parked trailer which is to travel to Powys, Wales will only be loaded with freight which is to be delivered to that destination.

Once the manifest has been collected, the lorry can then be unloaded. In order to unload freight from the lorry, the company utilises several forklift trucks. There are various types of forklifts utilised, including ones specifically designed for white goods and ones which are capable of unloading both a single and double decker lorry. There are approximately 4 forklift trucks available onsite and each is driven by an onsite worker.

However the number of forklifts used to unload a lorry is dependent on their demand. For example if there is only 1 lorry queuing to be unloaded 2 or 3 forklifts will help unload the lorry, however if 2 Lorries are queuing to be unloaded the number of forklifts will be distributed between both lorries, in hope of reducing the queuing time of each lorry. Once the lorry has been unloaded the lorry either departs for another collection or parks up onsite if the lorry drivers shift has finished.

Sheldon Clayton operation a 24 hour business, however the number of lorries entering the warehouse to be unloaded significantly increases between 4pm and 6pm every day, but even more so on Tuesdays and Fridays. Consequently the demand often exceeds warehouse capability therefore a queue of lorries form on the red route shown on fig.1.

In hope of tackling demand effectively, Clayton operates two types of shifts; day and night shifts. Within each shift a number of employees are assigned. The purpose of the multiple shift patterns is to ensure continued and efficient operations throughout the day and night regarding booking, imports and exports.

Sheldon Clayton has recently undergone an alteration to the way in which their logistical operations are conducted onsite, although their modification appears to be effective a weakness is still present on site. This weakness regards the queue of lorries waiting to be unloaded. This queue occurs on a daily basis and can at times be so severe that the queue overflows onto the main road onside of the site, which is significantly dangerous for not only lorry drivers themselves but also general road traffic

V. Model Development

A. Logic Identification

Flowchart was utilised as the use of simplistic graphics allowed for a common understanding between the company and the researchers to be established and therefore any errors within the flowchart or the researchers understanding of the current work flow were identified and rectified accordingly. Fig.2 demonstrates the "As-Is" Processes at Sheldon Clayton along with their relationships.

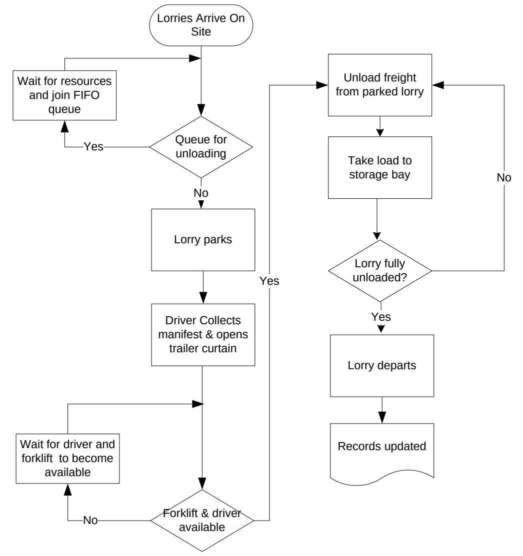

Fig.2. Sheldon Clayton Logistics "As-Is" flow Chart

As fig.2 shows, lorries arrive on site at various points in time during each day. The arrival time of each lorry is heavily dependent on customer demand and company scheduling. However between 4pm and 6pm the arrival of lorries is thought to thought to reach its peak. If resources (forklift drivers and forklift trucks) are available on the lorry's arrival, the parks to be unloaded, however if the resources are busy they are forced to wait in a first in first out queue.

When parked, the lorry driver collects a manifest from the warehouse office. The manifest is a paper document which details the final destination of freight, which is to be unloaded from the lorry. By knowing the final destination, the lorry driver is able to inform the forklift truck drivers where to store the freight as it is unloaded. In addition to collecting the manifest, the lorry driver opens the trailer curtain, ready for freight to be unloaded.

When parked within a bay, the lorry then has to wait for both an onsite worker and forklift to become available. When available an onsite worker will acquire a forklift truck. The onsite worker then drives the forklift truck to the parked lorry in order to start unloading. As freight is unloaded the forklift driver takes the freight and places them in a specific storage area, which is dependent on the freights final destination. The forklift driver will continue to make multiple journeys from the lorry to the storage areas, and vice versa, until all freight is unloaded.

Once all freight is unloaded the resources are freed and lorry departs from site. Additionally records of the lorry's drop off is recorded and stored electronically for the company's reference. This entire process is then completed once again on the arrival of another lorry.

B. Data Collection

A number of tools and techniques were selected as they were believed to be the most effective at capturing data quickly, see figures 3 and 4. It should also be noted that it was important to select specific individuals to provide the data. A selection of individuals were selected from various levels of the company's hierarchy, therefore the risk of capturing biased data was removed.

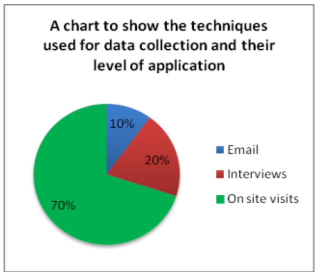

Fig.3. Techniques used for the collection of data

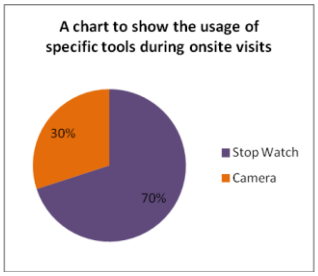

Fig.4. Usage of tools during onsite visits

Fig.3 visualises the usage of the data collection techniques described above. As can be seen the most used technique was on site visits; 70% of the data collected for the project was collected via this method. Interviews were also used but only accounted for 20% of the data collected. Email was the least popular method of data collection; only 10% of data was collected via this approach as it was used as a confirmation tool only rather than a primary technique.

Fig.4 shows that a stop watch and a camera where crucial tools when collecting data during the multiple onsite visits. The camera helped collect qualitative data whereas the stop watch ensured the collection of quantitative data. When compared, the stopwatch provided greater levels of data than that of the camera. 70% of the data captured on site was via the stopwatch, whereas the remaining 30% was seized via the camera.

C. Simulation Model Development

The development of the model was a rather lengthy and complex process, mainly due to the multiple aspects and characteristics implemented within the model, of which shall now be discussed. In order to capture an understanding of the various storage areas simulated, fig. 5 below provides a screenshot of the simulation model with all associated components.

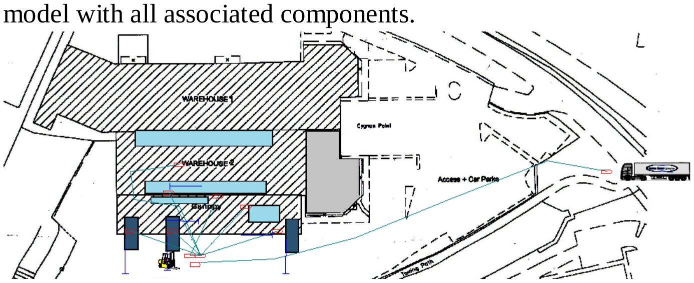

Fig. 5. A visualised model for the Sheldon Clayton storage areas

During on-site visits data was collected regarding where goods are stored once they are unloaded from the parked lorry. The collection of data identified 6 specific storage areas which are in constant use. These included 3 parked trailers located underneath the sites canopy, 2 outside storage areas underneath the canopy and an inside storage area within warehouse 2.

Each of these two warehouses represents a final destination, for example data collection demonstrated that freight stored within warehouse 2 has a final destination located within the West Midlands, including Coventry and Dudley for example. Whereas freight stored on the trailers has daily differing final destinations but commonly includes Aberdeen and Powys, Wales.

The amount of freight which is stored within each storage area is dependent on customer demand, however data collection suggested that 25% of freight unloaded is stored within outside storage area 1, 10% is stored within warehouse storage 2, 5% stored on trailer 1, 10% on trailer 2, 30% on trailer 3 and 20% is stored within warehouse 2. In addition, behaviour of data collected concerning the random inter-arrival times of lorries was captured and modeled. This data collected was inputted into an Arena software tool known as Arena Input Analyser. The purpose of this was to ensure that most appropriate distribution fitting was utilised as fig.6 shows

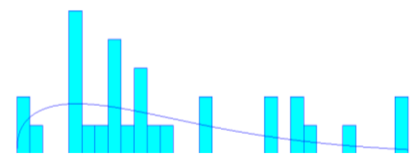

Fig.6. Interarrival time distribution fitting

However as can be seen by referring to fig. 6, the best fitted distribution was the Weibull distribution of (12.5, 1.35).

- The "As-Is" Model Description

The "As-Is" model is an imitation of the current operations flow at Sheldon Clayton. This imitation provides an overview of the model, as it shows current weaknesses, results and potential areas of improvement, instead this was provided within the Arena simulation reports.

- "What-If" Experiments

EXPERIMENT 1: INCREASE NUMBER OF WORKERS FROM 3 TO 5

In this scenario, it is assumed that by increasing the number of resources, the time to pick and drop off freight would decrease and therefore the resources would be able to cope with the current demand.

EXPERIMENT 2: MOVE NON FIXED STORAGE BAYS CLOSER TO THE PARKED LORRY

In this experiment, an additional canopy was added to the original. By adding this additional canopy, storage areas which were originally stored under the original canopy including the parked trailers and the 2 outside storage bay could be moved under the second canopy. Consequently storage areas would be located closer to parked lorries than that within the ''As Is'' model.

EXPERIMENT 3: CREATE TWO SEPARATE QUEUES FOR THE PICKING PROCESS

This scenario is based on developing two separate queues for lorries to enter when they arrive on site. The purpose of this was to try to reduce the queue length experienced within the "As-Is". The resources were organised to pick goods from a lorry placed within either queue.

EXPERIMENT 4: DECREASE NUMBER OF RESOURCES BY 1

In this scenario, it is assumed that by removing an individual employee the workload between the remaining two workers would increase and therefore so would the utilisation rates.

EXPERIMENT 5: PICK FROM MORE THAN 1 LORRY AT A TIME

This experiment specifically focuses on the way in which freight is picked. The "As-Is" model was modified to allow more than one lorry to be served at a time. In order to achieve this all 3 resources were utilised but were shared across arriving lorries, rather than all 3 of them working on one lorry at a time. However to achieve this, set of resources within the model was removed, instead each resource was designed to work on their own, therefore they could start work without having to wait for others.

In this paper, only average queue time for lorries before they can be unloaded is considered as a key performance indicator.

D. Overall comparison

The following provides a comparison of each experiment compared to the "As-Is". By conducting an overall comparison, the benefits provided within each experiment could easily be identified (see Fig.7).

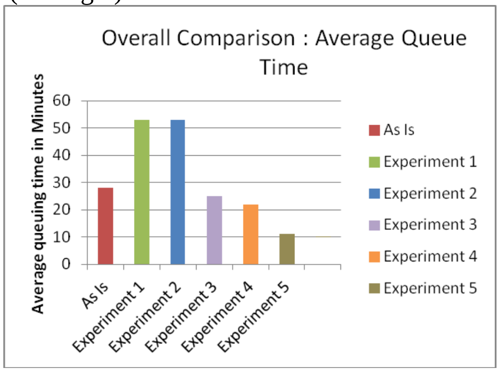

Fig.7. Overall Comparison, average queue time

The average queuing time was thought to be a highly important KPI throughout modelling improvement opportunities, as the time would decrease company efficiency if not managed effectively. As can be seen by referring to fig.7, 2 of the experiments (2 and 3) conducted increased the average queuing time by approximately 52% and for this reason, these improvement scenarios were not considered for implementation. The average queue time appeared to be reduced within experiment 3, however this was because the queues were split in half. In order to make experiment 5 feasible designating a set of resources for each queue should be considered. Nevertheless experiment 5 appeared to be the most effective improvement opportunity when compared overall. Although the improvement was only small, its improvements were still considered worthy of recognition.

VI. CONCLUSIONS AND FUTURE WORKS

This project was based on the development of a spatial simulation model, in order to identify areas of improvement in regards to warehouse operations at Sheldon Clayton. In particular the picking of goods, storage of goods and resource utilisation were focused upon.

The simulation technique appeared to a highly effective approach, not only did it allow the current system at Sheldon to be experimented with without disrupting daily operation, it provide a visual animation of which aided and understanding of the current system but also the multiple experimental scenarios.

Although complications were experienced, the simulation technique should not be overlooked in future projects as it proved to be a very useful tool especially when time is a restriction.

For the future study, it is recommended that a different research methodology is used, in particular a mathematical approach such as linear programming. Although more technical and difficult to communicate, it is thought that the mathematical technique will provide a far more formal approach to finding the optimum picking policy, storage quantities and locations compared to that experienced via the simulation technique, and therefore the results captured would provide far greater weight.

VII. REFERENCE

[1] Angus D.(2005). Problems in Transport and Logistic: Technical Report (2005). Centre for Intelligent Systems & Complex Processes, Swinburne University, Melbourne, Australia.

[2] Ellram, L. M., La Londe, B., J., & Weber, M. M. (1999). Retail logistics. International Journal of Physical Distribution & Logistics Management, 29(7), 477-494.

[3] Friedrich H. (2010). Simulation of Logistics in Food Retailing For Freight Transportation Analysis. 12th WCTR, July 11-15, 2010 – Lisbon, Portugal, pp:1-19.

[4] Gagliardi J.P., Renaud J., and Ruiz A. A simulation model to improve warehouse operations. Proceedings of the 2007 Winter Simulation Conference S. G. Henderson, B. Biller, M.-H. Hsieh, J. Shortle, J. D. Tew, and R. R. Barton, eds.page 2012-2018.

[5] Jain S., Ervin E.C., Lathrop A.P., Workman R.W. and Collins L.M. (2001). Analysing the Supply Chain for a Large Logistics Operation Using Simulation. Proceedings of the 2001 Winter Simulation Conference B. A. Peters, J. S. Smith, D. J. Medeiros, and M. W. Rohrer, eds. pp(1123-1128).

[6] Kunene N. (2012). Simulation of Dispatch Operations at Bidvest Panalpina Logistics Warehouse. Dissertation Submitted in partial fulfilment of the requirements for the degree of bachelors of Industrial Engineering, University of Pretoria.
[7] Law A. M. , Kelton W.D. (2000). Simulation modelling and analysis. McGraw-Hill series in industrial engineering and management science.
[8] Lättilä L. (2012). Improving Transportation and Warehousing Efficiency with Simulation-Based Decision Support Systems. PhD thesis, Lappeenranta University of Technology, Lappeenranta, Finland.
[9] Linwei, X. and Li, Z.X. (2012). Simulation and Optimisation of Logistics Collaborative Operation Based on Flexsim. Advances in Intelligent and Soft Computing Volume 125, 2012, pp 453-457
[10] Maidstone, R. (2012). Discrete Event Simulation, System Dynamics and Agent Based Simulation: Discussion and Comparison. System, 1-6.
[11] Quayle, M. & Jones, B. (1999). Logistics: An Integrated Approach. 2nd ed. Newcastle Upon Tyne: Athenaeum.
[12] Schwarz, L., Ward, J. & Zhai, X. (2006). On the Interactions between Routing and Inventory-Management Policies in a One-Warehouse N-Retailer Distribution System. Manufacturing & Service Operations Management, vol. 8 (3), 253-272.
[13] Shu, J. and Zhang, J. (2011) Simulation and Optimisation of Loading and Unloading Operation System in Port Logistics Park Based on Arena. ICTE 2011: pp. 476-481.
[14] Theodore P. Stank and Patrick Traichal, (1998), "Logistics Strategy, Organizational Design, and Performance in a Cross-Border Environment," Transportation Research Part E: The Logistics and Transportation Review, Vol. 34, No. 2, pp. 1-12.
[15] Transfrieght (n.d) What is logistics [online] available from <http://www.transfreight.com/Lean_Logistics_Overview/What_Is_Logistics.aspx> [15 may 2012]
[16] Zvirgzdina B., Tolujevs J. (2012). Simulation-Based Meta-heuristic Optimisation of Logistics Systems. Proceedings of the 12th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'12), 17–20 October 2012, Riga, Latvia, p. 221–226.