An Intelligent Multi-Agent Based Model for Collaborative Logistics Planning

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Abstract

Efficient freight distribution is indispensable for sustaining customer demand in modern times. In recent years, there has been a steady growth in the use of information systems in the logistics domain towards facilitating an agile distribution process. This study investigates the problem of collaboration planning in logistics and proposes an agent based approach for better management of collaborative logistics. Based on the approach, a decision support system is designed that utilizes RFID technology for ensuring inventory accuracy and monitoring carriers' delivery movements.

The proposed approach involves three steps. In the first step, a conceptual framework is designed. Afterwards, a simulation agent based model is developed including six autonomous agents namely (RFIDG, Supplier, Retailer, Carrier, Network, and City Administrator) interacting with each other, as well as, with the surrounding environment. In the second step, game theory is utilized to study and analyze suppliers' collaboration and carriers' collaboration behavior in detail. Modeled games are solved using Nash Equilibrium. Finally, correctness of the games is verified by formulating them mathematically. Developed optimization equations are fundamental to the operations research field. They employ the simplex and goal algorithms of linear programming.

Results prove that there are plethora of advantages such as automatism and real time response, cost reduction, increased suppliers' profits, time management, and a collaborative framework for implementing the proposed agent based model where suppliers, retailers, and carriers will receive immediate benefits. Major contributions of the thesis stems from considering future technologies such as RFID and agent oriented strategies to provide fast quality services to customers.

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This thesis is dedicated to my parents, my husband,

and my beloved daughter Rose…

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List of Acronyms

Acronym	Description
ABM	Agent Based Model
DSS	Decision Support System
GTM	Game Theory Model
JIR	Just In Request
JIT	Just In Time
LPM	Linear Programming Model
LTL	Less than Truck Load
ODD	Overview, Design concepts, and Details
RFID	Radio Frequency Identification
SCM	Supply Chain Management
STD	State Transition Diagram
TMS	Transportation Management System
UML	Unified Modeling Language

Chapter 1:

Introduction

1.1 Background

Citizens' freight demands are increasing and accordingly, there is a considerable load on developing efficient distributive logistics. This accentuates the need to develop an optimized approach for handling and managing freights' distribution to eliminate any existing problems.

SCM is usually performed in collaboration between various logistical entities. The collaboration especially in the transportation field is happening by exchanging commodities and sharing vehicles' weights (Bailey *et al.*, 2011).

The collaboration requires rapid and effective techniques for decision making. Agent based modeling technique is recommended because it is fast and provides accuracy in performing the work. Accordingly, implementing an agent based model will speed up the supply chain process, make it JIT, JIR, more accurate, and efficient.

Considering the futuristic perspective in planning the strategy, there is a need to take time and speed into account. Therefore, the study proposes utilizing and leveraging RFID technology with Agent technology by integrating them into one powerful system. There are several advantages of integrating the RFID technology with the proposed agent based DSS. RFID technology can check-in suppliers' inventories into the system's database and check them out once they get delivered to retailers. Moreover, it automates the work, makes it more accurate, and, less costly since it provides an instantaneous scanning of large quantity of products at once (Wolff, 2001). The scanning process is performed using either a handheld scanner or by attaching RFID tags to physical places such as the entrance of a warehouse. Considering distributive SCM, RFID tags provide highly traceability since commodities can be tracked once moved in/out of depots or if necessary, they can be tracked once they moved in/out of carriers' vehicles. RFID tags can be attached to carriers' vehicles for the purpose of monitoring their delivery movements, thus, ensuring deliveries to right retailers within expected delivery times. An online access to freights being delivered can be authorized to involved logistics entities such as retailers, suppliers, etc. through the proposed application to facilitate real-time monitoring process. Zhang *et al.* (n.d.) admit that shipping solutions must enable both suppliers and retailers to rate, ship and track shipments in order to cut costs and expedite the shipping process.

1.2 Problem Definition

Unorganized distribution of freight has several negative consequences such as the LTL problem. The LTL problem occurs when carrier's vehicles transport shipment, but the shipment allocated is less than the maximum vehicle's weight, which eventually ends with having a large vehicle moving in a city with an empty space. This problem results in crowding of the city roads and air pollution, which in turn affects citizens' health negatively. Hernández *et al.* (2011) claim that LTL results in idle weights in transporting vehicles. The American Trucking Association (ATA) claimed that the fuel average cost has increased by 73% during the last eighteen months, so, we can imagine how much the gas cost is rising up yearly if vehicles are moving at LTL capacity. There is a dramatic increase in the carriers' insurance costs, which made 1,320 carriers to leave market in the third quarter of 2000 (Lynch, 2001). Another considerable problem is the unorganized communication between various logistical entities, which causes deficiency in satisfying customers' requests.

Eliminating these and other problems caused by unorganized distributive logistics needs an intensive analysis and studies in order to reach the optimized solution, which is the goal of this study.

1.3 Research Objectives

Our research objectives in the thesis are described as follows.

1. Which collaborative approach suppliers need to follow in order to fulfill their retailers' needs?
2. Which freight distribution strategy maximizes the number of potential retailers served while minimizing the delivery costs?
3. How does the physical environment affect the freight delivery cost?
4. Which factors have the highest influence on the freight delivery cost?

1.4 Thesis Organization

After *the introduction,* the second chapter presents *literature review* on collaborative logistics. It presents the methodologies in use and research gaps.

In the third chapter called the *solution approach,* we present multi-agent based model for collaborative logistics. It includes the design, development, and steps of the simulation model, as well as, its implementation through RFID integrated DSS. Afterwards, the chapter models each of the suppliers and the carriers' collaboration behaviors in detail utilizing game theory and finally, formulates each modeled game using linear programming.

The fourth chapter is *the numerical application* chapter. It presents the application of the proposed Agent based model on randomly generated datasets.

Finally, the last chapter contains *the summary, conclusions, and future works* and completes the thesis.

Chapter 2:

Literature Review

2.1 Collaborative Logistics

Logistics is the science of planning, implementing, and controlling the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption[1]. Wallenburg *et al.* (2011) claim that the complexity in today's world supplying businesses increased the need for materials and shipping out products that led to emergence of “Logistics” as a business concept in 1950's. Logistics is usually performed in collaboration between various entities. For instance, suppliers might need to collaborate in order to satisfy their retailers whether it is national or international collaboration. Chinho *et al.* (2004) conduct a study regarding the factors that influence SCM and based on collected data, they found out that there is an important correlation between the quality management activities and the supplier collaboration in the supply chain field. There are two dimensions of collaboration in SCM, which are vertical and horizontal (Renko, 2009). Each dimension of collaboration can take one of three types that are no collaboration, partial collaboration, or full collaboration.

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[1] Council of Supply Chain Management Professionals, CSCMP. http://cscmp.org/default.asp; accessed 09 May 2012.

2.1.1 Present Problems in Collaborative Logistics

Frazzon *et al.* (2006) mention in their research that "*aiming to achieve economies of scale in transport operations is one of the problems to be handled by decision makers within global supply chains*". Accordingly, this study is intending to reduce delivery cost and maximize suppliers and carriers profits and revenues through utilizing the proposed intelligent online application. Borade & Bansod (2007) claim that industries have shown an increased need of adopting practices that support the use of SCM since 1980s. Konicki (2001) present in his article "*E-Logistics Gets the Kinks out of Supply Chains*" the importance of using E-logistics in supply chain projects in order to solve problems that might occur in manually performed logistics. A survey of logistics and supply chain about buyers who are implementing their businesses using manual paper work have revealed that there were postponed logistics related projects and some buyers have cancelled their projects because they realized the significance of using electronic logistics rather than manual work. He also adds that a business with a supplier that doesn't use E-logistic systems is too costly compared with other companies that perform their businesses electronically. Many industries have used document automation technology in some ways to provide supply chain activities over the Web (Rose, 2010). Even though, the advent of the Internet and electronic communication has enabled companies to be more responsive to their customers than ever (Sanchez & Perez, 2003); there are several problems accompanying this advent. Although the developers are facilitating several online logistical collaborative solutions; these systems are customized and dependent based on each business' needs and are not standardized for all type of businesses.

2.2 Distributive Supply Chain Management

Nagurney (2006) defines supply chain as a system of organizations, people, technology, activities, information and resources involved in moving a product or service from upstream supplier to downstream customer. According to Chopra & Meindl (2001), a supply chain not only includes the manufacturer and suppliers, but also transporters, warehouses, retailers, and customers. SCM is the systematic, strategic coordination of the business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole (Mentzer, 2001). An international survey made by Larson & Halldorsson (2004) revealed that there is an argument in clearly defining the SCM meaning for which the involved parties can collaborate upon. Nonetheless, all the collaborated parties must at least understand each other's perspectives. Sandberg (2005) says that SCM introduces some significant perspectives such as facilitating the lowest total cost, service improvements, and reduced inventory levels. Paradkar (2011) defines distributive SCM as a logistic process that involves transporting finished goods or services to the consumer from the production facility including handling and managing orders, transportations, and distributions.

2.3 Methodologies for Improving Collaborative Logistics

Several studies have addressed the problem of collaborative logistics using different methodologies. These methodologies can be mainly categorized into simulation and optimization. Simulation is an imitation of reality, where researchers can test their hypothesis on artificially generated or historical data that can be easily compared and implemented. Simulation is not an exact approach. Simulation methods include: discrete event simulation, continuous simulation, agent-based simulation, hybrid simulation, etc. Optimization on the other hand is an exact approach. Optimization methods include: linear programming, non-linear programming, integer programming, goal programming, etc. They are used in structural equation modeling, game theory, hybrid optimization…etc. Few other methods that have seen rapid growth in recent years are metaheuristics, greedy methods, and the stochastic methods, etc. However, there will be always new approaches incoming and more advanced solution methods will be developed depending upon problem complexity.

For using above mentioned methods; there is a need to collect data first in most of the cases before analyzing them. The collected data are closely related to the studied problem. This enables researchers to gain deeper understanding about the problem that needs to be solved, as well as, enables them to test proposed solutions on the collected data. Interviews, surveys, questionnaires, experts' opinions, etc. is usually the approach to collect useful related information. Afterwards, a suitable solution method can be applied to manage the problem.

2.3.1 Simulation

Simulation methodologies are used because many scientific fields require testing and analyzing data, which might be costly if experimented on real life circumstances. Salamon (2011) claims that simulation modeling is heavily used in different fields of engineering. Special cases of simulation are discrete event simulation and continuous simulation. Carvalho & Luna (2002) admit that in discrete models the state variables build a schedule of events because they do not treat time as continuous. While, in continuous models the state variables change their values continuously with respect to time. Dlouhy *et al.* (2005) indicate that if the differential equations are not able to solve the problem of continuous simulation model then, it becomes the task of the model to find a numerical solution.

Furthermore, agent-based simulation is a special case of simulation. It is developed using a bottom up structure starting from the individual agents who represents the necessary part of the system up to the whole complex system. This structure makes the analysis of the system easy to perform. A combination of multiple simulation methods or techniques can be used in conjunction and then it becomes "Hybrid simulation". The reason behind hybrid simulators is that some special systems require a set of tools in a collection of simulators. Thereby, hybrid simulation allows the use of this combination of tools within a single simulation environment. For instance, GoldSim Technology Group[2] is a hybrid simulator that is able to combine the features of continuous simulators and discrete-event simulators. Moreover, AnyLogic multi-method simulation software is a hybrid simulator that can provide the functionalities of agent-based simulators along with discrete-event simulators

[2] http://www.goldsim.com/Web/Introduction/SimulationTypes/; accessed 11 October 2013.

and dynamic systems. The bullwhip effect in semiconductor supply chain can be simulated using AnyLogic[3] technology. The model is used in communication with customers for a collaborative work on reducing the bullwhip effect in supply chains. It assists companies in identifying particular situations where bullwhip effects occurs and how it affects the supply chain work negatively.

2.3.2 Optimization

Optimization methodologies can take many forms because there are numerous mathematical methods to improve collaborative logistics. Exforsys (2007) claims that "*the supply chain optimization begins with the use of advanced planning and scheduling (APS) technology*". The efficient use of APS technology allows planner to make right collaborative decisions after testing the case using appropriate statistical models. Note that, statistics require the selection of appropriate variables to form accurate functions/equations. Integer programming (IP) is a special type of the statistical optimization methods. It is used to solve linear problems where some or all of the variables are integers. Motozawa & Redl (2009) claim that the operations research optimize the utility of limited resources. Moreover, Chinneck (2004) claims that IP can take the form of binary integer programming (BIP) or mixed integer programming (MIP). The values of the variables in a BIP problem can take only one of two values that is either 0 or 1; while, the values of the variables in a MIP problem are mix of integer values and fractional values.

[3] http://www.anylogic.com/case-studies/bullwhip-effect-in-semiconductor-supply-chain; accessed 12 October 2013.

Note that, MIP can in fact solve a problem that has a combination of real, integer, and binary values.

Another optimization method that is being used intensively to optimize the collaborative logistics is the "Game theory". Webster (2009) claims that decision makers in a game theory are called "*players*", which bid in order to optimize generated results, called "*payoffs*". Hence, any game usually consists of three factors: players, actions, and payoff. There are two trendy game theory models for describing uncertainty in taking decisions: probability model and state-variable model. Nash equilibrium is a significant solution concept in the game theory. It is named after the American mathematician John Nash. Mehrizi (2013) clarifies that "*equilibrium*" is realized when every player in the game is willing to change its endeavor to achieve best results corresponding to other players. In addition, Watson (2008) mentions "*congruity*" behavior in Nash equilibrium games. He explains it as beliefs/rules that are already agreed on or are discussed before playing the game. The previous knowledge about these rules affects other players' decisions. Rodriguez (2006) states that using a combination of different methods is sometimes better to handle problems than using any one method. Having one technique including approaches from various frameworks is called "Hybrid optimization". The advantage of using hybrid technique is that it compiles many mechanisms, which enable the selection of most suitable approach based on each dealt problem and taking advantage of each approach while minimizing its disadvantages. Cavazos *et al.* (2006) indicate that there is no specific method that is always preferable instead, based on each problem situation, there is a more suited method. Their study involves machine learning by employing heuristic technique to select the best hybrid optimization algorithm. Since the problem is general, they experimented it on register allocation problem by developing a hybrid allocator chosen during compilation time of the algorithm. It choses between graph coloring and linear scan algorithms based on computing identified set of features.

Table 1, summarizes some previous related studies and categorizes them into three main categories: a) collaboration, b) logistics, and c) collaborative logistics.

Table 1
Summary of some previous related studies

Category	Author, Year	Problem	Solution	Strength	Limitation	Application
Collaboration	Wang *et al.*, 2014	Conventional routing problem	Simulation	Exploit external resources of other logistical entities in coalition	Generate a bunch of routes instead of selecting the minimal cost route	Transportation market
	Lau *et al.*, 2006	Control global supply chain	Agent-based simulation	Promote for economics in transportations	Does not allow for intermediary storages	Transportation market
	Frazzon *et al.*, 2006	Complexity of orders flow in global supply chain	Agent-based simulation	Consider the effects of agents to perform the collaborative planning and execution of complex activities	Test and analysis of proposed system is not included in the study	Transportation market
	Kwon *et al.*, 2007	Uncertainties presented in supply and demand	Agent-based simulation	Facilitate collaboration in the emergence of high uncertainties	Focus only on the production and inventory problems	Industrial applications
Logistics	Chen & Tu, 2009	Tracking manufactured products	Agent-based simulation	Improve the traceability and visibility of daily numerous manufactured products	Structure a special RFID tag data to be used in the proposed system	Manufacturing companies
	Ingalls & Kasales, 1999	Dynamics exist in supply chain processes	Discrete event simulation	Analyze dynamics exist in SCM using a Compaq supply chain analysis tool	Handle one dimension of SCM	Industrial applications
	Anand, 2013	Manage retailers' economics	Agent-based simulation	Optimize retailers' achieved profits	Retailers collaboration is not considered	Retailers stores
	Dresner & Stone, 2006	Transporting freights	Simulation	Manage road transportation problems	Does not handle collaboration	Transportation market
	Russo & Carteni, 2005	Vehicle routing	Simulation	Help select most suitable route for transporting freights	Depend on successive points on route	Transportation market

	Nazari-Shirkouhi *et al.*, 2013	Supplier selection and order allocation	Mixed-integer programming	Provide reliable decision tool for suppliers selection	Does not incorporate uncertain demands in supplier selection	Purchasing departments
	Erdem & Göçen, 2012	Suppliers evaluation and order allocation	Goal programming	Provide dynamic, flexible, and fast DSS	Collaboration and discussion in selecting suppliers is not considered	Purchasing departments
	Agus, 2011	Managers perceptions regarding SCM	Structural equation modeling	Demonstrate the associations between SCM, product quality, and business performance	Limited to three criteria	Manufacturing companies
	Uchiyama & Taniguchi, 2010	Vehicle routing	Game theory	Present a route choice model considering congestion obstacles and travel time reliability	Other criteria in choosing optimal routes such as minimal cost, etc. were not considered	Transportation market
	Siamo *et al.*, 2009	Fleet management	Hybrid optimization	Combine both machine learning technique along with mathematical programming to manage fleet	Consider only high-dimensional state variables fleet	Transportation market
Collaborative logistics	Berger & Bierwirth, 2009	Vehicle routing	Optimization	Offer LTL pickup facility that led to significant financial benefits	Limited for traveling salesman tours	Transportation market
	Cruijssen & Salomon, 2004	Vehicle routing and sharing quantities	Simulation	Study the impact of efficient trucks routing and investigate the advantages of sharing shipments between carriers	Does not test and compare proposed techniques on multiple auction stores	Auction stores
	Lee *et al.*, 2002	The strategic level of supply chain	Hybrid simulation	Show benefits of using hybrid modeling to simulate collaborative SCM	Combines only two modeling techniques, which are discrete and continues	Industrial applications
	Hernández *et al.*, 2011	Deterministic dynamic single carrier collaboration	Branch and cut algorithm	Formulate the problem as binary multi-commodity minimum cost flow problem	Proposed collaborative strategy is time-dependent	Small to medium sized LTL industry

	Vornhusen *et al.*, 2014	Pickup and delivery problem in collaborative scenarios	Mixed-integer programming	Introduce transshipments during vehicles routing and evaluate carriers saved costs corresponding to participating in coalition	Does not evaluate cost saving in large transshipment instances of carriers collaboration	Small to medium sized vehicles
	Bailey *et al.*, 2011	Cost minimization	Hybrid optimization	Add pickup and delivery tasks of collaborative carriers to their backhaul and reroute the empty backhaul trucks to fulfill other collaborative carriers' requests	Lack of incentives to enable carriers selection	Small to medium sized vehicles
	Yilmaz & Savasaneril, 2012	Collaboration in the presence of uncertainty	Game theory	Introduce retailers characteristics to benefit the collaborative environment	Limited to small shippers and did not specify the contribution of shippers to the coalition	Transportation market
	Krajewska *et al.*, 2007	Vehicles routing and scheduling	Game theory	Present real-life and artificial instances to prove incrementing carriers' profits by solving addressed problem	Limited to unique multi-depot pickup and delivery requests within specific time windows	Truck transportation industry
	Dai & Chen, 2009	LTL transportation	Hybrid optimization	Develop general mathematical model suitable for both shipper and carrier collaboration	Presented solution space and speed need more enhancements	Transportation Market
	Zhou *et al.*, 2011	Stochasticity in demands	Simulation	Provide the basic approach for studying collaborative strategies to be used by firms in competing with other practitioners in freight consolidation	Depends on two criteria only, which are shipment quantities and calculated profits	Industrial applications

2.4 Integrated E-Logistics

One possible definition of E-logistics is that they simply mean processes necessary to transfer commodities sold over the Internet to customers (Auramo, 2001). "*Customer satisfaction and cost concerns drive the adoption of Internet-based systems*" (Konicki, 2001). Logistics aim to deliver products to their customers as quickly as possible, while E-logistics concern with automating logistics activities and providing integrated end-to-end fulfillment and SCM services to the players of logistics processes. This provides visibility of supply chain processes.

According to Kovačič & Groznik (2004), the successful integration of SCM depends on the implementation of E-business in Logistics called E-logistics. One of the results they conclude is the business model creation process renovation. Examination and reengineering of current business policies procedures and activities can be adopted by establishing proactive distinctive internet systems. In addition, they highlight that information technology plays critical role in renovating business processes since it minimizes the negative results generated from manual procedures and this advantage achieved by automating the procedures. Lynch (2001) mentions that the market of the TMS, which emerged in early 1990, is evolving rapidly and that there are many systems that offer numerous best features to all logistics parties. The use of technology and information systems is necessary in making the collaboration between supply chain entities smoother and easier.

An example of electronic collaboration has been introduced by Sophie & Mikael (2008) where a web-based application is used to find routes between suppliers and consumers.

Sanders (2005) claims that the use of information technology motivates the integration between suppliers and customers and has direct, as well as, indirect positive effect on both strategic and operational performance measures. Holzmuller & Schluchter (2002) claim that internet-based business-to-business (B2B) electronic marketplaces are ‘‘*open electronic platforms facilitating activities related to transactions and interactions between multiple companies*’’.

2.5 Agents Technology

Treytl *et al.* (2006) define software agents as "*entities that autonomously fulfil a given task. They operate in a multi-agent system (MAS) environment and exchange information between each other*". Agents are "intelligent" code programmed into computer software to achieve a goal. They can be a robot, function, equation, etc. Salamon (2011) believes that an individual agent is usually not capable of performing the entire intended process by it-self. The required generated result of the simulation model, usually occurs when individual agents communicate with each other and with the surrounding environment. In other words, agents are able to interact with each other and respond to environmental effects to simulate specific process even though it is not necessary for them to contain memory or to store data.

Frazzon *et al.* (2006) state that in order for agents to be intelligent; they should adopt three features including being autonomous, that is capable to function without the need of another agent or person's decision, cooperative agents that interact and help each other's to execute processes, and learning agent, which contain some artificial intelligence since they should be able to learn from instructions and historical information.

Chen & Tu (2009) consider agent as "*a software entity that continuously monitors the data sources in a global computer network where the information of interest is made available in real-time and when certain signals are detected in the data*". The RFID journal (2002) mentions that the MIT Media Laboratory has software agents group and they clarify in their website the difference between software agents and traditional programs by clarifying that software agents are "*long-lived, semi-autonomous, proactive, and adaptive*".

2.5.1 Agents Based Models (ABM)

A model is a representation of a real system and thus, it is an abstraction of the reality [4]. "*The word "modeling" comes from the Latin word modellus which describes a typical human way of coping with the reality*" (Schichl, n.d.). Models can take various forms such as mathematical equation, drawing, computer code, etc. However, there is a common purpose of all designed models, which is to simplify the complexity presented in the real system or problem. Therefore, models usually contain only the main aspects of the real system (not all details). Modeling is usually done through several steps. Railsback & Grimm (2012) define the modeling cycle as consisting of five iterating steps:

1. Formulating the accurate research questions
2. Assembling hypotheses for the necessarily processes and structures
3. Choosing scales, entities, state variables, processes, and parameters
4. Developing the required model
5. Analyzing, testing, and finally revising the model

[4] http://www.businessdictionary.com/definition/model.html; accessed 10 September 2013.

2.5.1.1 Strengths of Agents Based Models

ABMs have several advantages and strengths over other traditional methods. Frazzon *et al.* (2006) claim that using agents to organize SCM work is a noticeable outstanding study. ABM can easily show the interaction between agents and with the surrounding environment since it provides an explicit graphical dynamic system. Moreover, it illustrates the different behaviors that agents can take during the run of the simulation (Brown, 2006). ABM highlights emergent phenomena and can be easily adapted to new barriers. In addition, it provides a framework that can test and answer many wondering questions without costing reality errors since it is just a simulation environment of real situations. Intelligent agents can use decision trees to be able to take wisdom decisions. When a researcher or a scientist is interested in understanding and exploring the behavior of a specific process or system; ABM is the most appropriate approach for finding solution to that problem (Salamon, 2011). Davidsson *et al.* (2005) mention that using agents in SCM systems especially in TMS can achieve two objectives, which are having DSS and automation system.

2.5.1.2 Weakness of Agents Based Models

Some weaknesses of ABM have been discovered since its production and development. The Journal of Artificial Societies and Social Simulation (JASSS) analyzed some of these problems over the past ten years. Meyer *et al.* (2009) conclude that some models are too simple so they do not represent the real intended scenario. On the other hand, other models are too complex, which make them difficult to understand and implement in reality.

Moreover, ABM usually have computational performance limits, which means that if the problem needs to be solved based on rigid pure mathematical computation. Then, ABM might not be the best method to follow. The traditional mathematical and statistical methods will be more appropriate in this case.

2.6 RFID Technology

RFID is an abbreviation for Radio Frequency Identification. It includes tags that can be classified as either active or passive. Active tags have longer reading ranges since they have an internal battery inside them and thus, can store up to one megabytes of data in their memory. On the other hand, passive tags have shorter reading ranges since they do not have battery inside them, instead they generate the power by converting the radio signals into power using part of the RFID called transponder. RFID passive tags can store up to one kilobyte of information (Harry *et al.,* 2006). However, both types of the tags are anticipated to live up to few decades (McDowell, 2009).

RFID is tiny sized memory chip that can save, update, and delete data. It might also take photos of persons and staff. Romer *et al.* (2003) clarify that RFID tag can handle various useful information besides recognizing identity. They claim that RFID tag can store geographic locations, as well as, physical nearby information. It can also access memory's history to act based upon historical information. RFID technology has been widespread in the telecommunication field and existed for decades. However, it has been used only recently in the operations of commodities (Mei, 2004) and demonstrated magnificent success in the logistics/distribution/SCM field.

The Laval link (2004) mentioned two well-known markets depending on supply chain logistics to achieve their work. They are the Wal-Mart and the US department of Defense (DOD). Both have used RFID technology to maintain and make their supply chain processes successful.

2.6.1 Benefits of RFID Technology

RFID technology is mainly utilized to ensure inventory accuracy. Moreover, it avoids risks of stealing shipments or having them lost. It helps controlling products' distribution, tracking them, and ensuring accurate deliveries to right persons within expected times. In addition, it is used to tag individual products to provide complete visible distribution process. RFIDs are highly intelligent wireless devices (Dixon, 2011).

Instead of having large number of labors working on inventory and checking in/out products; RFID will do the work faster and more efficient. Thereby, it saves costs of both labors and missed products. RFID technology generates automated paperless maintenance of information because the system's database monitors and records every product inside it. The RFID technology is more powerful than the barcode technology since it enables reading large quantity of tags at once using sinlge handheld scanner. Laval link (2004) mentioned that the sensitivity presented in RFID readers enable them to perform both tag singulation and aggregation. Thus, they can recognize individual tags in SCM and at the same time, they can scan/read huge number of tags as group because they do not require close line of sight to perform the reading (Wolff, 2001). RFID tags are featured than traditional bar codes because they can be programmed to hold useful information such as time, destination, etc. Moreover, Wolff (2001) claims that RFID tags are placed inside packages and thus, they are less prone to damage unlike traditional bar codes, which are placed on the outside of packages and therefore, can be easily scratched or destroyed. Finkenzeller (2003) mentions that RFID offers more advantages than other technologies; it can recognize identity of an object and record its current status, as well as, its status in the past and in the future.

2.6.2 Limitations of RFID Technology

One of the restrictions of RFID technology that might not let all companies use them is their cost, especially when dealing with low price products such as goods in groceries. However, smart labels can be used in this case to provide cheaper technological chips that are able to hold information and being manufactured in high quantities with tens of cents prices instead of dollars (Wolff, 2001). Another limit is related to passive RFID tags because they do not use battery and therefore, they have distance limit, as well as, computational power limit that is specified by the available energy exists in the electromagnetic field placed on the RFID reader (Treytl *et al.*, 2006). Kaur *et al.* (2011) mention that conductive materials such as water and metal can be barriers for the RFID reader since water can absorb data signals and metal can reflect them, which causes data deterioration during their transmission to the RFID application.

2.7 Power of RFID Technology Integrated with Agents Technology

According to Treytl *et al.* (2006), integrating RFID technology with agents' technology seems reasonable because RFID helps identifying products, while agent handles information provided by RFID readers allowing masterly monitor and control of all orders throughout the whole supply chain system. In addition, they claim that "*If the RFID identifying the product and the agent managing the manufacturing of the product are (physically) bound together, advanced solutions for practical problems can be found*". Chen & Tu (2009) propose the use of ontology and RFID technology to improve the traceability and visibility of daily numerous manufactured products. The system is an agent-based manufacturing control and coordination (AMCC) system where every manufactured product should be tagged with RFID to provide real time enterprise management process. The RFID journal (2002) published an article titled "*Agents Key to RFID Supply Chain*". It highlighted the substantial role intelligent software agents perform in logistics SCM in particular when combined with RFID technology. It mentioned that the biggest effect of integrating agents with RFID technology is to facilitate a successful collaboration between various logistical entities. Beside responding to real-time instructions and learning from history, real strength of intelligent agents appears in their ability to predict incidents especially critical ones and notify involved logistical entities to enable them to avoid risk before it occur.

A good implementation of above practice was presented in a conference in Orlando by SAP's system group. They featured a smart shelf with a set of bottles on it. The intelligent agent can report the amount of sold out bottles and alert the vendor in case of sensing more consumptions than expected to enable him to arrange to get more supplements. The RFID journal mentioned that the BiosGroup, which is a software consulting and development company "*sees a world in which agent technology is distributed throughout the supply chain and reacts instantly to information coming from RFID tags*". Moreover Fred Seibel, who is a BiosGroup's responsible for supply chain technologies, admits that agents' technology complements the RFID technology because agents instantly respond to real-time data received from RFID readers.

Exploiting the power of agents technology with the RFID technology will significantly improve the logistics SCM and will present entirely innovative ways of performing the work. Treytl *et al.* (2006) believe that there are two ways of integrating RFID technology with agents' technology. Agents can be directly hosted on RFID tags' readers or existed on a separate platform to process data read from the RFID tags' readers. They also claim that it is more effective when agents are migrated from RFID tags because agents' existence on RFID tags requires more amount of memory to hold agents' codes, as well as, it consumes more power and cost.

2.8 Research Gaps

According to carried literature review, it is found that most of conducted studies in logistics have focused on and remedied only one dimension in SCM. For example, some studies focused on demands fulfillment, while others focused on avoiding and mitigating risks.

Moreover, there is deficiency in the research field of SCM in some important aspects such as, utilizing recent technologies for facilitating the collaboration planning. There is lack in the knowledge of making effective practical collaboration between various logistical entities that can be implemented on reality. It is challenging to develop models similar to the dynamic real logistics. In addition, limited scenarios have considered treating uncertainties that might occur during freights' distribution. Furthermore, some papers focused on solving supply chain problems but, missed proving correctness and accuracy or missed ensuring standard quality performance.

Economics and cutting costs are also crucial aspects to be considered when discussing supply chain optimization, which were also neglected in some papers.

Even though, finding optimal strategies is significant; operating those strategies in an efficient way is significant as well. Hence, although there is no doubt, internet is the commonly used method in today's world in achieving everything. With today's rapid technological advances there is a need to develop systems that besides being online, are fast, effective, and accurate. In other words, employed systems should be intelligent enough to accomplish the work successfully.

Most of the studies in collaborative logistics concerned with only exchanging messages to perform the integration and did not consider having an effective intelligent communication approach that is JIT and JIR. Thereby, this research investigates the reasons behind above mentioned inadequacy and provides ultimate solution for successful collaboration in integrated E-logistics collaborative systems.

Chapter 3:

Solution Approach

This chapter begins with introducing the simulation agent based model, which discusses two subjects: the system analysis and design, and the system implementation. The first subject designs conceptual multi-ABM. Afterward, model's concept is represented using unified modeling language to simplify its implementation. Moreover, ODD protocol is employed for model formulation. The second subject concerns with the system implementation. It begins with identifying the relations and interactions between agents. Then, model's assumptions and criteria are indicated to help develop the actual simulation model on Netlogo software.

After introducing the simulation ABM to represent and simulate freight' shipments, we model major collaboration problems presented in the simulation ABM in more depth by employing GTM and formulating modeled games mathematically using LPM.

3.1 Selected Method to Conduct the Study

This study aims to solve multiple collaborative logistics problems through three different methods. The ABM simulation is mainly used because it tremendously supports understanding the behavior of a specific system (Salamon, 2011) since it provides an explicit graphical dynamic system that can illustrate different behaviors agents take during run of the various simulated scenarios. Simulation ABMs are used for optimizing logistics/SCM (Wadhwa & Bibhushan, 2006), thus, a multi-agent based simulation model aims to formulate the collaboration problem in general and represent the distributive logistics is designed and developed.

In addition to the agent based simulation model, another optimization method is employed, called the game theory. The reason behind using it is that agent based simulation model alone cannot sufficiently cover all topics in the model due to limited computational power (Salamon, 2011). Moreover, the suppliers' collaboration and the carriers' collaboration part of the study are extended parts of the simulation that base on specific defined notations, rules, strategies, etc. Thus, using the GTM to intensively analyze these two particular parts of the study is more efficient than, just including them briefly within the ABM. Furthermore, the GTM concerns with mathematical models and hypothetical problems attempting to resolve cooperation and conflict between intelligent rational decision makers (Myerson, 1991).

Finally LPM is employed to formulate modeled games mathematically and to indicate quantities of freights.

Therefore, the study utilizes three different methods, which are agent simulation, game theory, and linear programming. Each method concerned with solving a particular problem that falls under the collaborative logistics. Figure 1 demonstrates the solution methods used in this study.

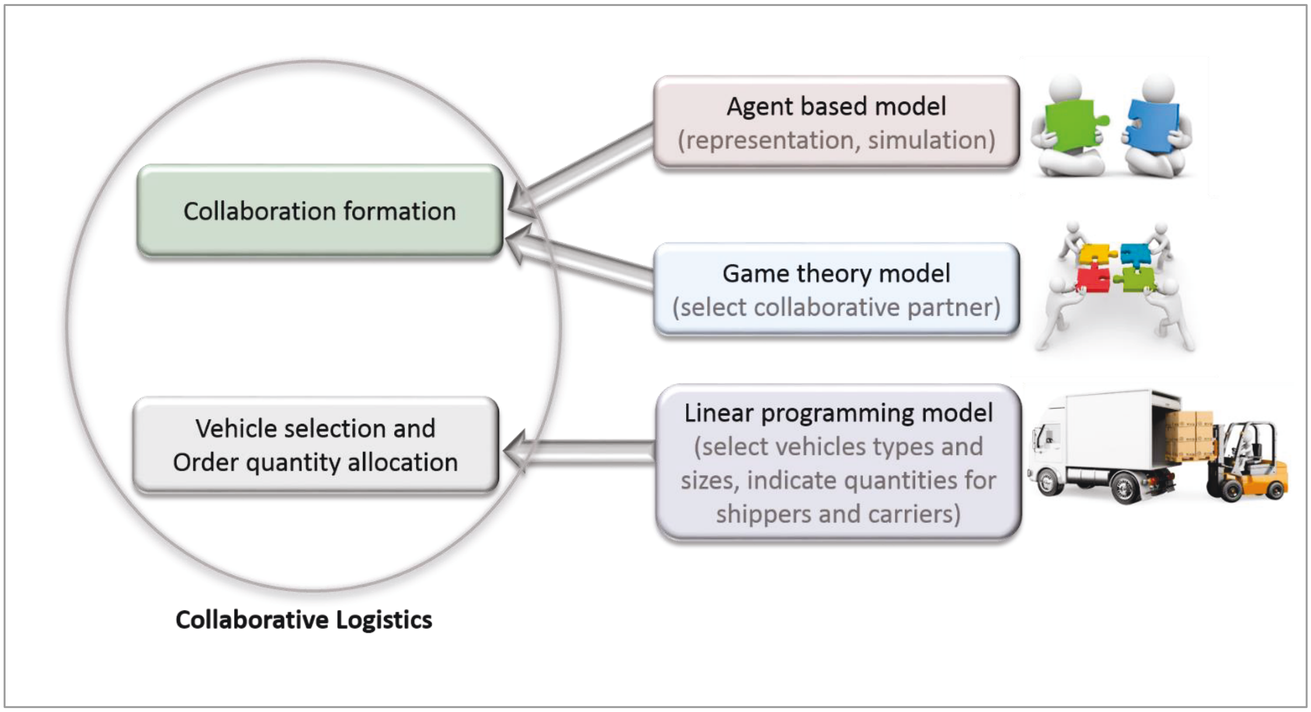


Figure 1: Solution Approach

The use of the three methods to optimize one subject is a very good plan for implementation. Figure 2, demonstrates the relation between the three employed methods in this research.

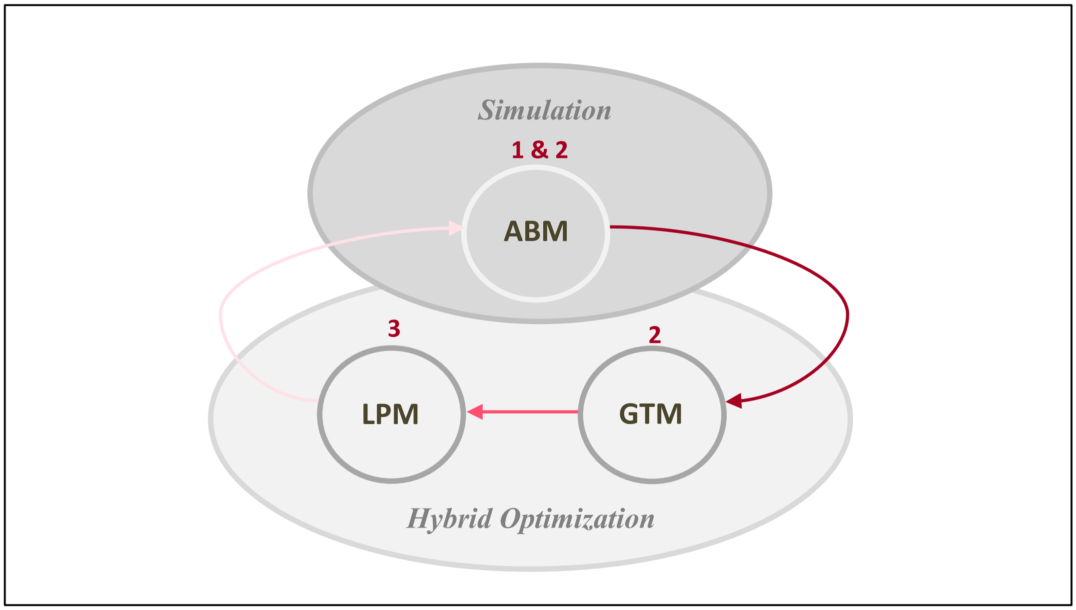


Figure 2: Relation between the three utilized methods

Each method has specific objectives to achieve, which are denoted by the numbers above them. Table 2, provides an explanation of the objectives entitled by the numbers.

Table 2

Major objectives of the utilized models

1	- Divide the simulation world into multiple different logistics cities, each has its own delivery rules and discuss encountered penalty when violating the rules - Scan delivery routes looking for neighboring retailers to be included along with the original one who initiated the freight delivery order and then, send them lower cost delivery offers in case of LTL problem existence

	- Measure congestion on delivery routes
2	- Encourage suppliers to enter in a game and collaborate toward maximizing profits and satisfying customers' purchasing requests - Ensure successful collaboration between multiple carriers to eliminate the LTL problem and to maximize vehicles' utilization rate.
3	- Execute modeled games and formulate them mathematically. - Select vehicles sizes and indicate quantities for shippers and carriers

3.2 System Analysis and Design (ABM)

3.2.1 Conceptual Model Design

The solution to solve the problem of having empty vehicles or LTL in logistics cities to deliver shipments is to implement an online DSS that has more than one agent interacting properly with each other, as well as with the surrounding environment. The modeled online application helps carriers to share vehicles' weights effectively and offer lower cost shipments to retailers by recommending delivering shipments through vehicles that are passing near their saved location via the system. This will improve the collaboration and automate the logistics communication, make it JIT, JIR, without the need to have real humans working on the application, which will eliminate humans' errors and will also speed-up the process.

Therefore, the system includes six agents: the **RFIDG** agent, which ensures inventory accuracy, the **Retailer** agent, which requests commodities, the **Supplier** agent, which provides commodities, the **Carrier** agent, which delivers freights, the **Network** agent, which scans delivery route, and the **City Administrator** agent, which plans and announces cities' delivery rules. Below is the conceptual model of the proposed multi-agent DSS.

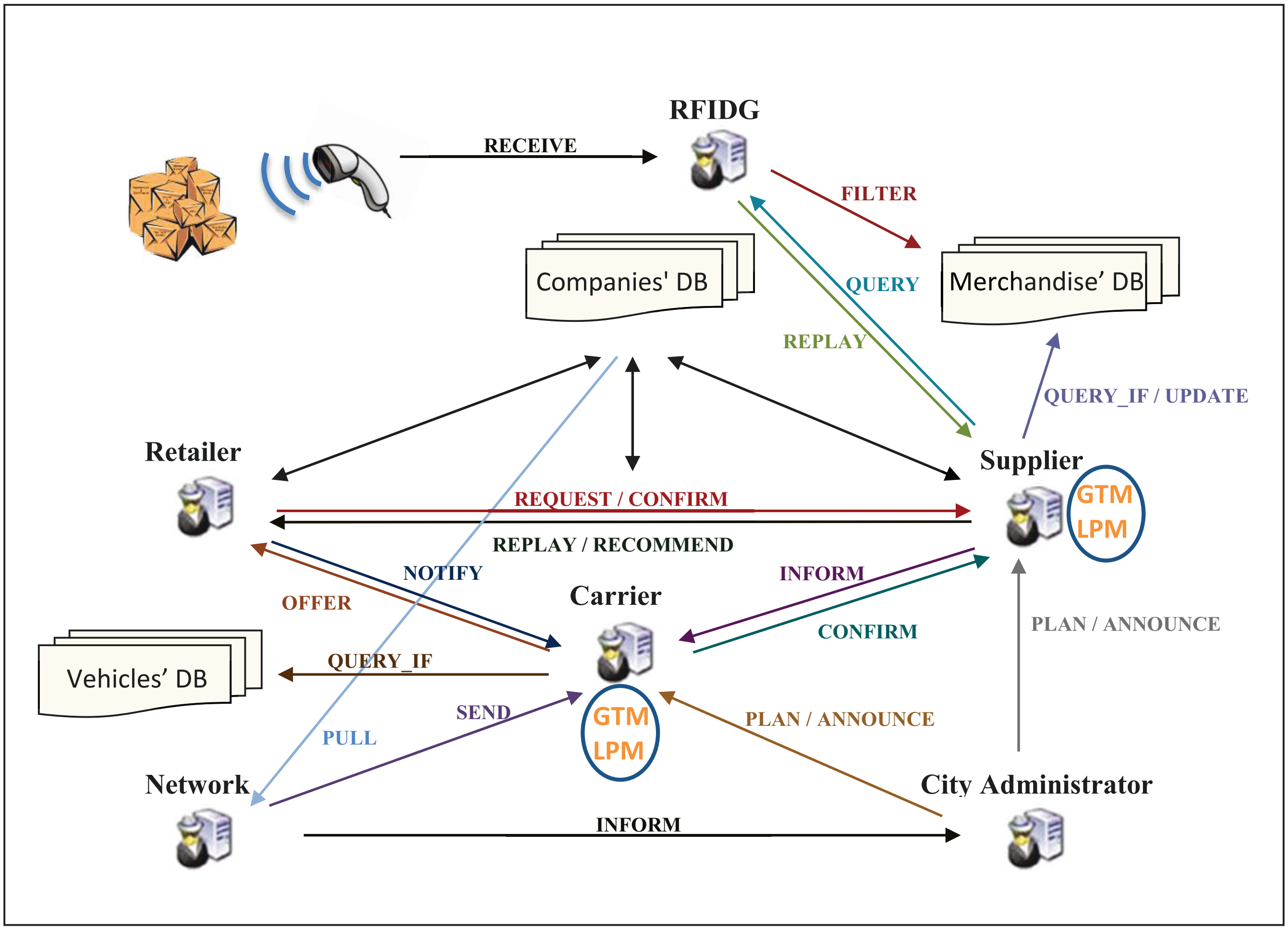


Figure 3: Designed conceptual multi-ABM

* The "GTM, LPM" notion is used beside the supplier and the carrier agents to clarify that the collaboration behaviour of these two agents will be modeled in detail later in the study using game theory and linear programming.

To achieve the overall goal of the model, which is to implement a successful collaborative system, each agent has a major role to play. Followings is an explanation of each agent in the proposed intelligent DSS:

- The RFIDG Agent: This agent receives data from the RFID reader and places them into the merchandise database after filtering to ensure their accuracy. Moreover, the agent removes duplicate scanned records and displays alert messages in case of sensing exotic behaviors. Such as scanning a product that has been placed in the wrong area. Since scanning products involve human intervention then, there are chances for errors. Thus, the agent's role becomes significant because the intent of the proposed model is to eliminate mistakes. Hence, ensuring inventory accuracy is the major task for the RFIDG agent. Considering there are several different data structures used in existing RFID tags, the RFID reader sends information to the RFIDG agent and the agent should process the data precisely. Checking the data type and the context, the agent takes necessary information and places them into accurate fields of the system's database. Besides its major role, the RFIDG agent holds all products unfiltered information. Then, whenever any supplier inquires about any particular information of a specific product that is not entered into the filtered accurate database, the supplier will contact the RFIDG agent to get that particular detail.

- The Retailer Agent: When a human retailer logs into the system to request shipment; the retailer agent notifies both the supplier agent and the carrier agent. It notifies the supplier agent to allow it to search in its database about the requested freight. While notifying the carrier agent to enable it to check in its records for arranged shipments with LTL that will pass nearby the retailer's saved location in the system, it also recommends lower cost delivery of shipments to that retailer in a specific date, which will eliminate the LTL problem.

- The Supplier Agent: Once the retailer agent informs the supplier agent about a new retailer's request; the supplier agent starts searching inside its database about the requested product and then, replies back to the retailer about the status of the request as either available or not. It also recommends another availability date of the needed product or another available amount if different from retailer's request. In case the retailer requests unavailable commodity or more than the available quantity in the supplier's depot, the supplier agent will search other suppliers in the system who have enough amount of the requested commodity with reasonable price and high quality, and will recommend the original supplier to collaborate with them. Suppliers' collaboration allows satisfying customers' needs. Note that for each specific supplier, the agent keeps record of the most collaborated suppliers. Thus, it recommends them first at later times for that specific supplier, which makes the supplier agent an intelligent agent. In addition, the supplier agent rates suppliers' performance, which is based on many criteria such as availabilities of their products, qualities, prices, coping situation with other suppliers. In the recommendation list of suppliers to collaborate with, suppliers with higher rates get listed after the most collaborated suppliers.

- The Carrier Agent: When a shipment request is confirmed by the retailer, then the supplier agent informs the carrier agent that there is a shipment delivery request. Therefore, the carrier agent will search in its database for an available vehicle in the required date and with adequate weight to assign it to the delivery order. Afterwards, the carriers' database will be updated automatically and a confirmation number will be generated and sent through the agent to both the supplier and the retailer to confirm them and keep up-to-date. Moreover, once a retailer logs-in to the system, the carrier agent gets notified by the retailer agent that she needs a freight delivery. Hence, the carrier agent looks for arranged delivery vehicles with LTL problem that will pass nearby that retailer's location to offer lower cost shipments to that retailer enabling him to allocate the available empty weight in the shipping vehicle. Furthermore, the carrier agent rates carriers' performance, which is based on their efficiency in delivering freights to right retailers and within expected times. For instance, the carrier agent weights a carrier high if he always delivers on time and lowers his rate if he has late deliveries for few times.

- ❖ The Network Agent: This agent is responsible about measuring congestion on delivery routes and informing the city administrator agent about existing severe congestion. In addition, it assigns the supplier's location as an origin point and the retailer's location as a destination point to calculate the shortest delivery path between them using the Dijkstra's algorithm and sends it to the carrier to enable him to deliver freights on time. Afterwards, the agent scans the shortest delivery route looking for neighboring retailers to the original one who initiated the freight's delivery order and sends the list to the carrier agent. The agent saves shortest paths with their neighboring retailers list to be able to recall them faster on future shipments.

- The City Administrator Agent: Once the carrier agent informs the city administrator agent about arranged freight delivery order, the agent announces the delivery rules of the city where the shipment is arranged, to both the carrier and the supplier. Announcing cities' delivery rules enable suppliers and carriers to obey with the rules. In case of rules violation, the city administrator agent recommends other alternative solutions to them. One solution can be dividing the shipment on two smaller vehicles instead of the large prohibited vehicle's size. Another solution can be changing delivery time to be within allowed times. Moreover, the agent should provide the carrier with the second shortest delivery route in case of receiving severe congestion alerts from the network agent. In case the carrier cannot go through the second shortest delivery route then, the agent should be able to provide other decisions. Another solution can be dispatching shipment to another retailer than the planned one in case of delivering to more than one retailer. Successful decisions will be stored in agent's history to be used in future similar situations. Thus, the agent is considered intelligent because it uses its knowledge and historical information to take better decisions.

Figure 4, presents the state transition diagram (STD) that clarifies the crucial functionalities available inside each one of the defined agents.

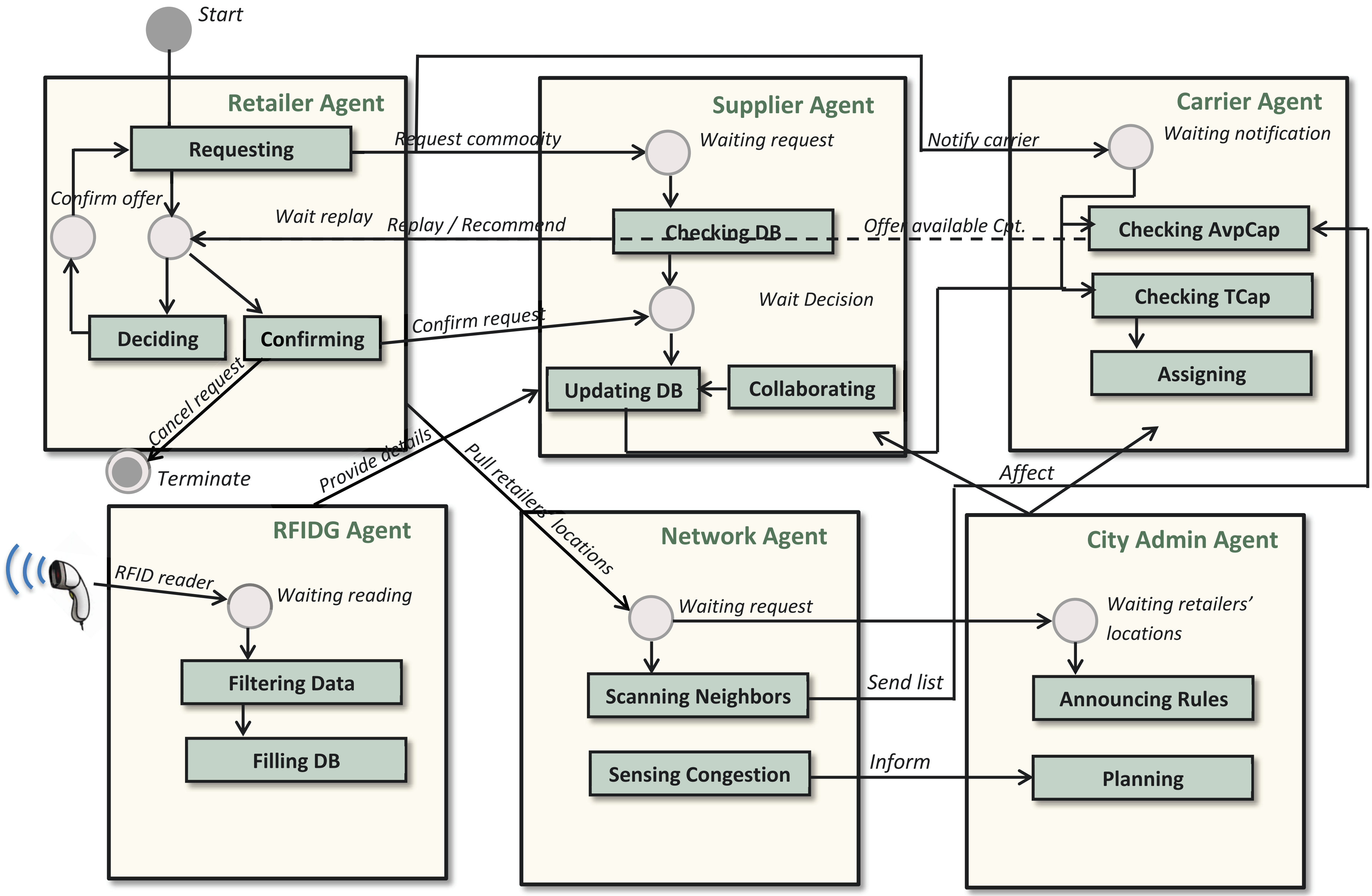


Figure 4: State transition diagram (STD)

3.2.2 Risk Management and Control Plan

Presented multi-agent framework covers both the production fulfillment and the risk management dimensions of the SCM. Each one of the defined agents in cooperation with other agents in the model has a risk management and control plan, which is based on agents' specialized functionalities and competences. Hence, agents are capable to anticipate, define, assess, and manage risks to either eliminate them before they occur in reality or decrease their effects in case they did emerge.

Utilizations:

- Suppliers might confront low production risk due to labor strike, damage in manufacturing instruments, low raw material, etc. This risk is rectified by allowing suppliers from various organizations to enter in a game and collaborate instantaneously upon availability of information to satisfy their consumers' requests.
- The game for suppliers' collaboration able to cure another risky situation as well. The situation arises when a retailer requests unavailable product or requests an amount of the product that is more than the available amount in supplier's depot. In this case, suppliers with higher performance rates and who are having the requested commodity will be listed to the original supplier to allow him to collaborate with them and accommodate his customers' purchasing needs.
- Another risk that carriers might face is having late deliveries due to accidents, construction work on delivery routes, etc. Late deliveries result in decreasing carriers' profits or exasperate their customers. Rectification to this risk will be facilitating real-time scanning of delivery routes. This task is performed by the Network agent, which

notifies the City Administrator agent in case of severe congestion. The City Administrator agent will in turn calculate the second alternative shortest delivery route and send it to the carrier during his delivery through a GPS system or on his smart phone. This enables carriers to deliver freights with less delay that might occur.

- Moreover, when carriers' shipments violate cities' delivery rules, the City Administrator agent recommends other alternative solutions such as dividing shipments on two smaller vehicles rather than the prohibited large vehicle's size.
- Simple mistakes such as placing products in the wrong area of a warehouse can cause the risk of eventually transporting wrong freights to retailers. Another mistake of scanning the same product multiple times and entering it into the merchandise database, might cause the risk of requesting retailers to unavailable products. These two mistakes can be rectified by authorizing the RFIDG agent to display alert messages on the system's screen to enable involved entities to correct the mistakes.

Above risks might be forecasted and planned ahead but, what about uncertainties, which represent significant component of risks. Each agent in cooperation with other agents should be capable to remedy occurred uncertainties through the risk management and control plan.

Optimal risk management and control plan performed by first, identifying risks/uncertainties, then, evaluating them. Afterwards, avoiding/correcting risks based on their assessments. Finally, optimizing selected decision by minimizing loss expenses that might occur due to expected/emerged risks (Hallikas *et al.*, 2004). We rank risks as either high, medium, or low. Note that, High risks encounter high loss and thus, need urgent rectification. While, medium risks are less urgent and thus, can be remedied after high risks. Finally, low risks encounter less damages and thereby, it is the choice of the decision maker to either rectify them or neglect them. This is decided based on the effort and the cost related to mitigate the risk. After ranking risks, we correlate specific range of numbers to each ranked category to be able to indicate the specific urgency of an occurred high, medium, or low risk. Note that, one of the risk assessment tasks is to calculate cost of expenses associated with risks, which is calculated by multiplying two probabilities, the probability of the risk to occur in reality multiplied by the potential damage (Giannakis & Louis, 2011).

3.2.3 Unified Modeling Language (UML)

UML is highly used in the systems engineering field. Based on the UML, the model's built design represents the general big picture of the model to be developed.

Salamon (2011) states that there are two levels for agents' diagrams; global level and detailed level. Global level UML illustrates the complete multi-agent based system. It represents all agents in the system, shows the way they communicate with each other, and the way they interact with the surrounding environment. On the other hand, detailed level illustrates each agent in detail by drawing it separately and shows its features.

Global Level of Agents Diagram:

There are six main agents represented in the global level diagram as shown in figure 5. Each agent has important main goal that is written within the brackets. Colored thick arrows represent agents' communications, while black thin arrows represent agents' interaction with the surrounding environment.

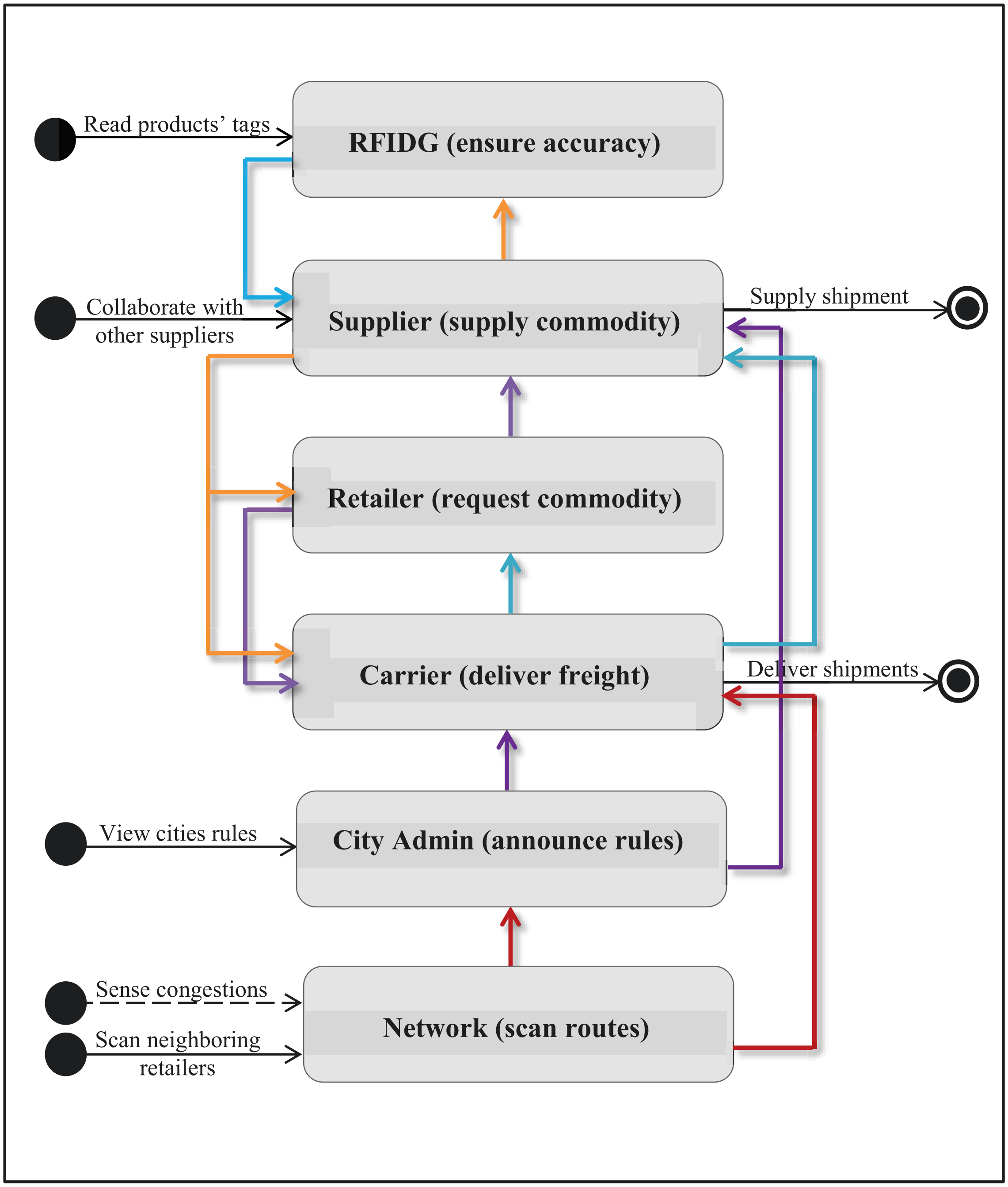


Figure 5: Global UML level of agents

3.2.4 ODD Protocol for Model Formulation

The ODD protocol is recommended by Railsback & Grimm (2012) in their book "*Agent-Based and Individual-Based Modeling*". ODD stands for "*Overview, Design concepts, and Details*". The protocol consists of seven elements. Planning and describing these elements before implementing the ABM model, helps the developer to design and develop his model distinctly.

Design Concepts:

The ***basic principle*** addressed by this model is simulating the optimized way of sharing weights of arranged transporting vehicles between neighboring retailers to eliminate existing problems occurring in freights' distribution process using an active multi-agent based application. The concept is addressed when shipments' requests ***emerge*** in the system. When a retailer requests shipment, the supplier agent checks the freight status in the system and replies back to the retailer using the ***adaptive behavior***. The adaptive behavior is modeled via an empirical rule that reproduces the observed behavior in real logistics world. If the shipment is not available in the requested date, then the supplier agent informs the retailer automatically when it will be available based on the information recorded in the suppliers' database and the same happens when the requested product type or amount is not available.

The model includes ***prediction*** concept. It occurs when a retailer logs into the system and the carrier has freight shipment with LTL that is arranged to deliver to a depot located near by the logged-in retails' location. Therefore, the carrier agent predicts that the logged-in retailer needs shipment's delivery. Thus, it notifies the retailer about the arranged shipment date, the available empty size in the vehicle to occupy, and recommends lower cost delivery to that retailer.

Sensing is important in this model: the network agent identifies patches that have neighboring retailers on them in order to offer lower cost shipments to those neighbors.

The model includes ***interaction*** among its agents and between the agents and their environment. The model's environment interacts with its agents by sensing severe congestion existing on the delivery route and also by scanning neighboring retailers. In addition, it checks cities delivery rules and announces them to both the supplier and the carrier to allow them to obey with the rules.

To allow ***observation*** in the model, a plot is added to clarify changes in delivery price over time. Moreover, monitors are added to each of the following: the needed amount and the new updated amount of the product with the supplier, the acquired supplier's net profits, counter of lower cost shipments delivery to neighboring retailers, initial and adjusted delivery price, cities maximum allowed weight, available vehicle's size, penalty charge, and an output active screen is added in addition to the Netlogo simulation world.

3.2.5 Properties of Model's Environment

Agents in the developed multi-agent simulation model are interacting and affected by the factors of the environment surrounding them. Thereby, the environment is a kind of an abstraction that influences its agents and therefore, it is important to identify its properties in details. Furthermore, identifying the exact properties of the model's environment is necessary because it is mimic of the real logistics supply chain environment. Russell & Norvig (1995) organize the environment according to the following properties:

- Accessible: the model's environment is considered an accessible environment since it can be easily understood from real logistics environment. In other words, the information about real collaborative logistics environment is accessible and can be reached at any time. Moreover, the agents can easily access the model cities' delivery rules, which concern with the maximum allowed vehicles' sizes and the allowed delivery times. In addition, the environment keeps record of the retailers' locations and the moving vehicle's location that enable it to offer lower cost shipments to neighboring retailers located on the delivery route.

- Deterministic: the environment is deterministic because all designed and programmed actions in the environment have a definite effect on the model. For example, when a delivery vehicle passes by a neighboring retailer, the offers counter will increase by one and the initial delivery cost will be decreased by 70$. Moreover, when the shipped freight has an amount more than the city's allowed maximum weight, then a penalty charge of 2$ will be added to each additional kilogram.

- Dynamic: the state of the model's environment changes based on agent's situation during the simulation run time. Thus, the model's environment is considered a dynamic environment. For instance, the initial state for the environment is that there is no collaboration between suppliers. However, this state will change to partial/full collaboration if the retailer agent requested more than the available amount of supplier's commodity in his depot.

- Discrete: the modeled environment is discrete because agents have a finite number of actions in correspondence to the environment. For example, when a retailer requests freight delivery, then the supplier will fulfill retailer's request and supply it to the carrier who will in turn assigns the suitable vehicle's size to the requested freight and finally, delivers it to the retailer.

- Episodic: first, we identify episodic from non-episodic environments. Salamon (2011) says in his book "*Design of Agent-Based Models*" that episodic means, there is independency between agents' operation segments while, non-episodic environments are just like humans-life because humans' future is affected by their past experiences. Therefore, based on Salamon's definition, the modeled environment is considered an episodic environment because each time we run the simulation model, we have to press on the "Clear" button first to erase all previously entered information, which enables us to re-execute the simulation again without being affected by past experiments.

- Dimensional: this environmental property added by (Salamon, 2011). It is crucial property in the developed model because the model depends basically on the space of the simulation world. Agents take decisions based on the dimensions they are moving in. For example, the vehicle senses and counts retailers who are located on patches that are near by the moving vehicle.

3.3 System Implementation (ABM)

3.3.1 Interaction in the Model

One agent will not be able to achieve the model's goal. The communication and interaction between all agents in the simulation model will achieve the desired goal efficiently. Thus, it is important to discuss the interaction and exchange of data between model's agents.

Information stored in the system's database needs to be exchanged between agents in order to operate effectively and accomplish the intended application's purpose. Exploring the system's database, there will be lots of tables including at least six significant tables. Each one of the agents will be mainly responsible about one or two of these six tables. Following is a description about the table(s) that each agent is responsible to manage:

- The RFIDG agent will be the main responsible about the merchandise table. This table includes all data read and filtered from the RFID scanner to be finally inserted into the merchandise table.

- The supplier agent will be mainly responsible about two tables, which are the merchandise and the companies' tables. The companies table holds the profile of each company joins the system and indicates whether the company is related to a supplier or to a retailer. The agent generates a unique serial id number for each new member.

- The retailer agent will be mainly responsible about two tables, which are the companies and the requests tables. The requests table contains all the necessary information about each new freight's delivery order generated by retailers.

- The carrier agent is mainly responsible about one table, which is the vehicles table. This table holds all vehicles information such as its availability, size, booked delivery date, etc.
- The network agent is mainly responsible about the roads table, which includes delivery roads information including their congestion and details of neighboring retailers located on the delivery route.
- The city administration agent is mainly responsible about one table, which is the cities table. This table contains each city's delivery rules. The rules are announced to both suppliers and carriers to enable them to obey with the cities' delivery rules.

3.3.2 Software's Background

The ABM model is implemented using Netlogo software[5], version 5.0.5, which uses LISP programming language and is a free open source application. Netlogo 5.0.5 was published on December, 2013 by Northwestern University and it was authored by Uri Wilensky since 1999. The reasons behind using this software among other ABM software is that it provides a multi-agent programmable modeling environment suitable for simulation, which simplifies understanding of complex systems. This software commonly known and used by numerous students, instructors, scientists, and researchers all over the world and it has shown effective reliable results. Netlogo has many features that support multi ABM. One of the most beneficial features used in developing the linkage model is the "*System Dynamics Modeler*". It is a computer aided approach to use with dynamic complex systems

[5] http://ccl.northwestern.edu/netlogo/5.0.2/; accessed 10 September 2013.

that requires formulation, design, implementation, and testing. Another beneficial feature is the “Behavior Space”, which enables modelers to create time series experiments that can help them to withdraw conclusions and monitor models’ behavior over time.

3.3.3 Assumptions of the Simulation Model

1) The retailer already has an account in the application that holds his location inside the database.

2) The model includes three suppliers: the original supplier has a quantity of the commodity entered by the model’s user, 1st supplier has 500 kg of the commodity, and 2nd supplier has 1500 kg of the commodity. We assume that the original supplier has a relation and a quick access to the other two suppliers. Because we aim to provide rapid system that is able to arrange quick dispatches to customers. If the original supplier required more than 2000 kg of the product then, he will need to enter in a game to accommodate his retailer’s request. The game is explained in detail in the next chapter.

3) Four sizes of shipping vehicles are available in order to be able to assign the most suitable vehicle size to each freight delivery order. Each vehicle has a unique identification number and an initial delivery cost assigned to it whether it will move full or with an empty weight as following:

- ID: 001: size = 5000 kg with initial delivery price = $600.
- ID: 002: size = 7000 kg with initial delivery price = $800.
- ID: 003: size = 9000 kg with initial delivery price = $1000.
- ID: 004: size = 11000 kg with initial delivery price = $1200.

4) The model's world is divided into four different cities distinguished by color. Each logistics city has its own delivery rules as illustrated below:

- City A: allows maximum vehicle's size of 11000 kg between 1 am and 9 am.
- City B: allows maximum vehicle's size of 5000 kg during any time of the day.
- City C: allows maximum vehicle's size of 7000 kg between 2 am and 2 pm.
- City D: allows maximum vehicle's size of 9000 kg between 11 pm and 7 am.

Figure 6: Delivery rules of the model's logistics cities

5) Supplier's net profit equals $2 per each purchased kilogram.

6) If the arranged shipment exceeded the city's allowed maximum vehicle's size then, a penalty charge of $2 for each additional delivered kilogram will be applied.

7) The initial price will be decreased by $70 for allowing sharing the vehicle's size with each neighboring retailer on route. Note that, allowing to share the carrier's vehicle's

size with large number of neighboring retailers qualifies the original retailer to have a free delivery to his location.

8) Each one of the neighboring retailers can allocate 250 kg of the shared vehicle's size.

9) No warehouses are assumed in the proposed model.

3.3.4 Simulation Model Overview

The simulation model represents successful collaboration among suppliers, carriers, and retailers. It simulates the distribution process of freights in logistics cities and recommends the use of multi-agent based DSS. The first step in developing the model on the computer after having the conceptual model ready and all the design details set-up was to develop the linkage diagram using the system dynamics modeler feature in Netlogo software as demonstrated in figure 7.

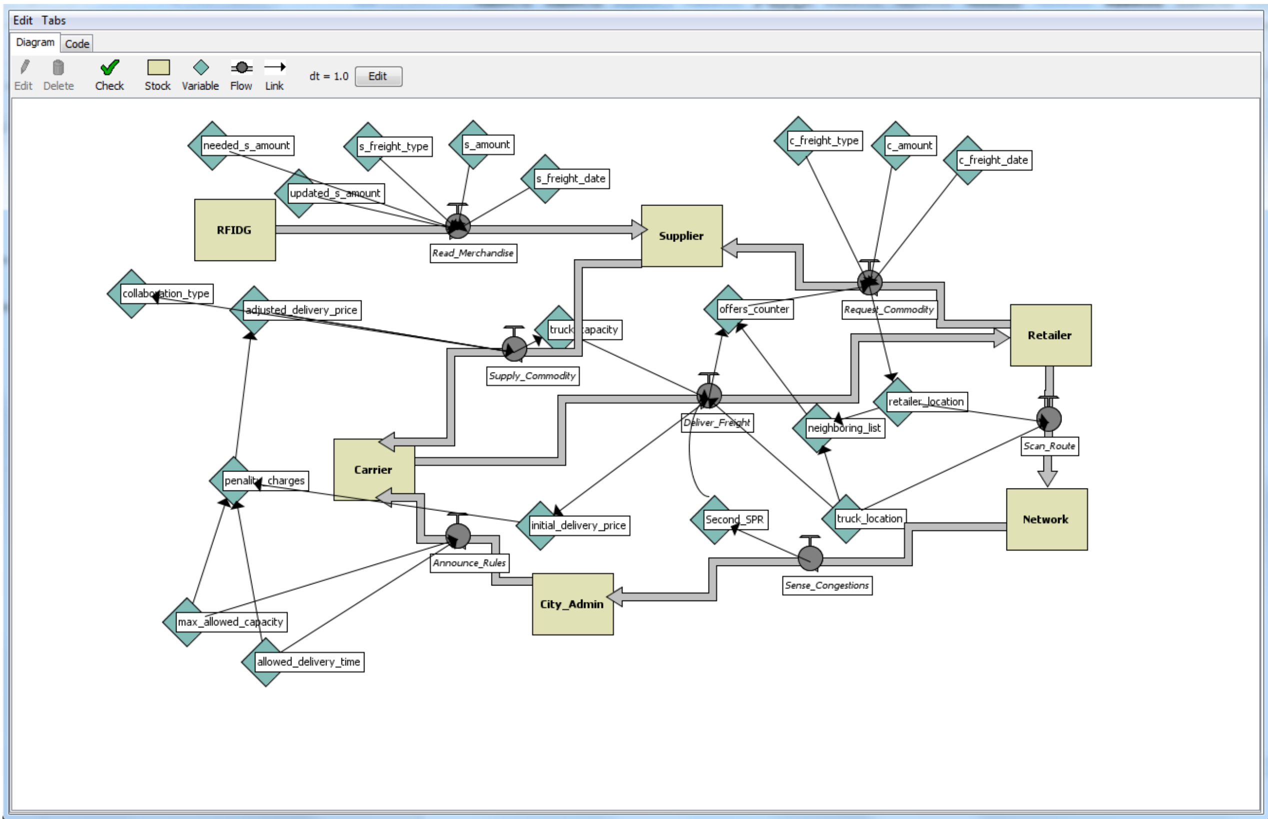


Figure 7: ABM system dynamics modeler

The linkage diagram has the six defined active agents in the designed conceptual model. Agents are represented using light green squares as illustrated in figure 7. They are linked through data flows titled with each agent's main goal. It also has twenty variables represented by the green diamonds.

This system's architecture built the base of the simulation model. After developing the system dynamic modeller, the interface of the simulation model was programmed employing the criteria listed in table3.

Table 3

Criteria in the multi-agent simulation model

Criteria	**Multi-agent Simulation Model**
1) Purpose of the model	Minimize the delivery cost through optimal strategy of distributing freights to retailers (optimization and solve the LTL problem). Moreover, it induces for suppliers' collaboration towards maximizing profits and at the same time, fully accommodating their retailers' purchasing requests.
2) Main functionalities	The model examines sharing transporting vehicles' capacities between neighboring retailers and offering lower cost shipments to them. It also presents various collaboration types between suppliers and encountered penalty when violating cities' delivery rules.
3) User of the model plays the role of the,	1. Supplier to enter products 2. Retailer to request products from the supplier 3. Carrier to check city's delivery rules and deliver freights
4) Number of retailers	By default is 50 retailers and can change using a slider that is range between 1 and 100
5) Number of suppliers	Fixed to three suppliers (assuming that only one is providing shipments and the other two is just to allow the original supplier to collaborate with them to satisfy his retailer's purchasing order)
6) Number of logistics cities	Four logistics cities (each city has different delivery rules. The model recommended alternative solutions and caused penalty when violating the rules)
7) Shipping vehicles sizes	Four different vehicles' sizes are available to be able to assign the most suitable vehicle size based on the ordered quantity of the freight (5000 kg, 7000 kg, 9000 kg, and 11000 kg)
8) Collaboration	Considered between suppliers to accommodate purchasing requests, as well as, between retailers to share transporting vehicle's size to get lower cost delivery offers.
9) Distance	The distance between the moving transporting vehicle and each retailer located near by the shipping route is considered because we need to find the neighboring retailers to the original one who initiated the freight

	delivery order and offer to them the rest available empty weight in the vehicle to allocate it and eventually, solve the LTL.

3.4 Modeling Major Collaborative Behaviors in the Simulation ABM

The simulation ABM highlighted emergent phenomena and could be easily adopted to new barriers. For example, it illustrated how the initial shipment's delivery cost is affected by the number of neighboring retailers who allow sharing size of the transporting vehicles. However, even though that the simulation ABM can test and answer many wondering questions without costing reality errors since it is just a simulation environment of real situations. Another optimization method is used, which is the game theory. The GTM helped to intensively model crucial objectives that should be achieved as a result of implementing the proposed ABM.

In this section two games are modeled. Both games formulate the collaboration behaviours in detail and select the most suitable partner to collaborate with. The first game ensures successful collaboration between suppliers towards maximizing profits and fully accommodating purchasing orders. Since, the game for suppliers in coalition has one major objective, which is to maximize profits, then it is formulated mathematically using the simplex algorithm of linear programming.

The second game ensures efficient collaboration between multiple carriers in coalition. The modeled game minimizes late delivers, maximizes the shipping vehicles' utilization rate, and qualifies retailers to get minimized delivery costs. Since, the game for carriers in coalition has three major objectives, then it is formulated mathematically using the goal algorithm of multi-objective linear programming.

3.4.1 Game for Suppliers in Coalition

This game represents suppliers' collaboration toward maximizing their profits, and at the same time, satisfying their customers purchasing orders. It is a two sets of *n* and *m* players' game; the sellers and the buyers. The game is sequential-move game in which players take turns. Therefore, buyers play first to place purchasing orders and afterwards, sellers take turn to evaluate buyers' decisions and respond to them accordingly. Although, the game is multistage (dynamic) game; it also has simultaneous-moves of players at the time that each set of players take turns. This occurs when all of the buyers request purchases from sellers at the same time without knowing that other buyers are also requesting the same seller for the same product. According to Webster (2009), simultaneous-move games are example of static games, where players move at the same time and all of them are unaware of other's decisions until all moves are done. Moreover, the game is cooperative one time game. It is cooperative because all players have the same interest. Watson (2008) claims that "*cooperative game theory is often preferred for the study of contractual relations, in which parties negotiate and jointly agree on the terms of their relationship*". The GTM attains "Nash Equilibrium" solution concept since it intends to profit all players entering the game and since suppliers cannot achieve better profits by switching strategies. It is optimal decision game since it ends with deciding most preferable suppliers to collaborate with based on acquiring high quality merchandise and maximizing profits. The game aims to assess suppliers based on making higher profits. For example, worst seller is the one that does not sell out and profits the least.

Players:

S_x: The set of all suppliers entering the game as sellers

B_y: The set of all suppliers entering the game as buyers

Where *x* and *y* are finite numbers indicating suppliers' id

$S_x \in \{S_1, S_2, S_3, \ldots, S_n\}$ for $x \in \{1,2,3, \ldots., n\}$

$B_y \in \{B_1, B_2, B_3, \ldots, B_m\}$ for $y \in \{1,2,3, \ldots., m\}$

Notions:

Each one of the sellers and the buyers have their own cost price and selling price. Note that, the cost price is the amount of money it costs the supplier to buy or make the product[6]. On the other hand, the selling price is the amount of money that the seller sells his product for.

SC_x: Seller's cost price

SS_x: Seller's selling price

BC_y: Buyer's cost price

BS_y: Buyer's selling price

[6] http://www.money-zine.com/calculators/investment-calculators/profitability-ratios-calculator/; accessed 04 May 2014.

Sellers, as well as, buyers have their own profits denoted as: SP_x and BP_y respectively.

Subtracting cost price from selling price indicates achieved profits. i.e.

Profit = Selling Price – Cost Price

Total Profits = (Selling Price – Cost Price) * Quantity

Strategies:

A finite set of pure strategies that formulate the decision plan for payers to help them choose their next move for every possible situation have been defined in the GTM. However, some of the rules were common between all players as following:

- All suppliers are concerned with making higher profits, which represents the payoff in this game
- Suppliers enter the game as either seller or buyer but, once a supplier enters; he is not allowed to change status
- Each supplier enters the game will be assigned a unique id to distinguish him from other suppliers. Note that sellers have their ids starts with the letter "S". Buyers on the other hand, have their ids starts with the letter "B". After the letter in the id, a unique sequential number starting from one is attached to the letter. Suppliers enter the game earlier get lower id numbers.
- All suppliers whether they are sellers or buyers in the game aim to sell their products after existing the game to consumers

- Buyers first send purchasing requests to recommended sellers based on buyer's assessments. Afterward, sellers evaluate buyers to decide to whom they prefer to sell
- Suppliers can see each other's products' types, selling prices, products' qualities, quantities, and availability date

Beside the common strategies between both of the sellers and buyers, each one of them has his own defined rules. For example, sellers follow below strategies:

1. Monitor market's prices before entering the game and thus, have the power to fluctuate selling prices either higher or lower but, once a seller makes a deal with a buyer then, the selling price cannot change
2. Aim to sell higher quantity of their products
3. Prefer to sell with the assigned selling price not lower
4. If a seller found out that two buyers or more causing him the same profits then, he will sell to the buyer with the lowest id assuming that s/he entered the game first and thus, got the higher priority.

On the other hand, buyers follow below sequential strategies:

1. Buy products with higher quality
2. Buy from sellers who offer selling prices that are less than both of the buyer's cost price and selling price i.e. $SS_x < BC_y$ & $SS_x < BS_y$. Set this situation as "Higher Profits"

3. Buy from sellers who offer selling prices that are equal the buyer's cost price but, less than buyer's selling price i.e. $SS_x = BC_y$ & $SS_x < BS_y$. Set this situation as "Same Profits"
4. Buy from sellers who offer selling prices that are greater than the buyer's cost price but, less than buyer's selling price i.e. $SS_x > BC_y$ & $SS_x < BS_y$. Set this situation as "Lower Profits"
5. Buy from sellers who offer selling prices that are equal the buyer's selling price for the aim of satisfying consumer's order (not for increasing supplier's profit) i.e. $SS_x = BS_y$. Set this situation as "Break Even". Break even points occur when the profits equal zero.
6. Do not buy from sellers who offer selling prices that are greater than the buyer's selling price i.e $SS_x > BS_y$. Set this situation as "Loss". Loss occurs when profits become with minus.
7. A buyer may ask a seller to minimize his selling price. In this case, the buyer should indicate the specific needed amount of discount.

3.4.1.1 Mathematical Formulation

This section formulates the main objective of the modeled game theory for suppliers in coalition mathematically. Considering the main objective, which is to maximize suppliers achieved profits then, a LPM that is solved using the simplex method is developed.

Decision variable:

Q_x: Quantity supplied by the x^{th} supplier. $x \in \{1,2,3,\ldots,n\}$. Q_x is represented in kg.

Parameters:

R_x: Requested quantity from the x^{th} supplier. $x \in \{1,2,3,\ldots,n\}$. R_x is represented in kg.

A_x: Available quantity with the x^{th} supplier. $x \in \{1,2,3,\ldots,n\}$. A_x is represented in kg.

Ps_x: Selling price of the x^{th} supplier. $x \in \{1,2,3,\ldots,n\}$. Ps_x is represented in \$.

Pc_x: Cost price of the x^{th} supplier. $x \in \{1,2,3,\ldots,n\}$. Pc_x is represented in \$.

P_x: Total profits achieved by the x^{th} supplier(s). $x \in \{1,2,3,\ldots,n\}$. P_x is represented in \$.

Objective function:

The objective function concerns with maximizing suppliers' profits through satisfying retailers' purchasing orders. Thus, the LPM can be used by suppliers in coalition who are engaged in selling products to retailers.

$$\text{Max } P_x = \sum_{x=1}^{n} (Ps_x - Pc_x) * Q_x \quad (1)$$

Subject to:

$$Q_x \leq A_x \text{ for } x \in \{1,2,3 \ldots,n\} \quad (2)$$

$$\sum_{x=1}^{n} Q_x \leq \sum_{x=1}^{n} R_x \quad (3)$$

$Q_x \geq 0$, for $x \in \{1,2,3, \ldots, n\}$ (4)

Constraint (2) ensures that the supplier has enough quantity of the requested freights to be supplied. While, constraint (3) ensures that the total supplied quantity satisfies the retailers requested quantity of the freight. Finally, constraint (4) makes sure that the supplied quantity cannot be negative, for $x \in \{1,2,3, \ldots, n\}$. Because "quantity" means the number of kilograms, which should be a positive number.

The profits maximization problem solved by above objective function is a classical problem of LP because Q_x for $x \in \{1,2,3, \ldots, n\}$ is variable and that the given parameters: R_x, A_x, Ps_x, Pc_x, and P_x for $x = 1,2,3, \ldots., n$. are positive real numbers. In addition, the *x* is a positive integer.

We say that the constraints (2), (3), and (4) define a feasible set of the problem (1). Or that the point A is feasible for the problem (1) if constraints (2), (3) and (4) are satisfied for Q_x, where $x \in \{1,2,3, \ldots, n\}$. We call the objective function $f\ (A)$ and say that the point $\hat{A}$ is the solution of the problem (1) if $\hat{A}$ is feasible and $f\ (\hat{A}) \geq f\ (A)$. The co-ordinates of the point $\hat{A}$ that give the maximum value will determine the optimal solution.

3.4.2 Game for Carriers in Coalition

This game ensures successful collaboration among multiple carriers in coalition. Therefore, it can be used by carriers who are engaged in distributing freights to retailers. It is a two sets of k players' game; the benefactors and the occupiers, which are both originally carriers. The game is sequential-move game. Therefore, carriers enter the game earlier got higher priority to satisfy their delivery orders first. Furthermore, it is multistage (dynamic) game because carriers occupy vehicles' weights based on previous knowledge that other carriers were already occupied other vehicles' weights. In other word, players are aware of other's decisions when they make their next move. Moreover, the game is cooperative one time game. It is cooperative because all players have the same interest, which is to deliver the requested quantities of the freights utilizing fully occupied shipping vehicles. Releasing fully occupied vehicles qualify the retailers to get minimized delivery costs, and at the same time, eliminate the LTL problem. The game attains "Nash Equilibrium" solution concept because it satisfies all carriers' delivery orders and since carriers cannot reach better decisions by switching strategies. It includes mathematical analysis that assist in making optimized decisions in regard to utilizing capacities of the collaborative transporting vehicles leaving less empty weights in them. Thus, it is considered an optimal decision game since it divides quantities of the total ordered freights on the vehicles' weights effectively and eventually, decides the optimal set of the collaborative vehicles to release.

Players:

B_j: The set of all carriers assigned in the game as benefactors (offer empty weights of their shipping vehicles to occupiers)

O_j: The set of all carriers assigned in the game as occupiers (occupy empty weights of the benefactors' shipping vehicles)

Where j is a finite number indicating carriers' id, $j \in \{1,2,3, \dots, k\}$

Notions:

Q_j: Quantity of the products asked to be delivered by the j^{th} carrier for $j = 1,2,3, \ldots, k$. Q_j is represented in kg.

V_{ij}: The i^{th} collaborative shipping vehicle that belongs to the j^{th} carrier. Where *i* is a finite number indicating vehicles' id for $j \in \{1,2,3, \ldots, k\}$ and $i \in \{1,2,3, \ldots, 4k\}$.

$D^{j}_{V_{ij}}$: Delivered quantity of the products by the j^{th} carrier utilizing the V_{ij} shipping vehicle for $j \in \{1,2,3, \ldots, k\}$ and $i \in \{1,2,3, \ldots, 4k\}$. $D^{j}_{V_{ij}}$ is represented in kg.

Y_i: Maximum weight of the i^{th}collaborative shipping vehicle , $i \in \{1,2,3, \ldots, 4k\}$.

Z_j: Delivery cost charged by the j^{th} carrier and it is represented in dollars.

LTL_i: Less than truck load in the i^{th}shipping vehicle , $i \in \{1,2,3, \ldots, 4k\}$. It is represented in kg.

Assumptions:

1) All carriers entered the game were requested from their retailers to deliver the freights on the same day.
2) Each carrier enter the game has exactly the same four weights of the collaborative shipping vehicles as illustrated in table 4.

Table 4

Collaborative shipping vehicles' weights

Collaborative Shipping Vehicle (V_{ij})	**Maximum Weight (Y_i)**
V_{1j}	11000 kg
V_{2j}	9000 kg
V_{3j}	7000 kg
V_{4j}	5000 kg

3) The shipping vehicles' weights can be shared between multiple carriers in the coalition.
4) Occupying full truckload qualifies 8% off the total delivery cost from each fully occupied vehicle.

Strategies:

A finite sequential set of pure strategies is defined. It formulates the decision plan for carriers to help them choose their next move for every possible situation in the game.

1) All carriers concern with occupying full truckloads to qualify their retailers to get minimized delivery cost, which represent the payoff in this game
2) Each carrier enters the game will be assigned a unique id to distinguish him from other carriers in the game. Note that, carriers enter the game earlier get lower id numbers.
3) Carriers can be either benefactors (their id starts with the letter "B") or occupiers (their id starts with the letter "O") but, not both. The game decides the role that each carrier should play.
4) Two main steps are followed to reach the optimal solution:

i. First, the set of the collaborative shipping vehicles to be released is identified.

ii. Second, each carrier starts fulfilling his delivery demands from his released shipping vehicles.

5) Assign carriers whom fully satisfied their delivery demands and still have available empty weights in their shipping vehicles as benefactors. On the other hand, assign carriers whom their planned released vehicles have not fully satisfy their delivery demands as occupiers.

6) The benefactors will offer the empty weights in their shipping vehicles to be occupied by the occupiers starting from the occupier with the lowest id.

7) All carriers in the game aim to release the minimal number of transporting vehicles leaving less empty weights in them. Note that, we assign the "less empty weights" higher priority than the "minimal number of released vehicles".

3.4.2.1 Mathematical Formulation

This section formulates the main objectives of the modeled game theory for carriers in coalition mathematically. Considering the main objectives, which are to minimize the delivery cost to retailers and to maximize the shipping vehicles' utilization rate. Another implicit objective of the game is to minimize late deliveries because carriers' collaboration lead eventually to expedite the freights' dispatching and distribution process. All presented objectives developed using a multi-objective LPM that is solved using the goal algorithm. Presented model is similar in its development to a previous goal programming model suggested by Erdem & Göçen (2012) to solve the supplier evaluation and order allocation problem. The goal programming method ensures overreaching the targeted goals' levels.

Decision variable:

$D^{j}_{V_{ij}}$: Delivered quantity of the products by the j^{th} carrier utilizing the V_{ij} shipping vehicle for $j \in \{1,2,3, \dots, k\}$ and $i \in \{1,2,3, \dots, 4k\}$. Since *i* is a finite number indicating vehicles' id then, $4k$ represents the total number of available collaborative shipping vehicles that belongs to all k carriers in the game.

Parameters:

α_{ij}: Fixed delivery costs. $i \in \{1,2,3, \dots, 4k\}$ and $j \in \{1,2,3, \dots, k\}$.

β_{ij}: Variable delivery costs. $i \in \{1,2,3, \dots, 4k\}$ and $j \in \{1,2,3, \dots, k\}$.

μ_i: Maximum weight of released vehicles, $i \in \{1,2,3, \dots, 4k\}$.

L_i: Late delivery rate. $i \in \{1,2,3, \dots, 4k\}$.

Goals:

i. Minimize delivery cost

$$\frac{D^{j}_{V_{ij}}}{\sum_{i=1}^{4k} D^{j}_{V_{ij}}} * \sum_{i=1}^{4k} (\alpha_{ij} + \beta_{ij}) \leq Delivery\ cost\ goal, j = 1,2,3, \dots, k. \quad (1)$$

ii. Maximize vehicles utilization rate

$$\frac{\sum_{i=1}^{4k} \sum_{j=1}^{k} D^{j}_{V_{ij}}}{\sum_{i=1}^{4k} \mu_i} \geq Vehicles\ utility\ goal, j = 1,2,3, \dots, k \text{ and } i = 1,2,3, \dots, 4k. \quad (2)$$

iii. Minimize late deliveries

$$\frac{D_{V_{ij}}^{j}}{\sum_{i=1}^{4k} D_{V_{ij}}^{j}} * \sum_{i=1}^{4k} L_i \leq Delivery\ time\ goal, j = 1,2,3, \dots, k. \tag{3}$$

The delivery cost encountered fixed costs, as well as, variable costs (Zhou *et al.*, 2010). Fixed costs include the shipping vehicle cost such as its fuel, maintenance, parking… etc. and the labor cost such as the time required to unpack and load vehicles, the wage…etc. On the other hand, variable costs include the cost of the quantity to be delivered and the long distance cost *(Schnotz, n.d.).* The quantity cost is calculated as \$/kg. While, the distance cost is calculated as \$/km.

Regular constraints:

$$\sum_{i=1}^{4k} D_{V_{ij}}^{j} \geq Q_j, \text{ for } j \in \{1,2,3, \dots, k\} \tag{4}$$

$$\frac{\sum_{i=1}^{4k} \sum_{j=1}^{k} D_{V_{ij}}^{j}}{\sum_{i=1}^{4k} \mu_i} = 1 \text{ , for } j \in \{1,2,3, \dots, k\} \text{ and } i \in \{1,2,3, \dots, 4k\} \tag{5}$$

$$D_{V_{ij}}^{j} \geq 0 \text{ , for } j \in \{1,2,3, \dots, k\} \text{ and } i \in \{1,2,3, \dots, 4k\} \tag{6}$$

Constraint (4) ensures satisfying the requested quantity of the freight by making sure that the delivered quantity through all shipments is greater than or equal the requested quantity. While, constraint (5) ensures that the total shipped quantities by all transporting vehicles are occupying full truckloads. Constraint (6) makes sure that the shipped quantity cannot be negative. Because “quantity” means the number of kilograms, which should be a positive number.

Since the multi-objective LPM has three goals then, we denote each goal as G_γ, for $\gamma \in \{1,2,3\}$. Overreaching a goal is represented by a positive goal deviation variable G_γ^+. On the other hand, miss-reaching a goal is represented by a negative goal deviation variable G_γ^-.

Goal deviation constraints:

Delivery cost goal:

$$\frac{D_{V_{ij}}^{j}}{\sum_{i=1}^{4k} D_{V_{ij}}^{j}} * \sum_{i=1}^{4k}(\alpha_{ij} + \beta_{ij}) - (G_1^+ - G_1^-) = Delivery\ cost\ goal, j = 1,2,3,\dots,k. \quad (7)$$

Vehicles utility goal:

$$\frac{\sum_{i=1}^{4k}\sum_{j=1}^{k} D_{V_{ij}}^{j}}{\sum_{i=1}^{4k} \mu_i} - (G_2^+ - G_2^-) = Vehicles\ utility\ goal, j = 1,2,3,\dots,k \text{ and } i = 1,2,3,\dots,4k. \quad (8)$$

Delivery time goal:

$$\frac{D_{V_{ij}}^{j}}{\sum_{i=1}^{4k} D_{V_{ij}}^{j}} * \sum_{i=1}^{4k} L_i - (G_3^+ - G_3^-) = Delivery\ time\ goal, j = 1,2,3,\dots,k. \quad (9)$$

Objective function:

The omnibus objective function combines all of the three identified goals. It is developed in respect to the cost associated with the deviation from the targeted goals' levels. Hence, a total cost deviation variables C_γ^+ and C_γ^- for $\gamma \in \{1,2,3\}$ are identified. The objective function intends to minimize these encountered costs.

$$\text{Minimize} \sum_{\gamma=1}^{3} C_\gamma^+ G_\gamma^+ + C_\gamma^- G_\gamma^- \quad (10)$$

Chapter 4:

Numerical Application

4.1 Simulation Agent Based Model

4.1.1 Running the Simulation Model

This section guides the model's user on the way to run the simulation model. Afterwards, it presents one example of model's execution that concerns with highlighting the difference between supplier's gained net profits when participating in collaborative scenarios than when not participating in collaboration.

To use the model, follow below steps;

1) Press on the "Supplier" button to enter commodity into the system.

2) Press on the "Retailer" button to request a shipment.

3) Check if the requested freight is available or not by pressing on the "Check" button.

4) If the freight is available then, press on the "Confirm" button to setup the model. Note that, if the requested amount of the commodity is not available then, press on the "Collaborate" button to enable the supplier to collaborate with other suppliers in the model to fully accommodate his retailer's purchasing request.

5) Press on the "City Rules?" button to check the delivery rules of the city where the shipment is arranged.

6) Finally click on the "Simulate Shipment" button to run the simulation.

- ➢ Note that, you can adjust the speed of the model's simulation by moving the speed slider placed on the very top of the model. Moreover, you can choose the number of retailers by moving the slider.
- ➢ Turn the Show_Offers? Switch on or off to be able to count the offers.
- ➢ Turn the Allow_Sharing? Switch on or off to be able to observe the adjusted delivery price if the switch is on. Note that, this switch only works when the offers switch is on.
- ➢ You can experiment another try by pressing on the "Simulation" button again to stop the vehicle movement successfully and then press on the "Clear" button to be able to clear all entered data into the model preparing it for the new experiment.

Now, we present a simulation scenario that compares results between collaborative and non-collaborative suppliers. Assumptions of this scenario are as following:

- The original supplier has 5000 kg of sugar.
- A retailer ordered 6300 kg of the sugar.
- Two other suppliers in the market have the requested product as following: Supplier01 has 500 kg and Supplier02 has 1500 kg.
- The supplier's net profits (*n*) equal $2 per each purchased kg of the sugar.

In this scenario the supplier does not have enough amount of the requested commodity. Thus, the supplier has two options. Either to collaborate with other suppliers in the market and accommodate his customer's request or to convince his customer to purchase the available 5000 kg of the product. The first case of the scenario is a collaborative case while, the second is a non-collaborative case. Note that, there is an obvious difference in the resulted supplier's net profits.

In the collaborative case, the supplier collaborated fully with the first supplier by purchasing all the available 500 kg of sugar with him. In addition, the original supplier collaborated partially with the second supplier and purchased the rest needed 800 kg of sugar from him. Therefore, the supplier was able to fully accommodate his retailer's purchasing order. Hence, he acquired a total net profits of $12,600 as illustrated inside the red clarification box in figure 8. Note that, the three green pentagons inside the green clarification box represent three suppliers who collaborated.

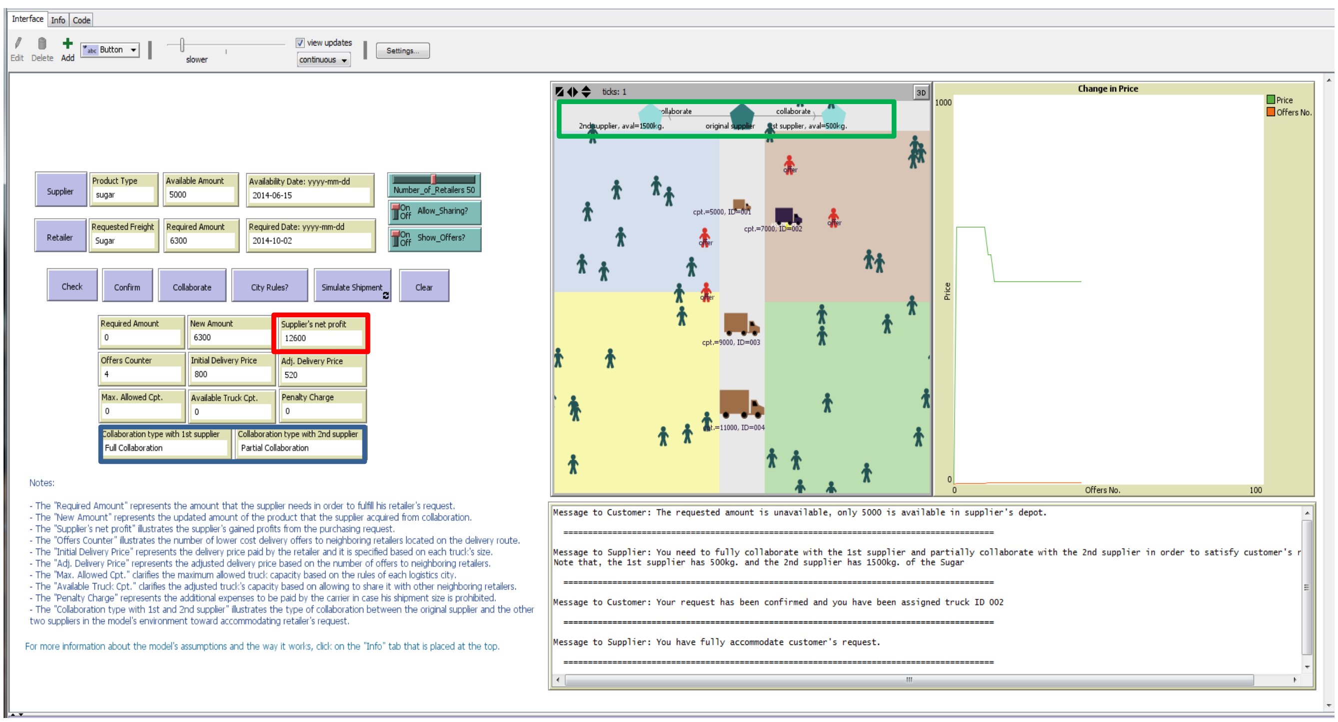


Figure 8: Results of the simulated collaborative case

* The game for suppliers' collaboration is explained in details in the beginning of next chapter.

On the other hand, in the non-collaborative case the supplier was not able to satisfy his retailer's request and thus, acquired net profits of only $10,000 as illustrated inside the red clarification box in figure 9.

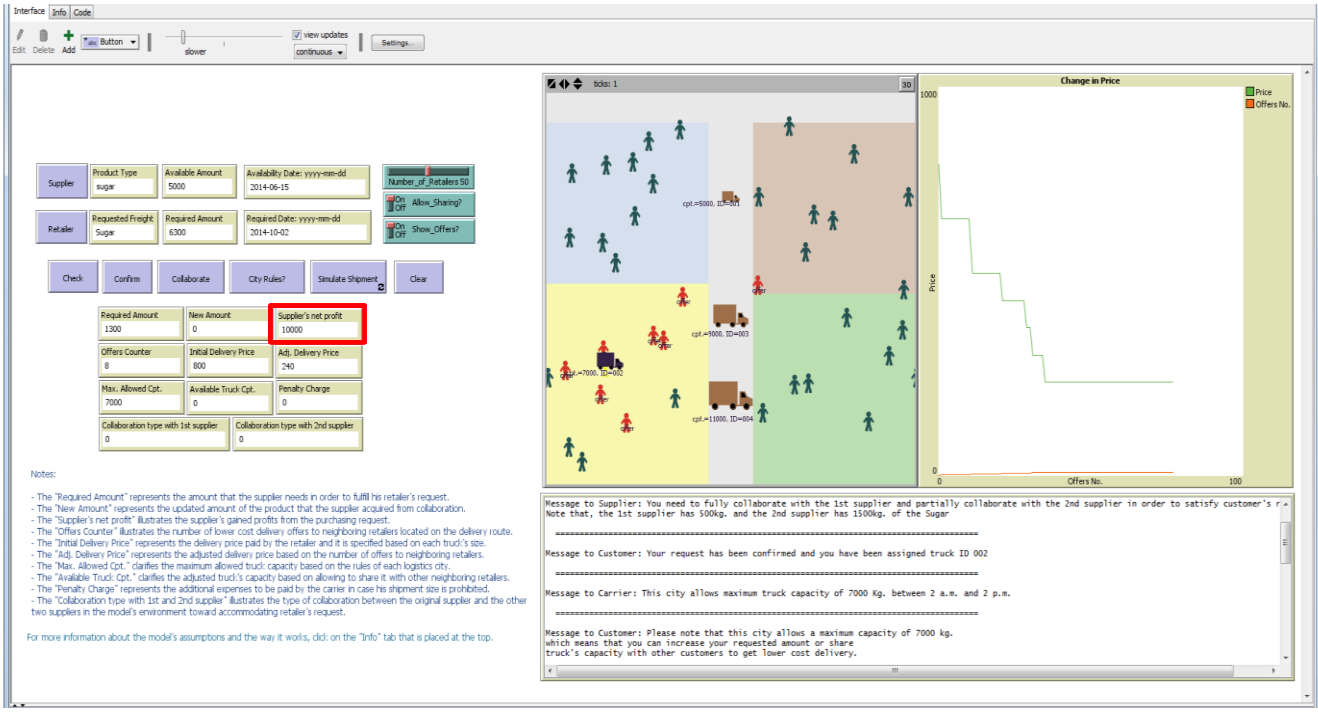


Figure 9: Results of the simulated non-collaborative case

Meaning that, there is a risk of losing $2600 in the non-collaborative case. Suppliers that are not connected with other suppliers in the market are highly exposed to encounter low production risks. Consequently, they will not be able to fully accommodate their customers' requests, which might result in decreasing their achieved net profits or losing their customers.

4.2 Game for Suppliers in Coalition

4.2.1 Programming

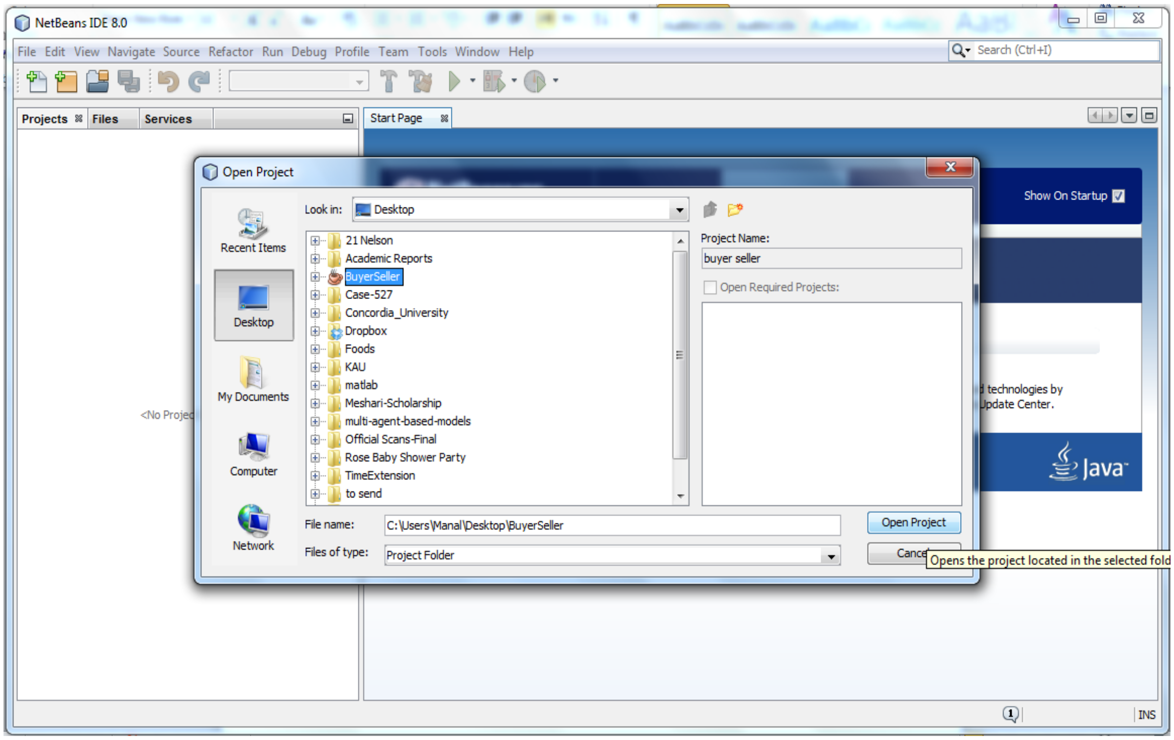
This GTM is programmed using Java programming language. There are comments at vital positions in the code. The program reads one input file, which is (input.xlsx). It has two sheets (sellers and buyers). While, the output contain three files (two excel sheets and an image) (buyer.xlsx, seller. xlsx, and output.png). Resulted image summarizes the most recommended suppliers to collaborate with in order to maximize profits and buy best quality in the market. It also indicates the exact amount of the commodity that should be sold. Many lib has been used to read the excel file and generate the image (apache poi used to read the excel file and jfreechart to generate the image).

The "JDK NetBeans[7]" can be used to run the project.

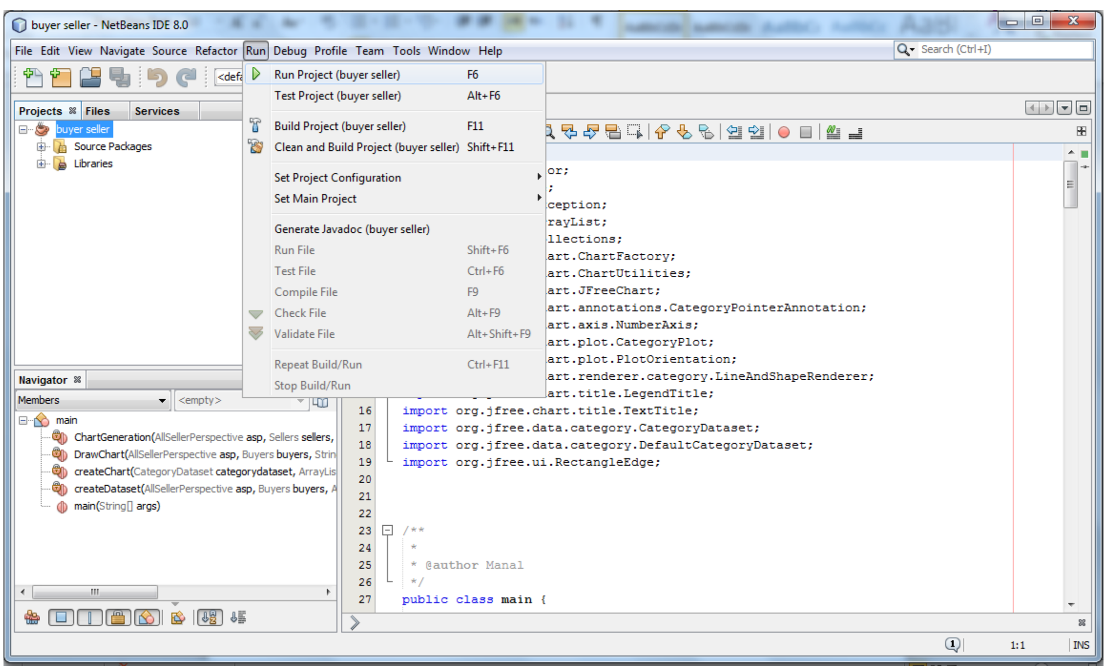
After installing the software, run the "NetBeans IDE".

Then, load and run the project from "File→ Open Project"

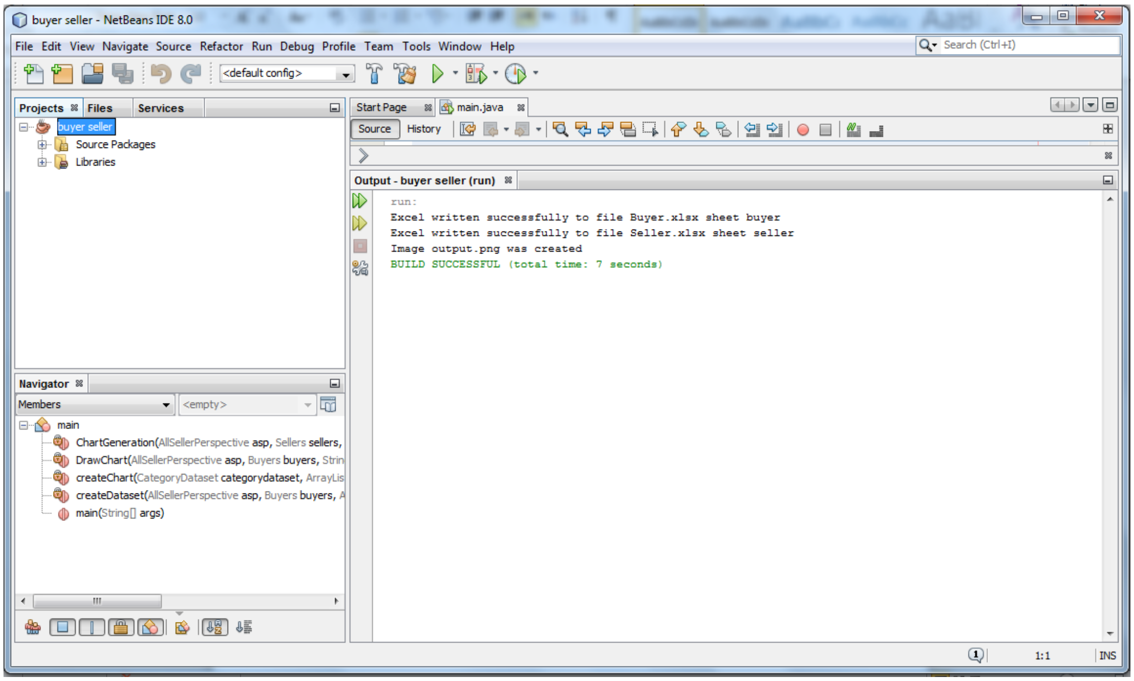
[7] http://www.oracle.com/technetwork/java/javase/downloads/jdk-7-netbeans-download-432126.html accessed 10 June 2014.



Afterwards, on the top bar click "Run→ Run Project"



The program will run successfully by reading the “input” excel sheet and generating two excel sheets, which are “Buyer” and “Seller”. Moreover, the program will generate “output” image that is summarizing the recommended suppliers to collaborate with as a result of running the program.



4.2.2 Game Theoretic Scenario

This scenario follows the rules identified in the modeled game for suppliers’ collaboration in previous chapter. It presents a game where entered players are collaborating either fully or partially to satisfy each other needs and maximize their profits. Assume that five sellers and three buyers entered the game as following;

$$n = 5, \quad m = 3$$

Table 5

Sellers entered the game (input table)

Seller ID	Product	Availability Date	Quantity	Quality	Cost Price	Selling Price
S_1	Rice	02-April-2014	900 Kg	High	$20/ Kg	$24/ Kg
S_2	Rice	16-January-2014	3000 Kg	Middle	$15/ Kg	$20/ Kg
S_3	Rice	01-May-2014	2000 Kg	Low	$09/ Kg	$17/ Kg
S_4	Rice	04-May-2014	500 Kg	High	$19/ Kg	$20/ Kg
S_5	Rice	28-February-2014	1000 Kg	High	$19/ Kg	$22/ Kg

Table 6

Buyers entered the game (input table)

Buyer ID	Product	Required Date	Quantity	Cost Price	Selling Price	Requirement
B_1	Rice	01-August-2014	1800 Kg	$18/ Kg	$20/ Kg	(Selling Price -1)
B_2	Rice	30-May-2014	2000 Kg	$20/ Kg	$24/ Kg	Same Selling Price
B_3	Rice	06-June-2014	3500 Kg	$20/ Kg	$25/ Kg	Same Selling Price

* The “Requirement” filed in above table indicates if the buyer is willing to purchase the product with the same selling price offered by the seller; or if she would like to get a discount. In addition, it denotes the needed discounted amount.

Looking to the first buyer, he needs 1800 Kg of rice. Thus, looking for sellers with “High” quality first. There is S_1 , S_4 , and S_5. The buyer decided to purchase all the 500 Kg of rice from S_4. This decision is made because S_4 has the lowest selling price among other sellers that selling high quality products. The buyer still needs more 1300 Kg of rice. Considering that the other two sellers with high quality products will cause a loss to the buyer since their selling prices ($24 and $22) are higher than the buyer’s selling price ($20). Then, the buyer decided to buy the rest needed kilograms of rice from S_2.

The second buyer needs 2000 Kg of rice. Thus, looking for sellers with "High" quality first. There is S_1 , S_4 , and S_5. The buyer decided to buy all the 500 Kg of rice from S_4 because he has the lowest selling price among other sellers offering high quality products. But, the buyer still needs more 1500 Kg of rice. Looking for the next seller with high quality and lower selling price; the buyer decided to buy all the 1000 Kg of rice from S_5. The last needed 500 Kg has been bought from the last seller selling high quality, which is S_1. Even though the buyer will not make profits from purchasing from S_1 since his selling price is the same as the buyer's selling price, the buyer decided to buy from him because of the high quality he is providing.

The third buyer needs 3500 Kg of rice. Thus, looking for sellers with "High" quality first. There is S_1 , S_4 , and S_5. The buyer decided to buy all the 500 Kg of rice from S_4 because he has the lowest selling price among other sellers selling high quality products. But, the buyer still needs more 3000 Kg of rice. Looking for the next seller with high quality and lower selling price; the buyer decided to buy all the 1000 Kg of rice from S_5.

There is still a need of 2500 Kg of rice. Therefore, the buyer looked for the third seller with high quality, which is S_1 and bought all his 900 Kg of rice. The last needed 1100 Kg has been bought from the seller with middle quality, which is S_2.

Table 7

Maximizing profits from buyers' perspective (output table1)

Buyer ID	Seller ID	Sellers Ordering	Bought Quantity	Quality	Profits	Status
$\boldsymbol{B_1}$	S_1		0 Kg	High	$0	Loss
$\boldsymbol{B_1}$	S_2	2	1300 Kg	Middle	$1300	Lower Profits
$\boldsymbol{B_1}$	S_3		0 Kg	Low	$0	Higher Profits
$\boldsymbol{B_1}$	S_4	1	500 Kg	High	$500	Lower Profits
$\boldsymbol{B_1}$	S_5		0 Kg	High	$0	Loss
$\boldsymbol{B_2}$	S_1	3	500 Kg	High	$0	Break Even
$\boldsymbol{B_2}$	S_2		0 Kg	Middle	$0	Same Profits
$\boldsymbol{B_2}$	S_3		0 Kg	Low	$0	Higher Profits
$\boldsymbol{B_2}$	S_4	1	500 Kg	High	$2000	Same Profits
$\boldsymbol{B_2}$	S_5	2	1000 Kg	High	$2000	Lower Profits
$\boldsymbol{B_3}$	S_1	3	900 Kg	High	$900	Lower Profits
$\boldsymbol{B_3}$	S_2	4	1100 Kg	Middle	$5500	Same Profits
$\boldsymbol{B_3}$	S_3		0 Kg	Low	$0	Higher Profits
$\boldsymbol{B_3}$	S_4	1	500 Kg	High	$2500	Same Profits
$\boldsymbol{B_3}$	S_5	2	1000 Kg	High	$3000	Lower Profits

* "Sellers Ordering" filed in above table indicates the best order of sellers from the buyers' point of view in regard to making higher profits while buying best quality in market.

Below is the first version of buyers' decisions about recommended sellers to collaborate with:

$B_1 \rightarrow S_4, S_2$

$B_2 \rightarrow S_4, S_5, S_1$

$B_3 \rightarrow S_4, S_5, S_1, S_2$

Above decisions represent best collaboration decision that buyers can take to satisfy their needs while maximizing their profits.

After buyers have sent purchasing requests to sellers; each seller will evaluate all buyers, paying more attention to the ones that already sent him purchasing request. Sellers assign sequential numbers to buyers starting by one and moving up. Note that one means the buyer with the best assessment in regards to purchasing the highest amount and/or making the highest profits. The buyers ordering is demonstrated in the “Buyers Ordering” field of table 8. The first seller received two purchasing orders from B_2 and B_3. Therefore, the seller calculated the profits achieved from collaborating with each one of the buyers. It has been found that B_3 will maximize the seller’s profits since B_3 ordered all of the available kilograms of rice with S_1. Hence, the seller decided to collaborate fully and sell to B_3. The second seller received two purchasing orders from B_1 and B_3. Since the seller has 3000 Kg of the requested product, which can accommodate both of the buyers purchasing orders. Then, after calculating the profits made from collaborating with each one of the buyers; it is found that both of the buyers will maximize the seller’s profits. Hence, the seller decided to collaborate partially with B_1 and B_3.

The third seller has a low quality product and thus, no buyer asked him for a purchase. However, because this GTM satisfies the “Nash Equilibrium” solution concept; where no player supposed to lose then, by the end of the game the third seller founds that both of B_2 and B_3 still needs more kilograms of rice. While, all other sellers have sold out their quantities. Therefore, the seller offered his available kilograms of rice to both of the buyers.

The fourth seller received two purchasing orders from B_2 and B_3. Therefore, the seller calculated the profits made from collaborating with each one of the buyers. It is found that collaborating with any of the buyers will result in the same profits; because both of them are ordering the same quantity of rice. Hence, the seller decided to collaborate fully and sell to B_2. Collaborating with B_2 instead of B_3 is just because B_2 has the lower id, which means that he entered the game before B_3. The fifth and the last seller in the game have the same case as the fourth seller. Hence, the seller decided to collaborate fully and sell to B_2.

Table 8

Maximizing profits from sellers' perspective (output table2)

Seller ID	Buyer ID	Buyers Ordering	Sold Quantity	Profits	Buyer's Requirement
S_1	B_1		0 Kg	$0	(Selling Price -1)
S_1	B_2	2	500 Kg	$2000	Same Selling Price
S_1	B_3	1	900 Kg	$3600	Same Selling Price
S_2	B_1	2	1300 Kg	$5200	(Selling Price -1)
S_2	B_2		0 Kg	$0	Same Selling Price
S_2	B_3	1	1100 Kg	$5500	Same Selling Price
S_3	B_1		0 Kg	$0	(Selling Price -1)
S_3	B_2		0 Kg	$0	Same Selling Price
S_3	B_3		0 Kg	$0	Same Selling Price
S_4	B_1		500 Kg	$0	(Selling Price -1)
S_4	B_2	1	500 Kg	$500	Same Selling Price
S_4	B_3	1	500 Kg	$500	Same Selling Price
S_5	B_1		0 Kg	$0	(Selling Price -1)
S_5	B_2	1	1000 Kg	$3000	Same Selling Price
S_5	B_3	1	1000 Kg	$3000	Same Selling Price

* The "Buyer's Requirement" filed clarifies to the seller if a specific buyer is willing to purchase the product with the same offered selling price or if s/he would like to get a discount.

Based on table 8 and after sellers' evaluation to buyers; sellers made their decisions about recommended buyers to collaborate with as following:

$S_1 \rightarrow B_3$

$S_2 \rightarrow B_1, B_3$

$S_3 \rightarrow B_2, B_3$

$S_4 \rightarrow B_2$

$S_5 \rightarrow B_2$

After that sellers confirmed their decisions, and assuming that the buyers agreed on these collaboration decisions. Because it maximizes their profits, as well as, it satisfies their purchasing requests. We can now visualize the final version of buyers' decisions about recommended sellers to collaborate with:

$B_1 \rightarrow S_2$

$B_2 \rightarrow S_4, S_5, S_3$

$B_3 \rightarrow S_1, S_2, S_3$

Figure 10, demonstrates the most recommended supplies to collaborate with. Noticing that, all entered players have collaborated either fully or partially and that there is no loser in this scenario. Thus, it fulfills the "Nash Equilibrium" solution concept.

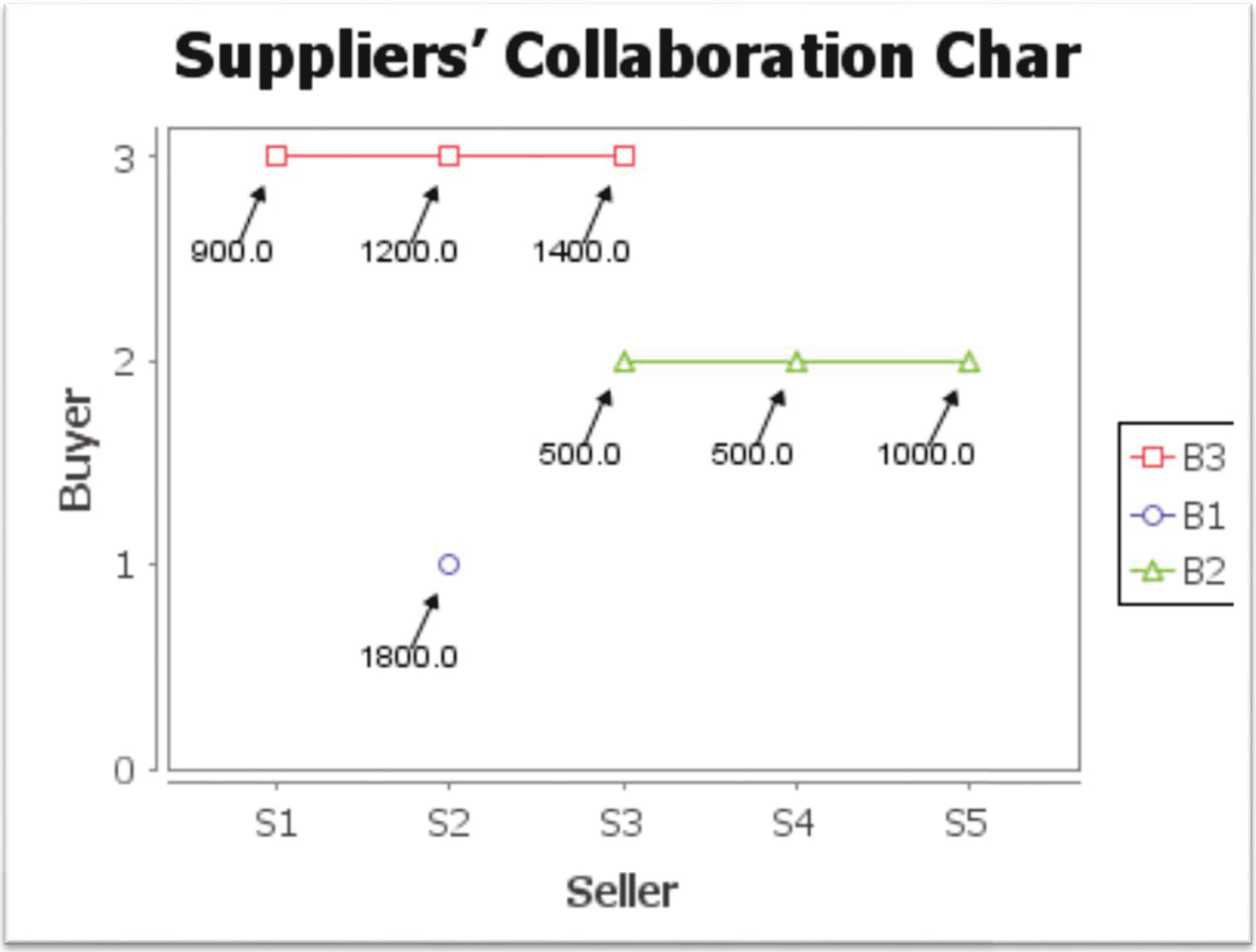


Figure 10: Suppliers' collaboration chart

4.2.3 Numerical Example for Mathematical Formulation

For a complete understanding of the objective function that is developed in previous chapter for supplier collaboration toward maximizing profits and to prove its correctness, we calculate the following numerical example. Assuming that three suppliers in the market want to collaborate by sharing their available quantity of the products as illustrated in table 9. To be able to decide the best collaborative scenario; the example calculates profits achieved in all cases and all types of collaboration. Note that there are $(2^n - 1)$ cases of collaboration, where n denotes the number of suppliers. While, there are three types of collaboration: 1- no collaboration (working individually), 2- partial collaboration (between two suppliers), and 3- full collaboration (between all the three suppliers).

Table 9

Details of the assumed three suppliers in coalition

Supplier (x)	**Available Quantity (A_x)**	**Requested Quantity (R_x)**	**Cost Price (Pc_x)**	**Selling Price (Ps_x)**
1	5000	1000	3	4
2	7000	8000	5	7
3	4800	5000	4	7

<u>Case (1): Coalition between supplier 1 and 2:</u>

The problem is:

Maximize $P_{(1,2)} = \sum_{x=1}^{2}(Ps_x - Pc_x) * Q_x = (Ps_1 - Pc_1) * Q_1 + (Ps_2 - Pc_2) * Q_2$

$$= (4 - 3) * Q_1 + (7 - 5) * Q_2$$

So, we can re-write the problem as;

Maximize $P_{(1,2)} = 1 * Q_1 + 2 * Q_2$ (1)

Subject to:

$Q_1 \leq 5000$ (2)

$Q_2 \leq 7000$ (3)

$Q_1 + Q_2 \leq 9000$ (4)

$Q_1 \geq 0, \ Q_2 \geq 0$ (5)

Substituting values of given parameters and putting the problem in a free calculator for LP[8], we get the following solution;

The maximum $P_{(1,2)} = 1 * 2000 + 2 * 7000$ = 16000$

The optimal value appeared at the point Â with the following co-ordinates (2000, 7000). The two resulted co-ordinates clarify the two needed quantities to supply as shown in figure 11. Note that the figure is graphed using a free linear programming graphic tool[9]. The white part in the graph represent the feasible region to the problem.

[8] http://www.zweigmedia.com/RealWorld/simplex.html; accessed 10 March 2014.
[9] http://www.zweigmedia.com/utilities/lpg/index.html?lang=en; accessed 12 December 2014.

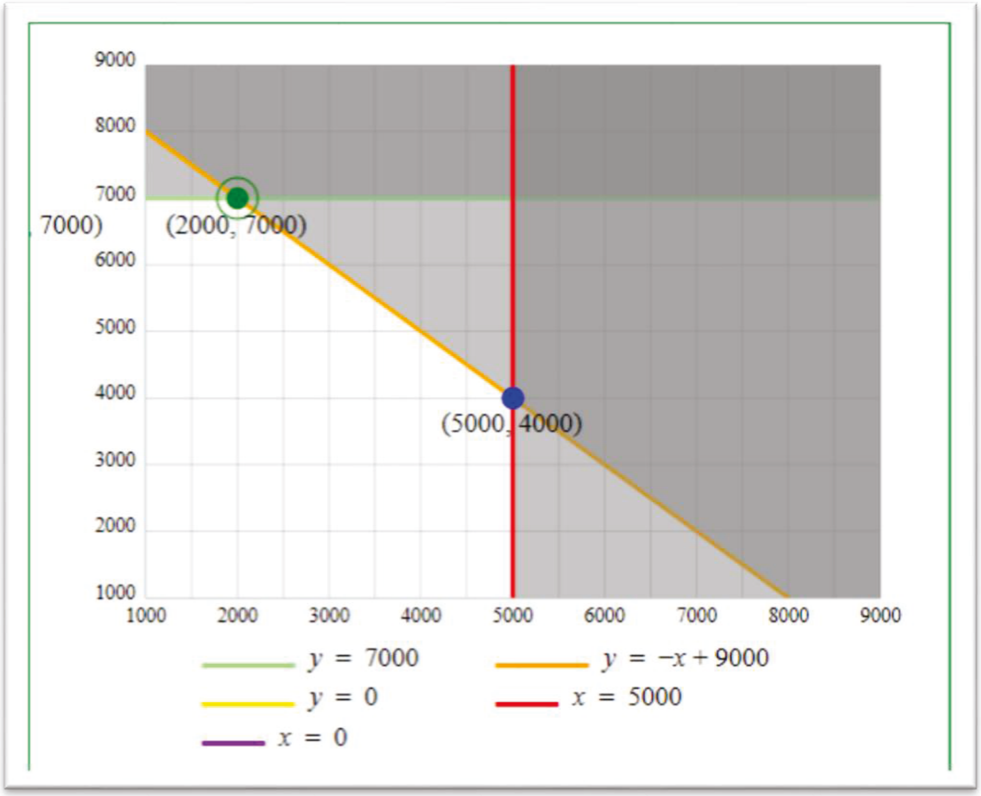


Figure 11: Coalition between supplier 1 and 2

Case (2): Coalition between supplier 1 and 3:

Maximize $P_{(1,3)} = (4 - 3) * Q_1 + (7 - 4) * Q_3 = 1 * Q_1 + 3 * Q_3$ (1)

Subject to:

$Q_1 \leq 5000$ (2)

$Q_3 \leq 4800$ (3)

$Q_1 + Q_2 \leq 6000$ (4)

$Q_1 \geq 0, \; Q_3 \geq 0$ (5)

The maximum $P_{(1,3)} = 1 * 1200 + 3 * 4800 = 15600\$$

The optimal value appeared at the point $\hat{A}$ with the following co-ordinates (1200, 4800).

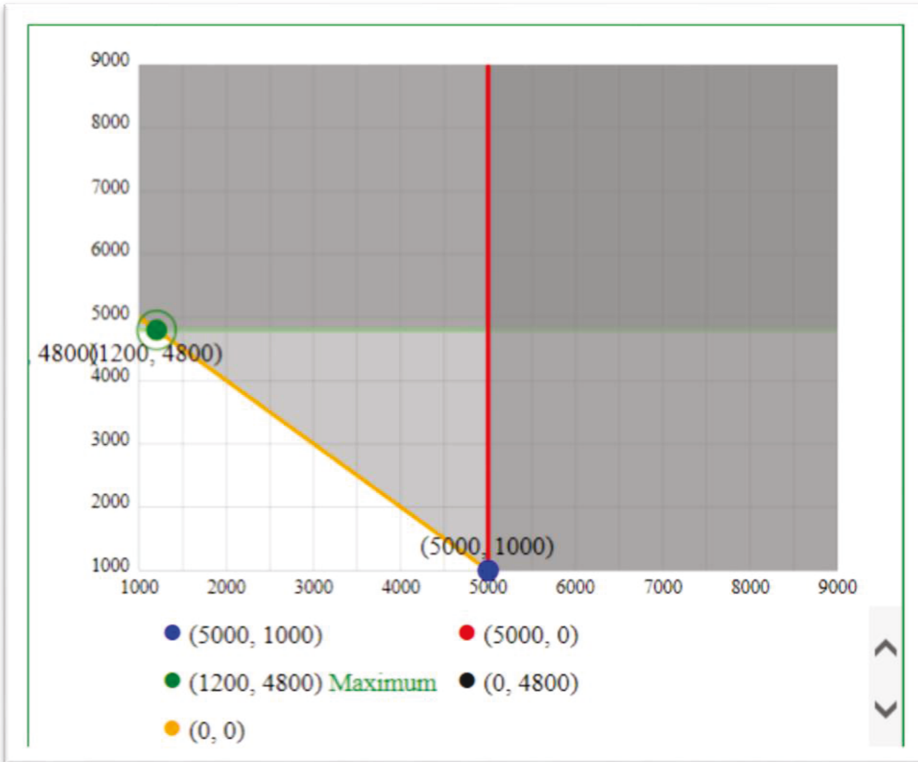


Figure 12: Coalition between supplier 1 and 3

Case (3): Coalition between supplier 2 and 3:

Maximize $P_{(2,3)} = (7 - 5) * Q_2 + (7 - 4) * Q_3 = 2 * Q_2 + 3 * Q_3$ (1)

Subject to:

$Q_2 \leq 7000$ (2)

$Q_3 \leq 4800$ (3)

$Q_1 + Q_2 \leq 13000$ (4)

$Q_2 \geq 0, \; Q_3 \geq 0$ (5)

The maximum $P_{(2,3)} = 2 * 7000 + 3 * 4800 = 28400\$$

The optimal value appeared at the point $\hat{A}$ with the following co-ordinates (7000, 4800).

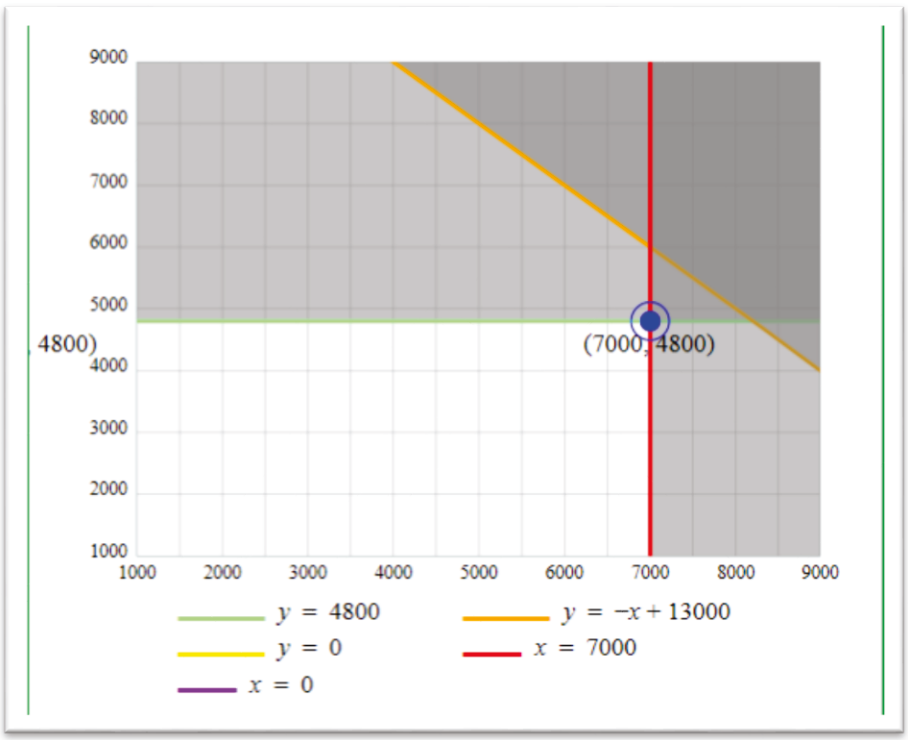


Figure 13: Coalition between supplier 2 and 3

Case (4): Coalition between all suppliers:

Maximize $P_{(1,2,3)} = (4 - 3) * Q_1 + (7 - 5) * Q_2 + (7 - 4) * Q_3$

$= 1 * Q_1 + 2 * Q_2 + 3 * Q_3$ (1)

Subject to:

$Q_1 \leq 5000$ (2)

$Q_2 \leq 7000$ (3)

$Q_3 \leq 4800$ (4)

$Q_1 + Q_2 + Q_3 \leq 14000$ (5)

$Q_1 \geq 0,\ Q_2 \geq 0,\ Q_3 \geq 0$ (6)

The maximum $P_{(1,2,3)} = 1 * 2200 + 2 * 7000 + 3 * 4800 = 30600$$

The optimal value appeared at the point $\hat{A}$, which is a three dimensional point with the following co-ordinates (2200, 7000, 4800).

Table 10, summarizes all the calculated collaborative cases and types.

Table 10

Numerical analysis of three suppliers in coalition

Suppliers in Coalition (x)	**Available Quantity (A_x)**	**Requested Quantity (R_x)**	**Supplied Quantity (Q_x)**	**Satisfy Customer?**	**Cost Price (Pc_x)**	**Selling Price (Ps_x)**	**Achieved Profits (P_x)**	**Max. Profits (M_x)**
1	5000	1000	1000	Y	3	4	1000	
2	7000	8000	7000	N	5	7	14000	
3	4800	5000	4800	N	4	7	14400	
12	12000	9000	9000	Y			16000	18000
13	9800	6000	6000	Y			15600	16000
23	11800	13000	11800	N			28400	
123	16800	14000	14000	Y			30600	33000

The "Achieved Profits" column in table 10 represents the total achieved profits for the suppliers when enter in coalition. While, the "Max. Profits" column represents maximizing the achieved profits even further based on successful collaborative decisions. The supplier who still needs additional quantity of the product will collaborate with other supplier by buying from him the needed kilograms based on the other supplier mentioned selling price. Afterwards, the supplier will be able to accommodate his customer's purchasing order by selling to him the full requested quantity utilizing his mentioned selling price. Note that the supplier who is providing additional quantity to another supplier to sell will increase his profits by earning half of gained profits of the given quantity to the other supplier. Hence, the individual supplier profit when participated in coalition is calculated on two steps. First, we calculate profits achieved by each supplier based on his original available quantity and profits (difference between the selling price and the cost price multiplied by the total sold quantity). Second, suppliers will collaborate by sharing requested quantities of the products and divide final achieved profits resulted from the collaboration equally between them to attain equilibrium solution.

For example, when the first and the second suppliers entered in coalition. The first provided 2000 kg. while, the second provided 7000 kg. as demonstrated previously in case(1). Thus, to calculate final achieved profits first, each supplier will sells out the available quantity in his depot based on his mentioned selling price. Therefore, the first supplier will sells out the available 1000 kg. and gains a total profit of (1000*1=1000$). On the other hand, the second supplier will sells out the available 7000 kg. and gains a total profit of (7000*2=14000$). Second, the first supplier will provide the second supplier with the additional needed 1000 kg. using his mentioned selling price, which is 4$/kg. The second supplier will in turn sells out the 1000 kg. based on his mentioned selling price, which is 7$/kg and gains a total profit of (1000*3=3000$), which will be divided equally between both suppliers in the coalition. Eventually, the first supplier gained a total profit of (1000+1500=2500$) and the second supplier gained a total profit of (14000+1500=15500$).

Likewise, when the first and the third suppliers entered in coalition. The first facilitated 1200 kg. while, the third facilitated 4800 kg. as demonstrated previously in case(2). Thus, to calculate final achieved profits first, each supplier will sells out the available quantity with him based on his mentioned selling price. Therefore, the first supplier will sells out the requested 1000 kg. and gains a total profit of (1000*1=1000$). On the other hand, the third supplier will sells out the available 4800 kg. and gains and total profit of (4800*3=14400$). Second, the first supplier will provide the third supplier with the additional needed 200 kg. to fully accommodate his customer's purchasing order. The third supplier will in turn sells out the 200 kg. based on his mentioned selling price and gains a total profit of (200*3=600$), which will be divided equally between both suppliers in the coalition. Eventually, the first supplier gained a total profit of (1000+300=1300$) and the third supplier gained a total profit of (14400+300=14700$).

In case of the second and the third suppliers' coalition. They could not maximize their achieved profits because they were not able to fully accommodate their customers' requests. Thus, it is not recommended for them to work together. Instead, it is recommended for them to collaborate with the first supplier because he has enough available amount of the product and thereby he is able to satisfy their customers' requests and maximize their profits.

When all the three suppliers collaborated, the first supplier facilitated 2200 kg., the second supplier facilitated 7000 kg., and the third facilitated 4800 kg. as demonstrated previously in case(4). To calculate final achieved profits first, each supplier will sells out the available quantity with him based on his mentioned selling price. Therefore, the first supplier will sells out the requested 1000 kg. and gains a total profit of 1000$. The second supplier will sells out the available 7000 kg. and gains a total profit of 14000$. The third supplier will sells out the available 4800 kg. and gains and a total profit of 14400$. Second, the first supplier will collaborate with both the second and the third suppliers by providing them with the rest needed quantity of the product. Thus, he will sells out 1000 kg. to the second supplier and 200 kg. to the third supplier to enable them to fully satisfy their customers' orders. The second supplier gained additional 3000$ from selling out the provided 1000 kg. and he splits it equally between him and the first supplier. Similarly, the third supplier gained additional 600$ from selling out the provided 200 kg. and he splits it equally between him and the first supplier. Eventually, the first supplier gained a total profit of (1000+1500+300=2800$), the second supplier gained a total profit of (14000+1500=15500$), and the third supplier gained a total profit of (14400+300=14700$).

Table 11, demonstrates achieved profits when working individually and when participating in coalition.

Table 11

Individual supplier profit when participated in coalition

Supplier	Collaborating with Supplier	Final Achieved Profits ($)	Final Sold Out Quantity (kg)
1		1000	1000
	2	2500	2000
	3	1300	1200
	23	2800	2200
2		14000	7000
	1	15500	8000
	3	14000	7000
	13	15500	8000
3		14400	4800
	1	14700	5000
	2	14400	4800
	12	14700	5000

We conclude from both table 10 and table 11 that the grand full coalition between all the three suppliers resulted in satisfying all requested quantities of the freights. Moreover, each supplier was able to achieve higher profits than when working individually.

Furthermore, the second and the third suppliers were not able to satisfy their customers' orders when working separately. On the other hand, when they collaborated with the other supplier in the market, they were able to satisfy their customers' requests. We notice significant increase in the final achieved profits as a result of sharing quantities of the products in an efficient collaborative environment. Thereby, suppliers are highly recommended to work together and participate in coalition.

4.3 Game for Carriers in Coalition

4.3.1 Game Theoretic Scenario

This scenario follows the rules identified in the modeled game theory for carriers' collaboration in previous chapter. It presents a game where entered players are collaborating either fully or partially to satisfy each other's delivery orders and, at the same time, minimize the LTL problem. Assume that three carriers entered the game as illustrated in table 12;

Table 12

Carriers entered the game (input table)

Carrier ID (j)	Total Requested Quantities (Q_j)
1	17000
2	26000
3	13000

<u>First step: Identify the optimal set of the collaborative shipping vehicles to release</u>

This step starts from the total requested quantities asked to be delivered by all carriers entered the game. Then, subtract it from the largest available vehicle weight $(Y_i - \sum_{j=1}^{k} Q_j)$ for $i \in \{1,2,3, \dots, 4k\}$ till reaching zero. Note that, if the resultant quantity to be delivered equals or is divisible on the available vehicles' weights then, it will automatically occupy them. Meaning that, it is not necessarily occupying vehicles' weights one by one, instead, it systematically occupy the most suited vehicles' weights.

In this scenario, the total requested quantities is $\sum_{j=1}^{3} Q_j = 56000$. Based on the second assumption; there will be twelve shipping vehicles available for the coalition as illustrated in table 13;

Table 13

Optimal set of released shipping vehicles (output table1)

Shipping Vehicles' Weights (Y_i)	**Total Requested Quantities (Q_j)**
$V_{11} = 11000$	56000
$V_{12} = 11000$	45000
$V_{13} = 11000$	34000
$V_{21} = 9000$	23000
$V_{22} = 9000$	14000
$V_{23} = 9000$	0
$V_{31} = 7000$	0
$V_{32} = 7000$	0
$V_{33} = 7000$	0
$V_{41} = 5000$	5000
$V_{42} = 5000$	0
$V_{43} = 5000$	0

Based on the results of table 13, we conclude that six collaborative shipping vehicles should be released, which are $V_{11}, V_{12}, V_{13}, V_{21}, V_{22}, \& V_{41}$. The first vehicle of all entered carriers in the game will be released. Moreover, the second vehicle of the first and the second carriers in the game will be released. The last released vehicle will be the fourth vehicle that belongs to the first carrier.

Second step: Satisfy carriers' delivery orders:

This step fulfills each carrier delivery order utilizing his released shipping vehicles that were decided on the previous step. Considering that the first carrier has three released vehicles, the second carrier has two released vehicles, and the third carrier has one released vehicle. Thereby, subtract the total quantities of the products to be delivered by each carrier from the total available weight of all his released shipping vehicles. Based on the sign of the resulting number; each carrier's role will be specified in the game. If the resulted number is positive then, the carrier will be assigned as a "Benefactor". While, if the resulted number is negative then, the carrier will be assigned as an "Occupier". Moreover, this step indicates the exact amount to give or to occupy.

Table 14

Planned weights to satisfy each carrier delivery order (output table2)

Carrier	Released Vehicles	$\sum_{i=1}^{4k} Y_i - Q_j$	Assigned Role
1	$V_{11} = 11000$ $V_{21} = 9000$ $V_{41} = 5000$	25000 – 17000 = +8000	*Benefactor*
2	$V_{12} = 11000$ $V_{22} = 9000$	20000 – 26000 = -6000	*Occupier*
3	$V_{13} = 11000$	11000 – 13000 = -2000	*Occupier*

Based on the results of table 14, we conclude that the first carrier is able to deliver all his requested quantities of the freight using his shipping vehicles. Furthermore, he has 8000 kg available empty weights in his shipping vehicles. Hence, he gives the empty weights to other carriers in the game. The second carrier is able to deliver only 20000 kg utilizing his planned shipping vehicles and he still needs to deliver 6000 kg. Thus, he will receive the needed weight from the benefactor's first carrier. As a result of the collaboration between the first and the second carrier, the second carrier will be able to fully satisfy his delivery order. The Third carrier is able to deliver only 11000 kg utilizing his planned shipping vehicle and he still needs to deliver 2000 kg. Thus, he will receive the needed weight from the benefactor's first carrier and then, will be able to fully satisfy his delivery order.

Table 15

Final quantities to deliver (output table3)

Carrier	**Delivered quantity ($D^{j}_{V_{ij}}$)**	**Total ($\sum_{i=1}^{4k} D^{j}_{V_{ij}}$)**
1	$D^{1}_{V_{11}}$= 11000 $D^{1}_{V_{21}}$= 6000	17000
2	$D^{2}_{V_{12}}$= 11000 $D^{2}_{V_{22}}$= 9000 $D^{2}_{V_{21}}$= 3000 $D^{2}_{V_{41}}$= 3000	26000
3	$D^{3}_{V_{13}}$= 11000 $D^{3}_{V_{41}}$= 2000	13000

The first carrier who is requested to deliver a total of 17000 kg of the freight, delivered it on two shipments utilizing his first and second collaborative transporting vehicles. The second carrier who is requested to deliver 26000 kg of the freight, delivered it on four shipments, utilizing his first and second transporting vehicles. Moreover, he collaborated with the first carrier to deliver his two remained shipments. While, the third and the last carrier who is requested to deliver 13000 kg of the freight, delivered it on two shipments, utilizing his first transporting vehicle and collaborating with the first carrier to deliver his remained quantity of the freight. Concluding that all of the released collaborative vehicles are fully occupied and thus, they are free of the LTL problem. Presented solution is optimal because it employs only six shipping vehicles and leaves no empty weights in them.

Assuming that all of the carriers in coalition agreed on these collaboration decisions. Because it satisfies their delivery orders, as well as, it qualifies them to minimize the delivery cost to their retailers. We can now visualize the carriers' collaboration chart, which is illustrated in figure 14.

Noticing that, all entered players have collaborated either fully or partially and that there is no loser in this scenario. Thus, it satisfies the "Nash Equilibrium" solution concept.

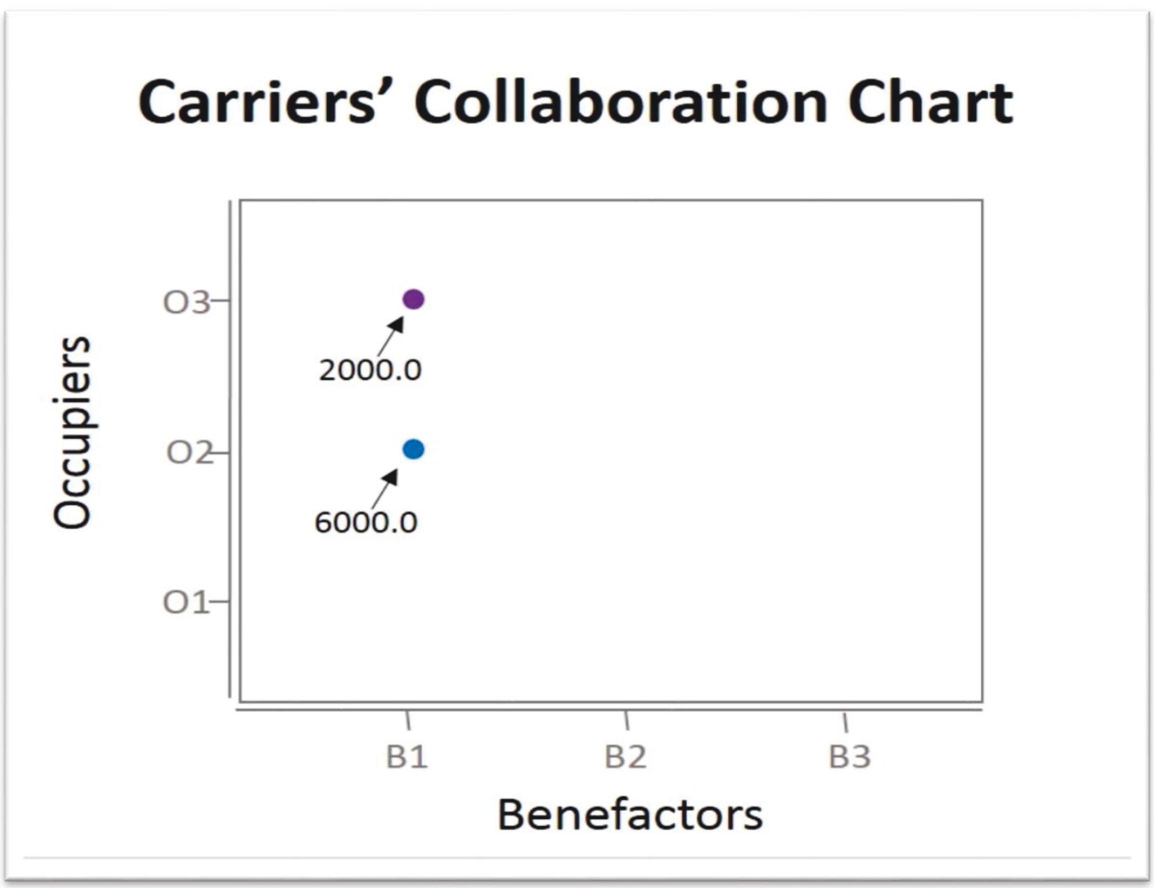


Figure 14: Carriers' collaboration chart

4.3.2 Numerical Example for Mathematical Formulation

We calculate the following numerical example to facilitate complete understanding of the objective function that is developed in previous chapter for carriers' collaboration toward minimizing delivery cost, maximizing vehicles utilization rate, and minimize late deliveries. Assuming that there are three carriers in collation and recalling the notations used in table 16;

$4k$: The total number of the collaborative shipping vehicles.

$\sum_{i=1}^{4k} Y_i$: Maximum available weight of all shipping vehicles.

Q_j: Total requested quantities of the products to be delivered by the carriers.

Z_j: Total delivery cost. For simplicity purposes we assume that the shipping cost equals two dollar per each delivered kilogram.

$$Z_j = (Q_j * 2) \ \text{, for } j \in \{1,2,3, \ldots, k\}$$

Used V_{ij}: The optimal set of the collaborative shipping vehicles to fully satisfy carriers' delivery orders.

V_{ij} No.: The number of the used vehicles to perform the delivery.

LTL_i: The final resulted empty weight in the released shipping vehicles. It is calculated by subtracting the delivered quantity from the maximum weight of the released vehicles:

$$\sum_{i=1}^{4k} LTL_i = \left(\sum_{i=1}^{4k} \mu_i - Q_j\right) \ , for\ j \in \{1,2,3, \ldots, k\}$$

Z_j^*: The updated total delivery cost after applying the percent of discount on it. It is calculated as:

$$Z_j^* = (Z_j - \%\text{Discount}Z_j)^{10} \quad, \text{for } j \in \{1,2,3, \dots, k\}$$

%Discount, calculates the percent of discount that is qualified only when occupying full truckloads. It equals 0.08 for each fully occupied vehicle.

Table 16

Numerical analysis of three carriers in coalition

Carriers in Coalition	$4k$	$\sum_{i=1}^{4k} Y_i$	Q_j	Z_j	**Used** V_{ij}	V_{ij} **No.**	LTL_i	Z_j^*	**% Discount**
1	4	32000	17000	34000	11000, 7000	2	1000	31280	8%
2	4	32000	26000	52000	11000, 9000, 7000	3	1000	43680	16%
3	4	32000	13000	26000	9000, 5000	2	1000	23920	8%
12	8	64000	43000	86000	11000, 11000, 9000, 7000, 5000	5	0	51600	40%
13	8	64000	30000	60000	11000, 9000, 5000, 5000	4	0	40800	32%
23	8	64000	39000	78000	11000, 11000, 7000, 5000, 5000	5	0	46800	40%
123	12	96000	56000	112000	11000, 11000, 11000, 9000, 9000, 5000	6	0	58240	48%

Analyzing generated results of the three carriers in the coalition; the higher encountered discount rate appeared in the grand full coalition between all the three carriers as 0.48. That is because the grand coalition resulted in satisfying all the requested delivery orders utilizing only six collaborative shipping vehicles and leaving no empty weights in them. On the other hand, when carriers worked separately; they released seven shipping vehicles leaving a total of 3000 kg *LTL*. Thereby, we notice that the carriers encountered the *LTL*

[10] http://math.about.com/od/percent/a/alg1perc.htm; accessed 14 November 2014.

problem when working individually while, the LTL problem was eliminated when they worked with each other's in an efficient collaborative environment. Furthermore, the carriers in the collation achieved higher discounts rates than the carriers in the non-collaborative scenarios. In conclusion, carriers are highly recommend to participate in collaborative scenarios to maximize the transporting trucks utilization rate, and at the same time, minimize the occurrences of the LTL problem. Effective collaboration between carriers, eventually lead to significant financial advantages that both of the carriers and the retailers benefit from.

Chapter 5:

Summary, Conclusions, and Future Works

This chapter of the thesis wraps up the proposed work and pinpoints significant results reached from the study. Finally, it presents limitations and provides an outlook for future works.

5.1 Summary of Research

The study presented complete DSS that goes along with the future foreseeable performances of modern logistics systems. It proposed employing advanced technologies and integrate them into one powerful and intelligent application that facilitates successful collaboration between various logistical entities. Four major problems in collaborative logistics were addressed and solved in this study. They are the collaboration formation, less than truckload, vehicles selection, and order quantity allocation.

Five main stages were followed to achieve the intended goal of this study as illustrated in figure 15. The initial stage involved studying current approach in performing collaborative logistics. Reading literature and obtaining experts' opinions helped to fully understand the current approach.

Afterwards, the conceptual model is designed. Agents' relationships and interactions are identified to help design the conceptual model. Moreover, drawing the state-transition-diagram and writing its pseudo code to explain each function inside the diagram also helped in designing the conceptual model. The Unified modeling language and the ODD protocol are employed to formulate the model as well.

After designing the conceptual model, the actual simulation model was developed. Model's structure and its user interface were built using the system dynamic modeler feature in Netlogo software. The fourth stage utilized game theory to intensively study and analyze major collaborative problems introduced in the preceding simulation ABM. The last stage concerned with proving correctness of the proposed games by formulating them mathematically and analyzing generated results.

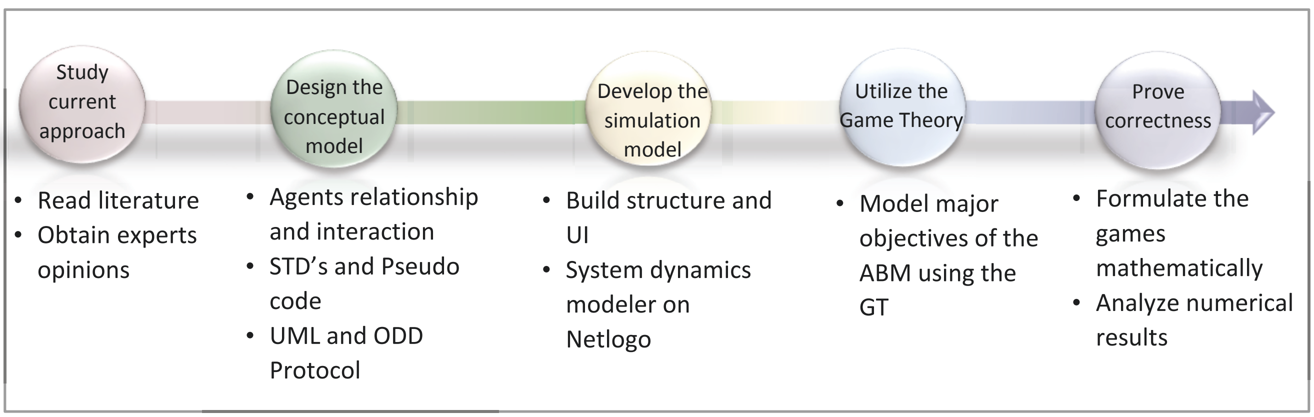


Figure 15: Main stages of the study

5.2 Answers to Research Questions

Modeled game for suppliers' collaboration intended to satisfy customers' needs. Hence, we can answer the first research question: "*Which collaborative approach suppliers need to follow in order to fulfill their retailers' needs?*"

The system should be capable to handle customers' requests and satisfy them even when they order unviable products or more than the available amounts. In case that retailers requested unviable product then, the supplier agent will notify them about the availability date and/or other similar available products that are ready to order.

If retailers ordered an available product but, more than the available quantity in supplier's depot then, the suppliers should enter in a game and collaborate with other suppliers to be able to accommodate their consumer's request. The game recommends other suppliers in the system who have enough amounts of the requested commodity with reasonable prices and high quality. The Supplier agent should rate suppliers' performance to be able to recommend them based on their reliability and loyalty.

In addition to accommodating retailers' requested freights, one of the retailers' important needs is delivering these freights on time. Thus, the application should sense delivery routes during the shipping vehicles' movements and measure congestions to be able to alert carriers in case of severe congestions and provide them with other alternative solutions.

Design and develop the simulation application that has multiple forceful intelligent agents and model the game theory for carriers' collaboration enabled us to reach the optimized freights distribution strategy. This answers the second research question: "*Which freight distribution strategy maximizes the number of potential retailers served while minimizing the delivery costs?"*

First, encourage retailers to pay full truckload and get a discount rate. This enables retailers to allocate full vehicle's weight and thus, eliminate the LTL problem. Many manufactures including P&G are encouraging their retailers to buy full truckload as mentioned in the RFID journal (2002). It also published that "*it is more efficient for suppliers to deliver full loads*". In case where retailer's order left empty weight in the shipping vehicles, calculate the shortest delivery route between the supplier and the retailer. Afterwards, scan the route to retrieve the list of neighboring retailers from nearest to farthest and send them lower cost delivery offers. Another solution is enabling carriers to collaborate by sharing transporting vehicles and fully occupying their weights.

Once the shipment is arranged for delivery then, run an optimization equation to find the best approach of dividing ordered freights on available vehicles' weights and manage their distribution to retailers.

According to the simulation ABM and modeled game for carriers' coalition we concluded that the environment, which includes the physical locations of retailers' depots does affects the delivery cost. Hence, we can answer the third research question: *"How does the physical environment affect the freight delivery cost?"*

Besides having an organized distribution of freights to retailers, the physical locations of retailers' depots should be taken into consideration. Cities where retailers are located affect the delivery cost. Because each city has its own delivery rules and thus, the role of the city administrator agent is to announce these rules to both the suppliers and the carriers and alert them in case of violating the rules. This will allow them to obey the cities delivery rules and at the same time will protect them from paying additional penalty charges.

Moreover, the number of neighboring retailers located in the environment and sharing vehicle’s weight affects the delivery cost as well. There is an inverse relationship between the number of neighboring retailers and the delivery cost. The initial delivery cost is supposed to decrease as much as there are more neighboring retailers needing freights delivery and sharing vehicles’ weights. Thereby, it is recommended to locate retailers at narrowed physical locations than spreading them over the space.

The last research question is: *“Which factors have the highest influence on the freight delivery cost?”*

The conducted study drove us to the highest influencing factors on the freight delivery cost. For instance, the allocated weight of carriers’ vehicles highly affect the delivery cost. If customers paid for full truckload then, they get a discount rate and thus, the delivery cost will be decreased. Another factor affecting the delivery cost is the number of neighboring retailers including their physical locations (the city of their depots) as mentioned in the previous solution to the third research question. Moreover, the date and the time of the ordered freight affect the delivery cost. Tightened date and time result in an increased freight delivery cost. Note that this factor affects only the original retailer who initiate the freight’s delivery order but, not the neighboring retailers who are sharing the transporting vehicle’s weight because they are accepting the original retailer’s requested delivery date.

5.3 Contribution and Conclusions Drawn

It is concluded that integrating agents' technology with RFID technology facilitates innovative DSS that satisfy customers' expectations of delivering high quality standards. In addition, it is found that game theory based models are effective to evaluate collaborative scenarios and that optimization linear programming methods are efficient for solving quantity selection and order allocation problems.

Strengths of this study stems from that it highly recommends collaboration and provides efficient strategies to achieve successful collaboration between various logistics entities. Stakeholders might be satisfied running their businesses separately with no connection with other stakeholders in the market. However, there are considerable financial benefits that stakeholders might not pay attention to if they did not participate in collaborative scenarios. "*Transferring opportunistic dogma to be synergetic ethos of collaboration, succeeded majority of logistics organization"* (Giannakis & Louis, 2011). Moreover, Lynch (2001) claims that the key to understanding collaborative logistics depends on recognizing how costs are distributed in logistics networks. Many scientists are promoting collaborative logistics. Tsai (2006) admits in his journal "*Supply Chain Collaborative Practices: a Supplier Perspective*" that efficient collaboration builds trust and strengthens communication. Building trusts is a demand in SCM because there is a need to share information and data between logistical entities (Handfield & Nichols, 1999). Accordingly, building trusted relationships becomes significant. In addition, sharing information between supply chain entities enable them to take better decisions and thus, optimize the dynamic logistics work (Mei, 2004). Businesses gain success through collaboration. Tarabori (2011) claims that collaborative relationships lead to significant financial gains.

Moreover, he developed the “5 C’s” collaboration and innovation model, which consists of:

- Communication Strategy
- Managed Competition
- Continuous Improvement
- Value-based Compensation
- Collaborative Processes

Proposed application presents successful framework for moving collaborative logistics way high steps from traditional used applications. It is concluded that implementing the proposed DSS meets several essential advantages such as,

A. Automatism and Real-time Response:

The agents based application provides an automated rapid and more controllable real time response to all freights’ requests. For instance, utilizing the RFID technology to automatically scan large number of products and filter necessary details to insert accurate information into the merchandise table accelerates the inventory process in an incredible way. In addition, less errors and mistakes will be generated since less human intervention is required.

B. Support Decision Making:

Logistics stakeholders can easily take their decisions based on the generated outcomes of the proposed application. For example, the mathematical formulation for carriers in coalition provides the optimal way to share weights of transporting vehicles between multiple carriers in coalition. Moreover, once suppliers enter to the game for suppliers' collaboration, the resulted figure will recommend best suppliers to collaborate with to attain higher profits and satisfy customers' purchasing orders.

C. Cost Reduction:

Customers will be able to have lower cost shipments to their locations if they paid for full truckload or if they shared transporting vehicle's weight with other neighboring retailers located on the delivery route. Noting that, the cost of distribution SCM and economics are essential for the decision making.

D. Increased Suppliers' Profits:

The modeled Nash Equilibrium solution concept in the game for suppliers' collaboration satisfies the win-win strategy where all entered suppliers achieve higher profits and gain high quality products.

E. Facilitate Healthier Environment:

This green practice will reduce the pollution and provide healthier environment to citizens in logistics cities since it proposes the implementation of an online application that is free of paper work. The application encompasses reduction in resources consumption whether its human resources, equipment's' resources, etc.

In addition, results of managed vehicles' movements will alleviate negative consequences in existing delivery process such as the LTL and wasting fuels. Thus, citizens' illness will be reduced as the environment becomes healthier.

F. Ensure High Quality Standards:

Proposed DSS ensures delivering high quality standards to all involved logistical entities as it is facilitating better coordination of supply chain distribution processes. The proper use of information technology applications integrates, organizes, and succeeds the supply chain distribution work. Moreover, it eliminates some existing problems in the current freights' distribution process.

G. Time Management:

One of the challenges in distribution SCM is to deliver shipments on time even if there is severe congestion on delivery routes. To enable delivering freights on time, there is a need to calculate delivery times plus times required for evacuating shipments to each one of the retailers who are sharing vehicle's size. In addition, there is a need to facilitate real-time scanning of the delivery route and notify carriers in case of sever congestion. Hence, the role of the City Administrator agent in planning and recommending best decisions is essential and that is where the intelligent and learning parts appear in the modeled system.

H. Provide Collaborative Framework:

One of the core benefits of using the application is that all involved logistical entities will be working on one integrated system and fully understanding its techniques and procedures. This creates an initiative collaborative logistics environment where retailers and suppliers up and down the supply chain can share information. Thus, provides more reliability and loyalty throughout the whole supply chain distribution system. Facilitating a one central DSS that combines numerous logistical entities advocates their cooperation and builds strong relationships and powerful links between them, which is crucial to provide convenient and successful collaborative environment.

I. Mitigate Uncertainties and Control Potential Risks:

Risks and uncertainties might occur during freights' distribution process, which might result in decreasing net profits or exasperate customers. Thus, the proposed framework highly supports the risk management and control plan inclusion in the collaborative system to be able to avoid potential damages and expenses associated with them.

5.4 Limitations and Future Works

Limitations of the current model were investigated. This study experimented and examined on generated data sets due to time constraint but, a future work can be to examine the proposed model on reality and compare results between the real data and the generated data sets. Currently, there is only one agent model on city logistics presented by (Anand, 2013). Brief comparison between the proposed model in this study and the found one city logistics model is demonstrated in table 17.

Note that, both models are developed using the same modeling tool, which is Netlogo. Furthermore, both are discussing distributive logistics (transporting goods from suppliers to retailers), which is a broad subject. However, the goal of each game is different, which is a main aspect to consider in the subject and thus, each model has its own advantages and limitations. However, it is difficult to say one model is better than the other because the core goal of each developed model is different.

Table 17

Comparison between two city logistics models

Model	Advantages	Limitations
Proposed research model	- Minimize the delivery cost to retailers and maximize suppliers' net profits (optimization). - Discuss profits and quality criteria to help suppliers collaborate and satisfy their customers' requests.	- No specific weight is assigned to retailers' depots - The criteria to help retailers select the best suppliers to purchase from is not considered
Anand , 2013 model	- Maximize retailers' profits and at the same time, minimize retailers'	- Collaboration is not considered

	purchasing cost from suppliers (optimization). - Discuss profits and stock level criteria to help citizens select retailers to buy from.	- Distance to retailers is not considered because the model is for one small logistics city

Several topics are left for future work for example in the order quantity allocation problem; we looked into the quantity of the products only, while a future work can consider the type of the products being delivered as well. For instance, considering if it is perishable or non-perishable products. Moreover, we can plan to manage problems affecting quality such as fake brands and refurbishing old products to put them again into the supply chain market.

In the simulation ABM we have introduced the “Network agent”, which is mainly responsible about measuring congestion on delivery routes. However, this agent can be upgraded even further by modeling it as a “Traffic Planner” agent that assists in designing best delivery routes to mitigate congestion and environmental impacts. Furthermore, the simulation ABM introduced the “City Administrator” agent, which is mainly responsible about saving and announcing delivery rules of logistics cities, while the agent can become more specific my modeling it as a “Municipal Administrator” agent that identifies delivery rules of logistics cities by zones. We can also expand the collaborative concept further by addressing and analyzing emerging uncertainties in customers’ demands that cause the bullwhip effect problem. Managing demands help to better forecast inventory and plan for risk management. Because as much as we reach precise predictions of demands as much as waste in supply chain will be minimized. Accordingly results in cost reduction, which is the aim of lean enterprises.

Modeled game theory for suppliers' collaboration in the study discusses sellers' criteria to help buyers select the most recommended sellers to collaborate with. Note that, both sellers and buyers are originally suppliers collaborating in the game toward maximizing their profits and satisfying their outside retailers. Therefore, the model can be improved further by considering suppliers' criteria to help retailers' select best suppliers to purchase from. Numerous decision criteria are utilized for solving the suppliers' selection problem. Pricing, quality, delivery, production weight, performance history, etc. are to name a few. The selected set of criteria are then employed in decision methods such as: the elimination method, the optimization method, and the probabilistic method (Benyoucef *et al.*, 2003).

At the end, there is no ideal method to solve a problem. Each method has its advantages and limitations. Thus, it is important to select the most appropriate set of methods based on the problem to be solved and integrate them effectively to reach the optimal solution.

Appendix A:

Experts Opinions

To explore and fully understand the current business approach in performing supply chain work in reality; obtaining experts opinions was a necessary and helpful idea to start this study. Thus, some basic questions directed to three well-known companies in the supply chain sector were undertaken.

A.1 Data Collection Technique

The chosen method to collect information was to interview some of the leading companies in SCM. According to Leedy & Ormrod (2001), the interview method is useful to ask a set of structured questions that helps the researcher gain knowledge about needed study. Saunders *et al.* (2009) claim that one-to-one non-standardised interviews can take various forms beside face-to-face such as, telephone interviews, internet, and intranet-mediated (electronic) interviews.

Figure 16: Research hierarchies, adopted from (Pickard, 2013)

A.2 Selected Companies Background

After researching the most involved and successful companies in the supply chain work, three leader companies in the supply chain sector were selected for this study. One of them is the Proctor and Gamble Company, which is a global well-known company in the field of logistics supply chain. The other two companies are Saudi local leading companies also in the field of logistics supply chain, which are Binzagr Company and the Modern Media Systems Business. The reason behind selecting these two companies beside P&G Company is to collect more information and be knowledgeable about the used E-logistics supply chain system in two different businesses' distributors one of which is a technology distributor while the other is a beverages and foods distributor.

1. Proctor and Gamble (P&G):

P&G[11] is a global well-known supply chain company. It provides branded products and services of superior quality and value to its consumers in more than 180 countries around the world. P&G brands serve nearly seven billion people on the world, which make it a very important and professional company in the field of integrated logistics supply chain management. P&G seeks the respect for diversity, the environment and sustainability in its partnerships because P&G believes that more value can be created in effective collaboration with the right partners than they could achieve alone. Therefore, in their efforts to foster effective collaborations, they continually seek to understand how their needs and capabilities can be aligned with their partners' to build the businesses together.

[11] http://www.pg.com/en_US/company/core_strengths.shtml; accessed 20 April 2012.

P&G business creates opportunities to connect technology and capabilities across categories and global regions in unexpected ways. Therefore, they seek collaboration in areas, such as packaging, design, distribution, business models, marketing models, consumer research methods, trademark licensing, and technology research. Thereby, P&G has a technical and an administration department in the logistics supply chain management. The administration department concerns with the supply chain planning, strategies, goals, techniques, etc. while the technical department works on the E-logistics system to guarantee an effective collaboration with all P&G brands around the world.

2. Binzagr:

Binzagar Company[12] is the leading distributor in the Kingdom of Saudi Arabia and has pioneered the use of IT systems to support its activities in supplies information and many others. Binzagr Company distributes a wide variety of consumer products via a network of 16 branches throughout the kingdom. Its portfolio is a mix of food and non-food products. For example Binzagr deals with Unilever, Kellogg's, Bruce Foods, Moussy, Hershey's, Kraft, Highland Spring, Continental Tire, Dunlop, Otsuka Pharmaceutical, Kikkoman, CO-RO Food, Meister Marken, Unipath, and the International Food Stuffs Company (IFFCO).

3. Modern Media Systems (MMS):

MMS[13] is a core business unit of the Al Faisaliah Group, one of the most respected business groups in the Middle East. Established in 1971, MMS supplies leading Saudi Arabian organizations with high quality and high technology products, professional engineering

[12] http://www.binzagr.com.sa/en/brand-products; accessed 25 April 2012.
[13] http://www.mms.com.sa/en/aboutus.aspx?id=6; accessed 07 May 2012.

services and market leading after sales support. MMS business concerns with supplying products in the field of Audio-visual systems; Professional broadcast video production systems/Security systems, Lighting solutions and Electronic Test & Measurement and Telecom solutions. This made it become a highly professional and ethical organization in the field of supplying products.

A.3 Summary of Collected Information

a) Proctor and Gamble (P&G)

The product supply planner at P&G Company was asked regarding the E-logistics supply chain management system. They are currently using to perform their business and he claimed that all the logistic departments including the materials management, products management, shipping department, warehouse, store room, QC/QA are using SAP application system since ten years ago and till now to perform their work.

Basic local training from P&G experts is given to new system's users to be able to use it properly and perform the intended requirements.

Moreover, he also mentioned other systems integrated with SAP application in different areas. The systems are as following:

A- *Supplier Manage Inventory*: SMI "Portal website" (to enable their suppliers to manage the stock level in P&G's warehouse for their materials and then send the needed quantities)

B- *Transportation Management System*: TMS "website" (To enable their carriers company to manage P&G's products ETS and prepare the right freight method).

C- *Corporate Standard System*: CSS (For all row and pack materials formula cards). Thus, P&G needs to integrate various applications with the main application they are using which is SAP system in order to be able to manage and accomplish their work more efficiently. Note that, most of the integrated systems are online based applications.

It is concluded that few entities aim to use the electronic applications to perform their work with P&G because the representative claimed that only five suppliers are using the SMI, two customers are using SAP application, and five carriers are using TMS application. On the other hand, most of the logistical entities tend to use the traditional communication methods as email, fax, and phone. However, P&G performs both domestics and international collaborations in order to meet their target.

In regard to the challenges/problems that P&G had previously faced with their used application, they mentioned that they face some problems from time to time and try to solve them locally within P&G company and if they could not then, they send a ticket with a description of the occurred problem to a global team to help them fix it. Eventually, all their problems get solved. Below are three problems they could solve successfully:

1- Customers' demand quantities were not reflected on SAP system: P&G had requested the global team to re-upload the demand again.

2- Materials stop ship date report showing wrong data: P&G found that the total shelf life for some materials have been changed by someone, when checked the access control they could found some users have this critical access with change mode. Then they stop their access and fix the shelf life parameters to have an accurate stop ship date report.

3- Planning report downloaded in excel with wrong format numbers: This lead to have completely wrong planning and after long journey P&G found out that the numbers format in excel is not matched with SAP numbers format and also not matched with PC setup. Simply they unite all the format and got at the end the same needed results.

At the end, the product supply planner at P&G pointed that they would prefer to work with an upgraded version if it offers more simplifications and facilitations.

b) Binzagr

Binzagar Company claims that they are using SAP ERP Production System since three years ago in performing their electronic logistics supply chain work.

The storekeepers, accountants, administration, sales, and management are involved in using the system and they require a basic training and a minimum certification as per job responsibilities.

Binzagr Company collaborates with approximately 20 suppliers, 32,000 retailers, and around 500 customers locally and globally using SAP system. The company's representative admitted that they faced technical problems with the system previously but all of the problems were successfully resolved.

Finally, the representative added that the system has all the features they need to perform the work which make them satisfied with using the current version of the system.

c) Modern Media Systems (MMS)

The Modern Media Systems' logistics manager was asked regarding the E-logistics supply chain management system they are currently using to perform their business and his answer was SAP electronic system.

The coordinators are using SAP system to collaborate with end users since ten years ago and till now. The manager noted that the system users require knowledge and training in dealing with SAP applications as compulsory. He also mentioned some tools and techniques needs to be integrated with SAP system in order to effectively perform the work such as: Sugar CRM, K Plan, and the K2 tools. MMS business communicates with more than a hundred vendors locally and globally for the purchases and supply chain solutions like Aramco, SABIC, Sony, and Fujinon customers.

MMS dedicate an IT department to resolve the problems that appear in the system and the IT staff was able to correct all encountered problems successfully.

Moreover, the logistics manager pointed that they would prefer to work with an upgraded version of SAP system that includes some advanced features such as an advanced payment to vendors including receipt from customers and reports for vendors' analysis.

A.4 Discussion of Results

Based on the obtained data, useful information have been collected to conduct the research study. Moreover, it is concluded that all of the three companies are using the same system to perform their integrated logistics supply chain work. The system they are using is called "SAP ERP Production System". Therefore, SAP system has been studied to check its functionalities, features, advantages, and disadvantages.

A.4.1 Advantages and Disadvantages of SAP Logistics System

Current international companies tend to use new effective electronic systems to do the supply chain work, which is usually performed using a one integrated Enterprise Resource Planning (ERP) system. There is a number of companies specialized in developing ERP systems and based on an American questionnaire covered more than 1300 companies using ERP systems, they found out that Oracle and SAP applications are the most used ERP systems (Altaweel, 2011). However, they also found that SAP system has been used more than Oracle system although that Oracle system is faster in the implementation and cheaper than SAP. The reason behind using SAP was because companies using it had admitted that it is easy and comfortable to do the work.

SAP Company has developed SAP system that is holding the company name and this system has become one the most successful used systems by numerous number of companies. SAP is an abbreviation for (Systems Applications and Products). This company allocated to develop management systems to assist institutes to integrate and centralize all its work using a one effective system. This kind of integration helps in compiling all companies departments work which lead to facilitating it by eliminate redundant data, reduce errors, facilitate search process, and provide a unite record of data. SAP system was completely developed using "ABAP" (Advanced Business Application Programming) language, which is similar to COBOL programing language. In recent versions of SAP system, programmers merged the use of many others programing languages such as the C and Java beside the use of the basic ABAP programing language in developing SAP system. This upgrade in SAP programing has positively added to its features and enabled institutions to create personal forms to preview or insert specific data. Several types of institutions have used SAP system such as hospitals, banks, industrial, governmental institutions, technical companies, etc. which is approximated to 172.000 institution in more than 50 country around the globe (Altaweel, 2011).

SAP system consists of many applications that are usually integrated with each other. All applications fall under one of three main categories called "SAP Modules" which are financial accounting, human resources, and logistics modules. Each institution decides if its needs one or more modules to perform its work. In our study we need to concentrate on the logistics module and to check to which extend it helps companies in performing successful collaboration.

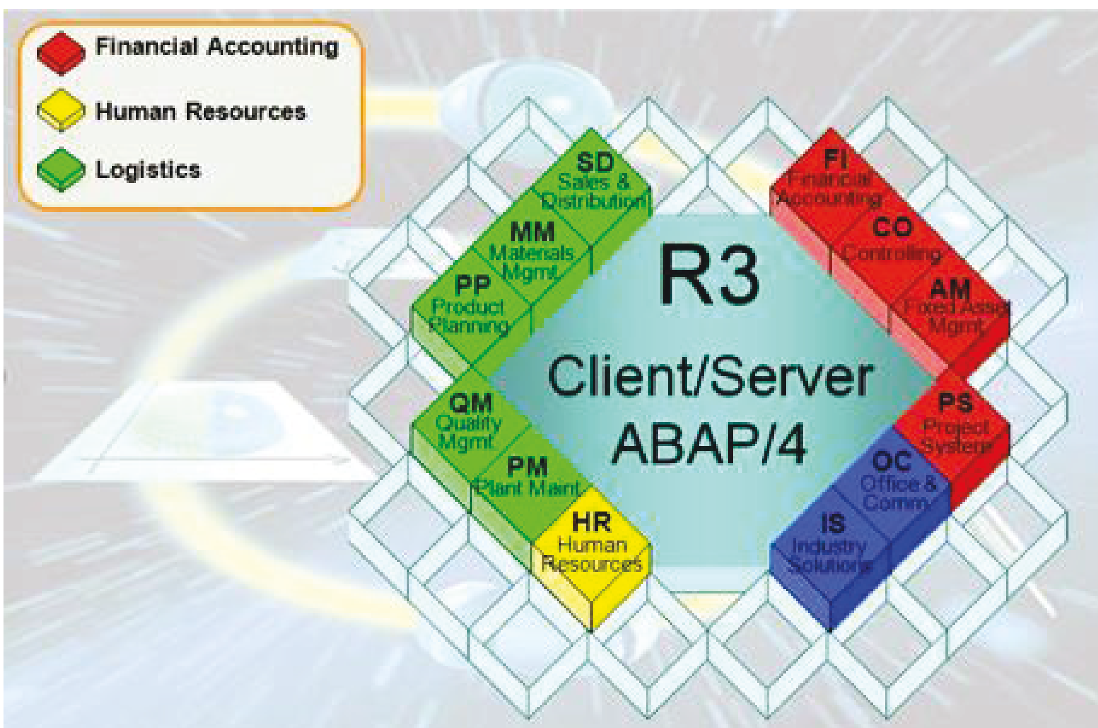


Figure 17: Applications of SAP system, source (Altaweel, 2011)

Advantages include: SAP system featured numerous advantages to its users including the financing, human resources, and logistics modules. However, this study concerns with the collaboration in logistics module in specific. SAP system allows its users to communicate using an easy open-source online tool called SAP StreamWork. This tool has many features to facilitate the collaborations among partners. It also offers collaborations form everywhere and at any time through installing the tool on the personal smart phones note that the tool has the chat feature in addition to other features. First, each SAP StreamWork member needs to create a workspace where he/she can add to it the folders, documents, etc. afterwards, the team member needs to invite required partners to the workspace and then, they both will have access to each other contents which facilitate the collaboration process. SAP StreamWork enables its users to upload/download several types of files such as: Microsoft Word, Excel, Access, Power Point, Pdf, and Image files to assist them in achieving their goals. It also enables the member to assign tasks to other participants and track the progress of assigned tasks completion status.

Disadvantages include: according to a research carried out at Florida in May (2009), most recorded problems in SAP system was performance related issues such as: slowness and in some cases hanging and returning and idle process. However, a SAP staff from the health check services replayed to above complain by explaining that the reason to these performance problems is due to SAP users (Kershaw, 2009). She claims that SAP database generally handling a massive number of data and that failing in retrieving historical data might cause the system to clog and therefore, will cause a longer run time. She also suggests a solution to this problem by advising the users to archive historical data in order to free up the live system.

A.5 Primitive Conclusion

Based upon taken experts' opinions, there is a need to improve supply chain processes and upgrade the current traditional approach in performing tasks with a more innovative method aiming to satisfy customers and achieve success. Putting in mind that future advances require rapidity in accomplishing tasks accompanied with accuracy. Accordingly, it becomes significant to research the recent inventive technologies and properly utilize them to better serve the integrated collaborative logistics work.

One of the daily necessarily demands is delivering freights to customers noting that there are some problems in the existing approach, such as empty trips and wasting fuels. Hence, we can improve this process in particular through the use of an advance collaborative intelligent application that intends to optimize the freights' distributions process. From this point, the study started to get scope and layout.

Note: The following ten pages present collected experts opinions about the current performed supply chain work. Papers are ordered as following: First the Proctor and Gamble Company, Second the Binzagr Company, and Finally, the Modern Media Systems Company.

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Appreciating your time and support in advance;

May 26, 2012

To: Procter and Gamble Company,

I am writing this to inform you that I am currently doing my Master Research in the topic of:

"**Successful Collaboration in an Integrated E-Logistics Supply Chain Management**"

And based on the fact that P&G Company is an international well-known company in this field and the leader in the Supply Chain industry using the most innovative Information Systems, I will be pleased if you can give me the chance to learn and get some information about the P&G E-logistics Supply Chain System. This will contribute a lot and adds value to my research paper.

Yours truly,

Manal Khayyat

Researcher Background

I am an Information Systems' lecturer at King Abdulaziz University, Jeddah - Saudi Arabia and currently doing Masters Degree in Quality Systems Engineering at Concordia University, Montréal - Canada.

To be filled by the P&G Staff Member

Sure Name: Turkistani , First Name: Ahmed
Position: Product Supply Planner / SAP Key User & Master data coordinator
Department: Site integrated planning (SIP)
E-mail: Turkistani.a@pg.com

1. What is the name of the electronic logistics system you are using to manage your supply chain products?

   SAP Application .

2. For how many years approximately you are using it?

   10 Years .

3. Who is involved in working with the system?

   All the logistic departments including: Materials managements, Products management, Shipping department, Warehouse, Store Room and QC/QA.

4. Is there any required background for the system's users?

   No, but basic local training is required.

5. Please indicate if there are any tools or techniques to be integrated with your system in order to perform the work?

   The following 2 systems are integrated with SAP application in different area's :

   a- Supplier Manage Inventory "Portal website" (to enable our suppliers to manage the stock level in our warehouse for their materials and then send the needed quantities)
   b- Transportation Management System "website" (to enable our carriers company to manage our products ETS and prepare the right freight method) .
   c- Corporate Standard System (for all row and pack materials formula cards)

6. How many suppliers, retailers, or customers do you communicate with using the system?

   We have almost: 5 suppliers using SMI, and 2 customers using SAP application, 5 carriers using TMS . CSS is managed by P&G only .
   However, we communicate the rest suppliers, retailers and customers via e mail, fax and phone.

7. Do you perform local/international or both collaborations with others who are using the system?

   Yes we have both collaboration type in order to meet the target.
   ----

8. Did you face any challenges (problems) with the system previously and could resolve them?

☒ Yes ☐ No

If yes, please list them and briefly describe the way you did to recover

a- Customers demand quantities not reflected on SAP system :
we request the global team to re-upload the demand again.
b- Materials stop ship date report showing wrong data :
We found that the total shelf life for some materials have been changed by someone, when checked the access control we found some users have this critical access with change mode. Then we stop their access and fix the shelf life parameters to have an accurate stop ship date report.
c- Planning report downloaded in excel with wrong format numbers:
This lead to have completely wrong planning and after long journey we found the numbers format in excel is not matched with SAP numbers format and also not matched with PC setup. Simply we unite all the format and got at the end the same needed results.

9. Did you face any challenges (problems) with the system previously and could **NOT** resolve them?

☐ Yes ☒ No

If yes, please list them,

In fact we face a lot of challenges from time to time, but there is a global team can resolve it immediately if it's out of our level and they need only to receive our ticket with the right description.

10. Please indicate if there are any features that are not currently in the system but you would like to add?

Frankly all P&G supply chain process have been maintained and managed over the SAP application (inventory management, orders management, purchases management, Project /initiative management, deliveries managements and cost/accountant management as well)

11. Would you like to continue using the current system or would you prefer to have an upgraded one?

    I would continue to work with the same system, but of course any upgrade will be required if it's have more simplifications and facilitation.

12. Please feel free to add any more comments you like

Again appreciating your time and support; please do not hesitate to contact me if you have any concerns

Manal Mahmoud Khayyat
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Saudi Arabia
NCB H.O 17th floor
21481 B.O 3555

Montréal,
Quebec,
Canada
1975 de Maissonauve Ouest#2207
H3H 1K4
E-mail: manal_417@yahoo.com

Appreciating your time and support in advance;

May 26, 2012

To: Binzagr Company,

I am writing this to inform you that I am currently doing my Master Research in the topic of:

"Successful Collaboration in an Integrated E-Logistics Supply Chain Management"

And based on the fact that Binzagr Company is a successful well-known company in this field, which made it become the leading distributor in the Kingdom of Saudi Arabia. Moreover, Binzagr pioneered the use of IT systems to support its activities in supplies information and many others activities, I will be pleased if you can give me the chance to learn and get some information about the Binzagr E-logistics Supply Chain System. This will contributes a lot and adds value to my research paper.

Yours truly,

Manal Khayyat

Researcher Background

I am an Information Systems' lecturer at King Abdulaziz University, Jeddah - Saudi Arabia and currently doing Masters degree in Quality Systems Engineering at Concordia University, Montréal - Canada.

To be filled by the Binzagr Staff Member

Sure Name: ----------------------------- First Name: -----------------------------
Position: --
Department: ---
E-mail: --

UNIVERSITÉ
Concordia
UNIVERSITY

1. What is the name of the electronic logistics system you are using to manage your supply chain products?

ERP Production System (SAP)

2. For how many years approximately you are using it?

Three years.

3. Who is involved in working with the system?

From storekeeper, Accounts, Administration, Sales & Management.

4. Is there any required background for the system's users?

Basic training required as per job responsibilities.

5. Please indicate if there are any tools or techniques to be integrated with your system in order to perform the work?

Should have minimum qualification. as per job.

6. How many suppliers, retailers, or customers do you communicate with using the system?

Suppliers – 20/Retailers – 32,000 Appr. /cust - 500.

7. Do you perform local/international or both collaborations with others who are using the system?

YES.

8. Did you face any challenges (problems) with the system previously and could resolve them?

☑ Yes ☐ No

If yes, please list them and briefly describe the way you did to recover

UNIVERSITÉ
Concordia
UNIVERSITY

----

9. Did you face any challenges (problems) with the system previously and could **NOT** resolve them?

☐ Yes ☑ No

If yes, please list them,

----

10. Please indicate if there are any features that are not currently in the system but you would like to add?

----

11. Would you like to continue using the current system or would you prefer to have an upgraded one?

YES we would like to Continue with the current system

12. Please feel free to add any more comments you like

Again appreciating your time and support; please do not hesitate to contact me if you have any concerns

Manal Mahmoud Khayyat
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E-mail: manal_417@yahoo.com

Montréal,
Quebec,
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1975 de Maissonauve Ouest#2207
H3H 1K4

Appreciating your time and support in advance;

June 03, 2012

To: Modern Media Systems Business,

I am writing this to inform you that I am currently doing my Master Research in the topic of:

"Successful Collaboration in an Integrated E-Logistics Supply Chain Management"

And based on the fact that MMS is a highly-professional and ethical business in this field which made it supplies the leading Saudi Arabian organizations with high quality and high technology products, professional engineering services, and becomes the market-leading in after-sales support; I will be pleased if you can give me the chance to learn and get some information about the MMS E-logistics Supply Chain System. This will contribute a lot and adds value to my research paper.

Yours truly,

Manal Khayyat

Researcher Background

I am an Information Systems' lecturer at King Abdulaziz University, Jeddah - Saudi Arabia and currently doing Masters Degree in Quality Systems Engineering at Concordia University, Montréal - Canada.

To be filled by the MMS Staff Member

Sure Name: FIRASATH ULLAH First Name: MOHAMMED
Position: LOGISTIC'S MANAGER
Department: LOGISTIC'S
E-mail: m.firasathullah@alfarsahah.com

UNIVERSITÉ Concordia UNIVERSITY

1. What is the name of the electronic logistics system you are using to manage your supply chain products?

S.A.P

2. For how many years approximately you are using it?

10 YEARS

3. Who is involved in working with the system?

END USERS – COORDINATOR'S

4. Is there any required background for the system's users?

KNOWLEDGE and TRAINING in SAP is COMPULSORY

5. Please indicate if there are any tools or techniques to be integrated with your system in order to perform the work?

SUGAR CRM, K PLAN, K2 Tools TO BE INTERGRATED TO PERFORM WORK EFFECTIVELY.

6. How many suppliers, retailers, or customers do you communicate with using the system?

MORE THAN 100 VENDORS / CUSTOMER'S

7. Do you perform local/international or both collaborations with others who are using the system?

LOCAL / INTERNATIONAL PURCHASING "SUPPLY CHAIN" SOLUTIONS IN ADOPTED BY MANY CUSTOMER / VENDORS ARAMCO / SABIC / SONY / FUJINON

8. Did you face any challenges (problems) with the system previously and could resolve them?

☑ Yes ☐ No

If yes, please list them and briefly describe the way you did to recover

we Have a dedicated - IT department to Cater to any Problems arising from the System - To my knowledge there were issues and were resolved and the details are not available with me

UNIVERSITÉ Concordia UNIVERSITY

----

9. Did you face any challenges (problems) with the system previously and could **NOT** resolve them?

☐ Yes ☑ No

If yes, please list them,

----

10. Please indicate if there are any features that are not currently in the system but you would like to add?

① Advance Payments to vendors " Receipt of Advances from customers
② Generation of Reports for vendor Analysis Value / currency wise

11. Would you like to continue using the current system or would you prefer to have an upgraded one?

would prefer to work with upgrade version of SAP

12. Please feel free to add any more comments you like

Again appreciating your time and support; please do not hesitate to contact me if you have any concerns

Bibliography

Agus, A. (2011). *Supply Chain Management , Product Quality and Business Performance*, *10*, 98–102.

Altaweel, Y. (2011). *Enterprise Resource Planning Systems – SAP System.* SAP Publication. Retrieved from http://www.yzd.cc/2011/10/10/sap-book-arabic/ on June 08, 2012

Anand, N. (2013). *City Logistics Game,* [video files]. https://www.youtube.com/user/CityLogisticsGame/feed Accessed: October 11, 2014.

Andréasson, I., & Molndal, S.-. (2002). *Reallocation of Empty PRT Vehicles en Route Reallocation of Empty PRT Vehicles en Route.*

Auramo, J., Aminoff, A., & Punakivi, M. (2002). *Research agenda for e-business logistics on professional opinions*. International Journal of Physical Distribution & Logistics Management: Vol. 32, No, 7

Bailey, E., Unnikrishnan, A., & Lin, D.-Y. (2011). *Models for Minimizing Backhaul Costs Through Freight Collaboration.* Transportation Research Record: Journal of the Transportation Research Board, 2224(-1), 51–60. doi:10.3141/2224-07

Barratt, M. (2004). *Understanding the meaning of collaboration in the supply chain, Supply Chain Management*. An international journal, Vol 9, No 1, pp 30-42.

Benyoucef, L., Ding, H., & Xie, X. (2003). *Supplier Selection Problem: Selection Criteria and Methods.* [Research Report] RR-4726, pp.38. Retrieved from https://hal.inria.fr/inria-00071860 on November 13, 2014

Berger, S., & Bierwirth, C. (2009). *The Collaborative Carrier Vehicle Routing Problem for Capacitated Traveling Salesman Tours*, 75–78.

Borade, A., & Bansod, S. (2007). *Domain of Supply Chain Management – A state of Art*. Vol. 2, Isse 4

Brown, D.G. (2006). *Agent-based models.* In H. Geist, Ed. The Earth's Changing Land: An Encyclopedia of Land-Use and Land-Cover Change. Westport CT: Greenwood Publishing Group, pp.7-13.

Carvalho, M. & Luna, L. (2002). *Discrete and Continuous Simulation*. Retrieved from http://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCMQFjAB&url=http%3A%2F%2Fwww.albany.edu%2Fcpr%2Fsdg

roup%2Fpad824%2FDiscrete_and_Continuous_Simulation.ppt on December 29, 2014

Cavazos, J., Moss, J. E. B., & O'Boyle, M. F. P. (2006). *Hybrid Optimizations: Which Optimization Algorithm to Use?* Proceedings of the 15th International Conference on Compiler Construction (CC '06), 124–138. Retrieved from http://link.springer.com/chapter/10.1007/11688839_12 on October 18, 2013

Chen, R. S., & Tu, M. (Arthur). (2009). *Development of an agent-based system for manufacturing control and coordination with ontology and RFID technology*. Expert Systems with Applications, 36(4), 7581–7593. doi:10.1016/j.eswa.2008.09.068

Chinho, L., Wing, S., Christian, N., Chu-Hua, K., & Pei Pei, Y. (2004). *A structural equation model of supply chain quality management and organizational performance*. National Cheng Kung University in Taiwan and Pace University in New York

Chinneck, J. W. (2004). *Chapter 13: Binary and Mixed-Integer Programming*, 1–11.

Chopra, S., & Meindl, P. (2010). *Supply Chain Management - Strategy, Planning, and Operation*. 4th ed. Pearson International Edition

Cruijssen, F., & Salomon, M. (2004). *Empirical Study: Order Sharing Between Transportation Companies may Result in Cost Reductions Between 5 to 15 percent*. CentER Discussion Paper 2004-80; Tilburg University – CentER and Faculty of Economics and Business Administration. Tilburg, Netherlands.

Dai, B. D. B., & Chen, H. C. H. (2009). *Mathematical model and solution approach for collaborative logistics in less than truckload (LTL) transportation*. 2009 International Conference on Computers & Industrial Engineering, 767–772.

D'Amours, S., & Rönnqvist, M. (2008). *Issues in Collaborative Logistics*. Institute for Research in Economics and Business Administration.

Davidsson, P., Henesey, L., Ramsted, L., Tornquist, J., & Wernsted, F. (2005). *An Analysis of Agent-based Approaches to Transport Logistics*. Transportation Research Part C: Emerging Technologies.

Dixson, P. (2011). *Future of Distribution, Logistics, Goods Transportation and Global Trends [video file]*. IBS client event. http://www.youtube.com/watch?v=hlhn5PqBPy4. Accessed: December 23, 2013.

Dresner, K., & Stone, P. (2006*). Learning and Adaption in Multi-Agent Systems*. In: vol. 3898/2006. Lecture Notes in Computer Science. Berlin / Heidelberg: Springer. Chap. Multi Traffic Management: Opportunities for Multiagent Learning, pp. 129-138

Dlouhy, M., Jan, F., & Martina, K. (2005). *Simulace pro economy*. Prague: Vysoka skola ekonomicka. ISBN: 80-245-0973-3.

Erdem, A. S., & Göçen, E. (2012). *Development of a decision support system for supplier evaluation and order allocation.* Expert Systems with Applications, *39*(5), 4927–4937. doi:10.1016/j.eswa.2011.10.024

Exforsys, I. (2007). *Supply Chain Optimization*. Retrieved from http://www.exforsys.com/tutorials/supply-chain/supply-chain-optimization.html on October 13, 2013

Finkenzeller, K. (2003). *RFID handbook: Fundamentals and applications in contactless smart cards and identification*. Wiley.

Frazzon, E. M., Jr, D. P. A., & Andrade, A. De. (2006). An Agent-based Approach for Controlling Global Logistic Processes, 1–9.

Geist, H., Ct, W., & Group, G. P. (2006). Published as: Brown, D.G. 2006. *Agent-based models.* In H. Geist, Ed., 7–13.

Giannakis, M., & Louis, M. (2011). *A multi-agent based framework for supply chain risk management.* Journal of Purchasing and Supply Management, 17(1), 23–31. doi:10.1016/j.pursup.2010.05.001

Hae, Y., Kwan, M., Jin, S., & Bae, Y. (2002). *Supply chain simulation with discrete ± continuous combined modeling*, *43*.

Hallikas, J., Karvonen, I., Pulkkinen, U., Virolainen, V., and Tuominen, M. (2004). *Risk management processes in supplier networks*. International Journal of Production Economics 90 (1), 47-58.

Handfield, R., & Nichols, E. (1999). *Introduction to Supply Chain Management*. Prentice Hall, NJ.

Harry, H. Chow, C. Lee, B. & Lau, C. (2006). *Design of a RFID case-based resource management system for warehouse operations*. Expert Systems with Applications, 30(4), 561–576.

Hernández, S., & Peeta, S. (2010). *Static single carrier collaboration problem for less-than-truckload carriers*. In: Proceedings of the 89th Annual Meeting of the Transportation Research Board, Washington, DC.

Hernández, S., Peeta, S., & Kalafatas, G. (2011). *A less-than-truckload carrier collaboration planning problem under dynamic capacities.* Transportation Research Part E: Logistics and Transportation Review, 47(6), 933–946. doi:10.1016/j.tre.2011.03.001

Identification, R. F. (2004). *RFID How is RFID technology evolving ? What are typical uses for RFID ?*, *6*(4), 4–7.

Ingalls, R. G. & Kasales, S. (1999). *CSSAT: The Compaq Supply Chain Analysis*. Proceedings of the 1999 winter simulation conference pp. 1201-1206, Phoenix, AZ.

Kaur, M., Sandhu, M., Mohan, N., & Sandhu, P. S. (2011). *RFID Technology Principles , Advantages , Limitations & Its Applications*, *3*(1), 151–157.

Kershaw, L. (2009). *90% of SAP users experiencing monthly performance problems*. Retrieved from http://www.computing.co.uk/ctg/news/1841370/90-sap-users-experiencing-monthly-performance on July 01, 2012

Konicki, S. (2001). *E-Logistics Gets The Kinks Out Of Supply Chains*. Retrieved from http://www.informationweek.com/news/6507888 on May 10, 2012

Kovačič, A., & Groznik, A. (2004). *E-logistics: Informatization of Slovenian Transport Logistics Cluster*. No. 158

Krajewska, M. a, Kopfer, H., Laporte, G., Ropke, S., & Zaccour, G. (2007). *Horizontal cooperation among freight carriers: request allocation and profit sharing*. Journal of the Operational Research Society, 59(11), 1483–1491. doi:10.1057/palgrave.jors.2602489

Kwon, O., Im, G., & Lee, K. (2007). *MACE-SCM: A multi-agent and case-based reasoning collaboration mechanism for supply chain management under supply and demand uncertainties*. Expert Systems with Applications 33. 690-705

Larson, D., & Halldorsson, A. (2004*). Logistics Versus Supply Chain Management: An International Survey.* International Journal of Logistics: Research and Applications, Vol 7, No 1.

Lau, J., Huang, G., Mak, H., & Liang, L. (2006). *Agent-based modeling of supply chains for distributed scheduling.* IEEE Transactions on Systems Man and Cybernetics Part a-Systems and Humans.

Laval link. (2004). A journal regarding *RFID technology*. Vol.6 No.4

Lee, Y., Cho, M., Kim, S., & Kim, Y. (2002). *Supply chain simulation with discrete-continuous combined modeling*. Elsevier Science Ltd. Computers and Industrial Engineering 43, 375-392

Leedy, & Ormrod. (2001). *Data Collection Methods*. Retrieved from http://people.uwec.edu/piercech/researchmethods/data%20collection%20methods/data%20collection%20methods.htm on June 09, 2012

Lynch, K. (2001). *Collaborative logistics networks – breaking traditional performance barriers for shippers and carriers*. Eden Prairie, MN 55344.

Mcdowell, G. (2009). *How Does RFID Technology Work?*. Retrieved from http://www.makeuseof.com/tag/technology-explained-how-do-rfid-tags-work/ on December 24, 2013

Mehrizi, H. (2013). *Iterative Combinatorial Auction for Carrier Collaboration in Logistic Services.*

Mei, Q. (2004). *RFID Impact in Supply Chain: Innovation in Demand Planning and Customer Fulfilment.* A Master of Engineering in Logistics Thesis. Massachusetts Institute of Technology, pp. 1-60

Mentzer, J. (2001). *Defining Supply Chain Management.* Journal of Business Logistics, Vol. 22, No. 2, pp. 1–25

Meyer, M., Lorscheid, I., & Troitzsch, K. (2009). *The Development of Social Simulation as Reflected in the First Ten Years of JASSS: a Citation and Co-Citation Analysis.* Retrieved from: Journal of Artificial and Social Simulation 12. URL: http://ideas.repec.org/a/jas/jasssj/2009-47-2.html on September 10, 2013

Motozawa, Y. & Redl, T. (2009). *Analysis of Linear, Integer, and Binary Programming and their Applications* – Senior Project, University of Houston. Retrieved from http://cms.uhd.edu/faculty/redlt/ymseniorproject.pdf on November 12, 2014

Myerson, R. (1991). *Game theory: Analysis of Conflict*. Harvard University Press paperback edition. ISBN 0-674-34116-3

Nagurney, A. (2006). *Supply Chain Network Economics: Dynamics of Prices, Flows, and Profits.* Edward Elgar Publishing: ISBN 1-84542-916-8

Nazari-Shirkouhi, S., Shakouri, H., Javadi, B., & Keramati, A. (2013). *Supplier selection and order allocation problem using a two-phase fuzzy multi-objective linear programming.* Applied Mathematical Modelling, *37*(22), 9308–9323. doi:10.1016/j.apm.2013.04.045

Paradkar, S. S. (2011). *Supply Chain Management - A Practical Solution Approach*, (July), 1–9. Retrieved from http://www.bptrends.com/publicationfiles/07-05-2011-ART-Supply%20Chain%20Management-A%20Practical%20Solution-Paradkar%2005July2011.pdf on October 10, 2013

Pickard, A. (2013). *Research Methods in Information*. 2nd edition. ISBN: 978-1-85604-813-2

Railsback, S., & Grimm, V. (2012). *Agent-Based and Individual-Based Modeling: A Practical Introduction*. Princeton University Press: ISBN 978-0-691-13674-5

Renko, S. (2009). *Vertical Collaboration in the Supply Chain. Faculty of economics and business.* University of Zagreb, Croatia. ISBN: 978-953-307-633-1

RFID Journal. (2002). *Agents Key to RFID Supply Chain*. Retrieved from https://www.rfidjournal.com/purchaseaccess?type=Article&id=175&r=%2Farticles%2Fview%3F175 on December 26, 2013

Rodriguez, I. (2006). *Towards hybrid methods for solving hard combinatorial optimization problems*. A PhD dissertation retrieved from: http://arantxa.ii.uam.es/~idotu/mythesis.pdf on October 18, 2013

Romer, K., Schoch, T., Mattern, F., & Dubendorfer, T. (2003). *Smart identification frameworks for ubiquitous computing applications*. In Proceedings of the IEEE international conference on pervasive computing and communications, pp. 253–262.

Rose, N. (2010). *Why big brand legal services are bad news for solicitors*. Retrieved from http://www.guardian.co.uk/law/2010/nov/02/aa-saga-legal-services-solicitors on May 04, 2012

Russell, S., & Norvig, P. (1995). *Artificial Intelligence: A Modern Approach*. Engle-wood Cliffs, New Jersey: Prentice Hall. ISBN: 0-13-103805-2.

Russo, F., & Carteni. (2005). *Application of a tour-based model to simulate freight distribution in a large urbanized area*. 4th International Conference on City Logisitics. Langkawi, Malaysia.

Salamon, T. (2011). *Design of Agent-Based Models: Developing Computer Simulations for a Better Understanding of Social Processes*. Lightning Source UK Ltd, ISBN 978-80-904661-1-1

Sandberg, E. (2005). *Logistics collaboration in supply chains* – a survey of Swedish manufacturing companies. *Department of Management and Engineering*, (93), 320.

Sanders, N. (2005). *IT Alignment in Supply Chain Relationships: A Study of Supplier Benefits*. Journal of Supply Chain Management: A Global Review of Purchasing & Supply, 41(2): 4-13

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Student*. 5th edition. Pearson Education Limited. ISBN: 978-0-273-71686-0

Schichl, H. (n.d.). *Chapter 2 Models And History Of Modeling*, 25–36. Retrieved from http://www.mat.univie.ac.at/~herman/papers/modtheoc.pdf on September 15, 2013

Schnotz, W. (n.d.). *How to Charge for Delivery Services.* Retrieved from: http://smallbusiness.chron.com/charge-delivery-services-43825.html on December 10, 2014

Simao, H.P. Day, J. George, A.P. Nienow, N. Gifford, T. & Powell, W.B. (2009). *An approximate dynamic programming algorithm for large-scale fleet management: a case application*. Transportation Science 43, no. 2.

Tarabori, J. (2011). *Supplier Collaboration: The Game Changer in Supply Ecosystem*. CGN & Associates

Treytl, A., Pratl, G., & Khan, B. A. (2006). *Agents on RFID Tags – A Chance to Increase Flexibility in Automation*, (Iso 14223).

Tsai, Y. (2006). *Supply Chain Collaborative practices : A supplier perspective*. The department of Marketing, University of Stirling, Scotland, UK, pp. 1–21

Uchiyama, N., & Taniguchi, E. (2010). *A Route Choice Model Based on Evolutionary Game Theory Considering the Travel Time Reliability and Traffic Impediment.* 12th WCTR, – Lisbon, Portugal.

Vornhusen, B., Wang, X., & Kopfer, H. (2014). *Vehicle Routing under Consideration of Transhipment in Horizontal Coalitions of Freight Carriers*. Procedia CIRP, 19(RoMaC), 117–122. doi:10.1016/j.procir.2014.05.008

Wadhwa, S., & Bibhushan, B. (2006). *Supply chain modeling: The agent based approach*. In: Information Control Problems in Manufacturing. Ed. By Alexandre Dolgui, Gerard Morel, & Carlos Pereira. Vol. 12.

Wallenburg, C., Cahill, D., Knemeyer, M., & Goldsby, T. (2011). *Commitment and Trust as Drivers of Loyalty in Logistics Outsourcing Relationships*. Journal of Business Logistics, Vol. 32, No. 1, pp. 83-98

Waner, S. (2010). *Finite mathematics utility: simplex method tool*. Retrieved from http://www.zweigmedia.com/RealWorld/simplex.html on February 27, 2014

Wang, X., Kopfer, H., & Gendreau, M. (2014). *Operational transportation planning of freight forwarding companies in horizontal coalitions*. European Journal of Operational Research, 237(3), 1133–1141. doi:10.1016/j.ejor.2014.02.056

Watson, J. (2008). *STRATEGEY: An Introduction to Game Theory.* 2nd Edition. ISBN: 978-0-393-92934-8. NY, London.

Webster, T.J. (2009). *Introduction to Game Theory in Business and Economics*. ISBN: 978-0-7656-2237-2. Armonk, NY. London, Eng.

Wilensky, U. (1999). *NetLogo*. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Wolff, J. A. (2001). *RFID tags – an intelligent bar code replacement*. IBM corporation, GSOEE200 (06-01) DP, pp. 2-16

Xiaoyong, D. (2010). *Approach to Monitor Traffic Congestion*. Retrieved from http://viajeo.eu/download/meetingsevents/Shanghaiseminar12sep2010/Presentations/deng.pdf on November 22, 2013

Yilmaz, O., & Savasaneril, S. (2012). *Collaboration among small shippers in a transportation market*. European Journal of Operational Research, 218(2), 408–415. doi:10.1016/j.ejor.2011.11.018

Zhang, L., Yadav, P., Akkiraju, R., Chao, T., Flaxer, D., & Jeng, J. (n.d.). *ELPIF : An E-Logistics Processes Integration Framework Based on Web Services.* Retrieved from http://researcher.ibm.com/files/us-bth/zhang.pdf on May 10, 2012

Zhou, G., Hui, Y., & Liang, L. (2011). *Strategic Alliance in Freight Consolidation*. Transportation Research Part E: Logistics and Transportation Review (Elsevier) 47, no. 1: 18-29.