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Abstract

This research in progress aims at investigating the role that information system (IS) and information quality (IQ) can play for the transformation of a Supply Chain. A case study was conducted to identify the supply chain evolution of a major French retailer that initiated consolidation centres for shared deliveries between several small suppliers to its warehouses. This initiative aims at developing just-in-time delivery for economic benefits and the retailer explains that this evolution meets environmental benefits through CO_2 reduction. However, the promised benefits for suppliers depend upon the development of information sharing and information quality and they have the choice to adopt the "green supply chain" or to continue delivering directly without using the consolidation centers. Therefore this paper presents the simulation of the research that is currently being performed in order to identify the necessary conditions for the benefits realization. For future research, we propose a multi-agent based modelling for understanding how IS and IQ are pushing towards the adoption of a green supply chain.

Keywords: Simulation, CO_2 reduction, green initiatives, information quality, supply chain management

1 Introduction

The reason as to why organizations should share information across the supply chain (SC) is no longer a big question mark. Researchers and practitioners are in agreement that sharing information about product, demand, and supply will significantly improve the overall economic performance of the SC (Lee et al., 1997; Rai et al., 2006). The focus for researchers should now be on how and what information is shared. We are particularly interested in where the focal corporation initiates a SC transformation and involves the transitioning of both information and product flows. Delone and McLean (2003) indicate that information system quality and information quality are antecedents to IS success. The model proposed by Delone and McLean (2003) states that information quality that is "personalized, complete, relevant, easy to understand, and secure" and system quality which are characteristics such as "usability, availability, reliability, adaptability, and response time" (Delone and McLean, 2003) are of value to the user and drive the users intention to user the system, which in turn allows them to use the system and ultimately ends with "net benefits" being realized by the stakeholders of the system. We can assume those are also necessary conditions for Green Supply Chain (GSC) success, which we define as the large adoption of a GSC model.

Some firms also integrate environmental considerations in order to gain goodwill or by a function of societal pressure (Wang et al., 2011). Following Sarkis, Zhu, and Lai (2011), we define Green Supply Chain Management (GSCM) as incorporating environmental concerns into the practices of Supply Chain Management (SCM). In the past, alleviating environmental concerns and gaining economic benefit were considered antinomies by many companies and thus addressing green issues was considered to be a luxury item for corporations (Corbett and Klassen, 2006). In today's business environment, corporations are under both economic pressure from stakeholder (Hall, 2001), and environmental pressure from growing governmental regulations (Delmas and Montes-Sancho, 2011). In order to meet these demands some corporations are taking SCM evolution to realize GSCM (Corbett and Klassen, 2006; Melville, 2010). The SC is evolving to include process considerations to minimize environmental impact (greenhouse gases, pollution, and waste).

The objective of this research stream is to investigate to what extent the information quality level impacts the cost – and environmental – effectiveness of SCs. The current paper uses simulation to evaluate these impacts in order to determine under which conditions suppliers will move from a traditional SC to a GSC.

2 IS, IQ, and SC restructuration

We utilize the definition of a 'Supply Chain' to be *"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer"* (Mentzer et al., 2001). The number of actors in the SC and the degree of complexity of the SC can present different levels of analysis. We concentrate on three different levels of actors; ABC (major retailer), the logistics service provider (LSP), and the many suppliers.

2.1 IS and IQ in SC

In SCM, tight integration between corporations enables the overall SC economic benefit (Simatupang and Sridharan, 2002). One aspect that is key to this success is information sharing since inefficiencies in the SC are linked to information distortion or asymmetry (Lee et al., 1997; Wang and Wei, 2007). Information can be seen as the enabler to reducing cost and improving SC efficiency and information can be used as a tool to allow the coordination of interorganizational activities (Tan, 2001). How information is shared is an important research activity and understanding how the IS supports information sharing and the improved efficiency of the SC is an important research endeavour. Both

data consistency and cross-functional SCM application integration are important elements for information technology (IT) infrastructure integration (Rai et al., 2006). In particular, *"data consistency is relatively more important, in comparison to cross-functional application integration, suggesting the high degree of importance of data quality and standards as facilitators of process integration"* (id.). Moreover, in SC networks IQ is a predictor and enabler of firm performance (Ramayah and Omar, 2010). However, we feel that the SCM literature has not paid enough attention to IQ. In particular we found a lack of past studies in the role of IQ in the transition of a traditional SC to a GSC.

2.2   The Context of the Modelling: Consolidation centres in SC

Our analysis started focusing on the context of the current SC with ABC, a major French retailer, who initiated a SC restructuration. The reasoning for this restructuration was to own less stock, alleviating some overhead in the maintenance of stock, and improving product availability at the point of sales (POS). ABC initiated the use of consolidation centres (CC), which are large warehouse facilities. In addition to the CCs, ABC currently operates 21 regional warehouse locations around France. ABC encouraged the 'small' suppliers to adopt the CC concept. The CCs are operated by a logistics service provider (LSP) between the suppliers and the logistics platforms of ABC, whose purpose is to evolve towards a just-in-time (JIT) delivery system, reducing stocks in the warehouses, while keeping the same level of shelves stocked in the POS.

With the CCs the goal is to have more frequent flow from the CC to the warehouse and POS facilities of smaller counts of supplier products. Suppliers are thus encouraged to 1. Deliver a full truck to the CC; 2. Store an average of three weeks worth of stock in the CC; 3. Allow the LSP to deliver full trucks sharing multiple products from the CC to the POS more frequently. The supplier can reject ABCs proposal and continue to be responsible for shipping and handling to a handful of the 21 warehouse locations. The SC transformation is noted as being GSCM due to the more frequent use of full trucks rather than partially empty trucks. Our goal is to verify the green benefits and identify the IQ level to achieve the economic and green benefits.

3   Methodology

For this research, we adopted a simulation based on a case study described in the context above (de Corbière et al., 2011). First we conducted a case study in the form of interviews in order to collect data on SC evolution, IS characteristics, and IQ considerations. The second stage involved taking the SCM layout and operations and simulating the new GSC, and how much impact the IQ has on the economic and environmental benefits. A simulation based on a case study allowed us both to experiment, through different scenarios, how a selection of key parameters impact the dynamics of a supply chain transformation, and to analyze the results, based on an in depth understanding of studied phenomenon.

3.1   A case study of ABC SC evolution

We synthesize in this sub-section the results of the case study of ABC we performed in 2011 (de Corbière et al., 2011). The eight interviews involved management members from all major players in the SC. There were four main areas in which we structured the interviews. First, we identified the current information sharing operations in the SC. This allowed us to identify what the firm considers is key in the transition of the SC processes to a GSC. Second, we noted the characteristics and relevant information in the IS. Third we focused on the IQ. In particular we queried for dysfunctions in the current SCM system, which allowed us to identify problems associated with poor IQ. The final part looked at the shared experiences between differing organizations from an economic and environmental point of view. Analysis of the interviews revealed a specific process of information and product flows to recreate the SC in the simulation. The information identified in the interview process is listed and addressed by the simulation in the next section (table 1).

3.2 Transformation of the flow of goods and associated IS

ABC's ambition is to have all of its small suppliers to buy into the resource-sharing scheme. A survey performed by Efficient Consumer Response (ECR) France shows that half of deliveries are done with fewer than 5 pallets. This means that there are many partially empty trucks being used in deliveries and the SC is far from being optimized. The new GSC with shared-resources should allow more full trucks to be used and be a green improvement over the current SC. ABC restructured the SC by offering the new CCs to the suppliers. For the supplier, number of points of delivery is reduced from a possible maximum of twenty-one warehouses to two CCs, one each in the north and south region of France. Currently 400 suppliers have adopted the CC method while 1100 have stayed with the old method.

The CC is not the property of ABC rather a third party logistics operator (3PL) owns the CC facility and runs the logistics in the facility. 3PL signs contracts with the suppliers that choose to use the CC system for stocking and maintaining products in the CC. Once the palette is leaving the CC, the logistics of the product is no longer the responsibility of the supplier and ABC charges 18 Euros per palette to be delivered from the CC to the warehouse. ABC implemented a Full-EDI web portal created by Generix to manage information exchange between the suppliers that choose to use the CC and 3PL. Purchase orders from ABC are sent to the supplier and copied to 3PL so that 3PL can implement the JIT delivery of the product.

Suppliers have the option to use "full-EDI" where orders are automatically validated and 3PL can prepare products stocked in the CC for delivery. When a supplier is just "Web-EDI", an employee from the supplier has to connect to the Web portal and validate each purchase order. With Web-EDI, once volume of orders goes beyond a certain amount, the supplier does not have enough time to validate all the orders and IQ problems increase. In fact, a high volume of staff makes it advantageous even for the supplier to go with full-EDI.

Stock levels are managed by 3PL in the CC and this information is accessible to the supplier in real-time through the IS platform, in both Full and Web-EDI. The supplier can anticipate and manage the stock level of the CC with delivery of full trucks: when accuracy, timeliness, and accessibility of stock levels in the CC are high, the supplier operates in a less uncertain environment. Therefore the suppliers "can optimize (their) CC delivery" and move towards GSCM with full trucks from the supplier to the CC. When IQ is not sufficient, orders can be refused due to delivery of non-ordered goods and JIT suffers causing the delivery of the product from the CC to ABC's warehouses to be inefficient.

3.3 Simulation development

The simulation took the case study results and modelled the current SC and the GSC. Currently the simulation is in the development process. The simulation was programmed using the NetLogo platform (http://ccl.northwestern.edu/netlogo/). The development of the simulation has been realized in three steps, flow of goods, IS integration, and agent-base. These are summarized in table 1.

First the flow of goods was identified. We are comparing two possible ways of delivering goods to the warehouses of ABC. The first one is directly from each supplier to each WH. The second one is from the supplier to each CC, then from CC to all WHs. In both cases, what is included in our simulation is the number of kilometres from the supplier to the WH, whether or not they go through the CC. This required the exact location of suppliers, warehouses, and the CCs. The two CCs and 21 warehouses were given exact coordinates. Initially there are only thirty suppliers placed on the geographic grid. The final number of suppliers will be more than 1500. The cost of shipping a palette from each supplier to the warehouse is 0.2 Euros per km and the CO_2 emissions are 30g/km. The cost of shipping a palette from the CC to the warehouse is of 18 euro per palette which is incurred by the supplier (charged by ABC to the supplier for use of CC). CO_2 emissions per palette are of 10g/km to factor in the fact that fuller trucks imply lower emissions per palette. Emission data were taken from an emission factors reference guide developed by the French Environment and Energy Management

Agency (ADEME, 2007). All costs and CO_2 emissions are calculated in terms of one cycle, aggregated over the whole SC network. We elaborate below on the delivery assumptions implied by these CO_2 emission factors. To start the simulation assumes that the fleet consists of only one type of vehicle, a full truck which carries 33 palettes when fully loaded in one level, products shipped are assumed to be non-perishable and of the same weight. Based on the case study, when delivery takes place through the CC, trucks are assumed to be fully loaded. When delivery takes place directly to the WH, trucks are assumed to be only a third loaded. These assumptions are made so that the simulation can be developed with a basic case of delivery mode. Differing vehicle types and products will be expanded in subsequent simulation iterations once agent-based decision-making is incorporated into the simulation.

SC Aspect	Step	How addressed	Status in simulation
Supplier locations	1	Located on simulation grid	Partially done (only 30 locations so far)
Warehouse locations	1	Located on simulation grid	Done
CC location	1	Located on simulation grid	Done
Types of retailer outlets	1	Attribute of outlet location	Pending
Mode of transportation	1	Attribute of transport	Pending
Type of delivery method	1	Attribute of transport	Pending
Mode of delivery (such as refrigerated or not)	1	Attribute of transport	Pending
Frequency of delivery	1	Simulation step is one delivery cycle	Partially done (currently set to one a day)
Delivery distances	1	Calculated by straight line of Cartesian coordinates	Currently assumes a straight line for distance
Delivery fleet	1	Types of transports	Pending
CO2 emission of fleet	1	Attribute of transport	Partially done
Cost of fleet operation	1	Attribute of transport	Partially done
Type of information shared	2	Security level of information	Pending
Methods of information system integration	2	Full EDI or Web EDI	Partially done with FullEDIPercent (Allows user input of adoption of Full EDI as percent)
Information quality failure	2	Simulation of error during order process using WebEDI	Partially done with IQFactor (Allows user to enter success rate as a percentage)
Delivery requirement of warehouse	3	Whether warehouse requires a delivery of not	Partially done with WarehouseDeliveryRate (Allows user to input a warehouse delivery percentage)
Cognitive decision making by agents	3	Agent-based recognition	Partially done with AcceptanceBySupplier (Allows user input of adoption percentage)

Table 1.   Current status of Agent-based simulation: SC Aspect is the SC item identified in the interview process.

The second step involved the type of IS and IQ. There were two types of IS identified in the case study, Web-EDI and Full-EDI. With Web-EDI manual confirmation of ordering was required, while Full-EDI incorporated an automated process, virtually eliminating human error during the ordering process. The simulation allows the user to specify the amount of adoption of the Web-EDI or Full-EDI by the suppliers by specifying the FullEDIPercent variable. FullEDIPercent is the percentage of adoption with 100 being full adoption of FullEDI and 0 being adoption of Web-EDI by all suppliers. While Full-EDI seems attractive there is a substantial start up cost to transfer from Web-EDI to Full-EDI. Based on the case study, we found that the typical adoption rate of Full-EDI was around 20%. Due to the lack of human error in the Full-EDI environment IQ factors into the supplier that uses the Web-EDI implementation. The simulation also allows the user to input the amount of IQ failure, IQFactor, as a percentage of orders that fail. When IQFactor is set to 100 there are no errors and when it is set to 80, 20% of orders fail due to insufficient IQ. When there is a failure the simulation assumes

that the order must be fulfilled with a second delivery, thus the economic impact is double the cost and the environmental impact is double the CO_2 emissions.

Step three consists of decisions made by the suppliers. These are currently programmed as static percentages that the user defines when running the simulation. First the supplier's acceptance of the CC model is programmed using the user defined AcceptanceBySupplier. When the variable AcceptanceBySupplier is set to 100, this means that all suppliers go with the new CC methodology. WarehouseDeliveryRate is used to determine whether delivery is required to a particular warehouse when using the old SC method. The user can define the variable WarehouseDeliveryRate, and when the WarehouseDeliveryRate is set to 100, this means all warehouses will require delivery.

4   First results and future developments

In summary, there are four user defined variables in the current simulation, FullEDIPercent (EDI), IQFactor (IQ), WarehouseDeliveryRate (WH), and AcceptanceBySupplier (AR). We ran different scenarios assuming the following values for these user defined variables as expressed in table 2. A base scenario of most likely scenario was identified. Other scenarios were developed, using variations on this base scenario, using extreme variations for each variable, one variable at a time, so as to test their influence on costs and CO_2 emissions. For the WH the extreme low scenario is 5% corresponding to one WH requiring delivery.

Name of Scenario	AcceptanceBySupplier	WhareHouseDeliveryRate	IQFactor	FullEDIPercent
BASE	25%	50%	90%	20%
AR0	0%	50%	90%	20%
AR100	100%	50%	90%	20%
WH0	25%	5%	90%	20%
WH100	25%	100%	90%	20%
IQ0	25%	50%	0%	20%
IQ100	25%	50%	100%	20%
EDI50	25%	50%	90%	0%
EDI100	25%	50%	90%	100%
All50	50%	50%	50%	50%

Table 2: list of scenarios used in the simulation

The simulation was run with 500 cycles and for each iteration of the simulation run, data was retrieved and sorted in ascending order. Totals for Cost and CO_2 were graphed to show differences in the levels dependent on the scenarios in table 2. Figure 2 shows the output with all scenarios represented at the top and select scenarios represented at the bottom to be able to see finer graphs that are clustered together. The cost graph is on the left side and the CO_2 on the right side.

When the suppliers rejected the use of CCs there was more variability than the total acceptance scenario due to the variability introduced by the EDI choice, IQ problem variation, and warehouse delivery subset. Finally the most variability was seen when the CC acceptance was half. We saw cost run from 20,320 Euros to 31,290 Euros. The CO_2 emissions numbers ran from 6086 kg to 16,821 kg.

We notice that both cost and CO_2 are dependent on how many warehouses require delivery. Cost and CO_2 dependency on the number of warehouses requiring delivery is a fairly obvious observation that we were expecting. For costs the IQ has the second most impact, and Full EDI was third. For CO_2, Acceptance rate of the CC had the second most impact. IQ and Full EDI factors were not seen to make much difference in the CO_2 emissions.

While whether delivering to a warehouse is out of the hands of the SC players, the suppliers do have control over whether they go with Full EDI and reduce IQ factor and whether they use the CC methodology. From our preliminary results we see that going with Full EDI would save on costs, while going with the CC methodology save on CO_2 emissions the most. So depending on what the

supplier wants to do, whether they want to save costs or CO_2, they should choose to go with Full EDI or the CC method respectively to make the most impact.
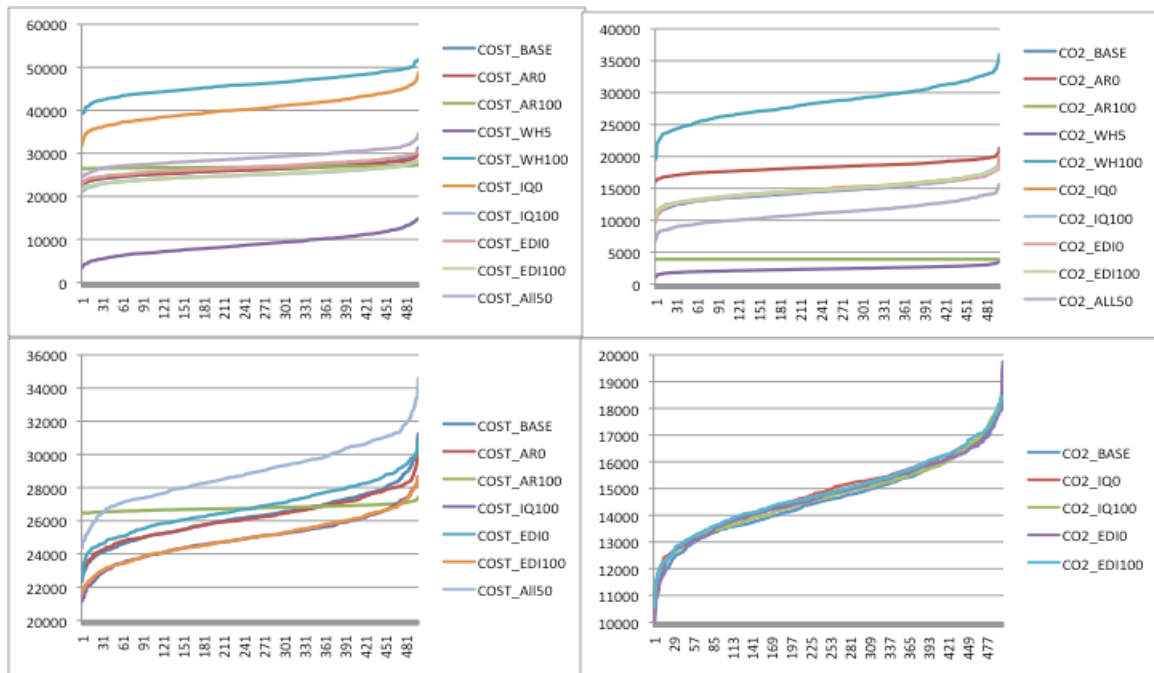

Figure 2.   *Cost (left side) in Euros, and CO_2 emissions (right side) in kg. Complete set of scenarios (Top), and selected set to further zoom (Bottom).*

One interesting observation was that going with the CC did not necessarily reduce the cost. Total acceptance of the CC method (AR100) did make the cost line flatter, which means that the cost became more stable with the CC method. The AR100 curve and the AR0 curve intersect each other, which means the CC method does not necessarily save on cost over the old SC method.

In conclusion, we can say that the SC restructuration by introducing CC is interesting since it provides an evolution into GSCM. We found that going with Full EDI is the better choice by the supplier for economic savings, while using the CCs had more impact on the CO_2 emissions. However, the research in progress needs further steps to better understand the influence of the variables on CO_2 emission and costs. By the introduction of agent-based autonomous decisions from suppliers, we will go further in the development of the third step.

A Multi-Agents System (MAS) will be selected in this research for two main reasons. First, this simulation method allows us to deal with cognitive and heterogeneous agents, and the agents are able to make decisions based on information garnered from results of their previous actions. The other simulation methods (i.e. system dynamics, genetic algorithm, or cellular automata) do not provide this advantage (Davis and al., 2007; Rivkin and Siggelkow, 2003). Second, MAS deals well with issues of emergence and change; it is well adapted to explore the evolution of a complex social system such as a supply chain restructuration. We feel that by using MAS we are able to measure the impact of IS and IQ on the transformation of a SC to a GSC.

Future implementations of the third step will define agents' characteristics and to integrate decision-making processes in the model. A feedback loop will be integrated based on the cost of IS solution – Full-EDI or Web-EDI – and of CC or warehouse delivery. The "supplier" agents will be able to change their choice according to the cost from the previous period of simulation (100 cycles) and its comparison with the average cost of the supplier group (small, medium or big suppliers). A superior cost will induce a probability of 5% that they change their IS solution or their delivery method.

The current initial study identified key aspects of the GSCM that suppliers had the choice in operation, such as the choice of going to full EDI and using the CC methodology and how these choices affected the CO_2 emissions and costs. In the next version of the simulation we feel that the addition of logic for the agents to make decisions based on evaluation of past costs and CO2 emissions will help us shed light on the relation of IQ and IS on the transformation of a traditional SC to a GSC. This additional development will allow us to have a better assessment of the dynamics and the individual behaviours of suppliers in the supply chain system.

References

ADEME, Mission Interministérielle de l'Effet de Serre (2007), Bilan Carbone Entreprises et Collectivités, Guide des Facteurs d'Emission, Version 5.0., 240 p.

Corbett, C.J. and Klassen, R.D. (2006). Extending the Horizons: Environmental Excellence as Key to Improving Operations. Manufacturing & Service Operations Management, 8(1), 5-22.

Davis, J., Eisenhardt, K. and Bingham, C. (2007). Developing theory through simulation methods. Academy of Management Review, 32(2), 480-499.

de Corbière, F., Habib, J., Le Dû, A., Rowe, F. and Takeda, H. (2011) "Information quality for the transformation into green supply chain: a case in the retail industry", SIG IQ Conference, Pre-ICIS, Shanghai, China, December, 2011.

Delmas, M. and Montes-Sancho, M. (2011). An Institutional Perspective on the Diffusion of International Management System Standards: The Case of the Environmental Management Standard Iso 14001. Business Ethics Quarterly, 21(1), 103-132.

DeLone, W.H. and McLean, E.R. (2003). The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. Journal of Management Information Systems, 19(4), 9-30.

Hall, J. (2001). Environmental Supply Chain Innovation. Greener Management International, 35, 105-119.

Lee, H.L., Padmanabhan, V. and Whang, S. (1997). Information Distorsion in a Supply Chain: The Bullwhip Effect. Management Science, 43(4), 546-558.

Melville, N.P. (2010). Information Systems Innovation for Environmental Sustainability. MIS Quarterly, 34(1), 1-21.

Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.W., Smith, C.D. and Zacharia, Z.G. (2001). Defining Supply Chain Management. Journal of Business Logistics, 22(2), 1-25.

Rai, A., Patnayakuni, R. and Seth, N. (2006). Firm Performance Impacts of Digitally Enabled Supply Chain Integration Capabilities. MIS Quarterly, 30(2), 225-246.

Ramayah, T. and Omar, R. (2010). Information Exchange and Supply Chain Performance. International Journal of Information Technology & Decision Making, 9(1), 35-52.

Rivkin, J. W. and Siggelkow, N., (2003). Balancing Search and Stability: Interdependencies among Elements of Organizational Design. Management Science, 49, 290–311

Sarkis, J., Zhu, Q. and Lai, K.-H. (2011). An Organizational Theoretic Review of Green Supply Chain Management Literature. International Journal of Production Economics, 130(1), 1-15.

Simatupang, T. and Sridharan, R. (2002). The Collaborative Supply Chain: A Scheme for Information Sharing and Incentive Alignment. International Journal of Logistics Management, 13(1), 15-30

Tan, K.C. (2001). A Framework of Supply Chain Management Literature. European Journal of Purchasing & Supply Management, 7(1), 39-48.

Wang, E. and Wei, H. (2007). Interorganizational Governance Value Creation: Coordinating for Information Visibity and Flexibility in Supply Chains. Decision Science, 38(4), 647-674.

Wang, F., Lai, X. and Shi, N. (2011). A Multi-Objective Optimization for Green Supply Chain Network Design. Decision Support Systems, 51(2), 262-269.