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AN ANALYTICAL MODELLING APPROACH TO ASSESS THE APPLICABILITY OF GREEN CHAIN OPERATIONS: A CASE STUDY FROM THE SRI LANKAN APPAREL INDUSTRY

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Abstract: Adopting 'green' practices have become synonymous with achieving long-term sustainability and many companies attempt to add value by adding "green" practices to their supply chains. However, manufacturers and suppliers are often hesitant to adopt green supply chain practices owing to the fear of incurring huge initial investments. To address the above issues, companies need a performance measurement framework to evaluate the applicability of Green Supply Chain Management (GSCM) practices in their industry. The Sri Lankan apparel industry is on the verge of embracing the GSCM practices into their supply chain processes. The objective of this study is to provide a framework to evaluate the applicability of GSCM practices in the Sri Lankan apparel industry from the operations management standpoint. Applicability is measured using performance measurement tools such as Balanced Scorecard (BSC) and Analytical Hierarchical Process (AHP) analysis. The proposed framework maps the key performance indicators hand-in-hand balancing economic performance and GSCM practices. Data collection was carried out from leading apparel manufacturers in Sri Lanka and the outcomes of this research helps determine the applicability of GSCM practices for Sri Lanka to yield economical, sustainable, and environmental benefits.

Keywords: Analytical Hierarchical Process, Apparel Industry, Balanced Scorecard, Green Supply Chain Management

Introduction

Sri Lankan apparel industry is one of the significant and dynamic contributors for the Sri Lankan economy, with a large contribution to the employment as well as foreign exchange earning within the country. The apparel industry is the second biggest contributor in Sri Lankan factory industry, behind the food and beverage production in the Factory Industry Production Index for 2015 (Central Bank of Sri Lanka, 2016). The supply chain of Sri Lankan apparel manufacturing process begins with the raw material, which is mostly supplied by foreign countries in order to maintain the quality of the product. Each apparel manufacturing organization comprises of multiple functional domains such as manufacturing, planning, and marketing. Sri Lankan apparel industry mostly behaves as a unit of a larger supply chain. (Perry et.al., 2012)

Operations for apparel production involves assembly, cut, make, and trim processes. Most apparel manufacturers cut and sew woven or knitted fabric, or knit apparel directly from yarn. Certain manufacturers perform cutting or sewing operations on material owned by another entity. Most apparel manufacturers have utilized lean manufacturing and modular systems for manufacturing operations. The manufacturers can decide on outsourcing the textiles from another establishment, or make the textile components in – house. All companies which have apparel manufacturing plants are intending to improve the efficiency to reduce the production lead

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time. intended to going under higher efficiency its help to reduce production lead time.

Green supply chain management means adding “green” component to the company supply chain. (Lakshmi Meera et.al., 2013). There are three large – scale Sri Lankan apparel manufactures which have introduced the green concept to their supply chains. However, the adoption of green practises in the above cases has been limited to wastage reduction (De Silva and Rupasinghe, 2016). Integrating green design or green manufacturing is still at an introductory level. The major reason behind this slow adoption of green practises in design and manufacturing was balancing supply chain at a low cost and being innovative to substantiate both environmental and economic sustainability which became a major challenge (Pagell, 2004, Liyanage and Rupasinghe, 2016). Environmental practises in Supply Chain Management (SCM) pose inherent complexity during adoption due to multiple stakeholders, uncertain implications and international presence, and have been a challenging field for researchers. GSCM research so far can be considered ad hoc, fragmented and partial (Lakshmimeera et.al., 2013).

Sri Lankan apparel manufacturers face the after-effects of transferring GSCM into their process. The cost of implementing GSCM practises is considerably high, and can rise further in the future if they are not properly managed. Furthermore, these practises involve a degree of uncertainty regarding market position, stakeholder concerns, and change. However, GSCM can reduce the ecological impact of industrial activity without sacrificing quality, cost, reliability, performance or energy utilization efficiency (Cooray and Rupasinghe, 2016). However the companies should identify the level of applicablity of green practises in Sri Lankan context, in order to achieve the aforementioned. If company shareholders see the benefits of applying GSCM to company processes, they will accept the changes. The companies currently utilizing GSCM will have a better opportunity to extend their applications. As such, the aim of this research is to find out the applicability of GSCM practises and how they can be used to improve company performance in apparel industry in Sri Lanka.

The research consists of following objectives;

- Study the current GSCM process and practises in Sri Lankan apparel manufacturing industry
- Identify current status of GSCM practises of Sri Lankan apparel industry as opposed to that of global apparel industry,
- Analyse the applicability of GSCM practises within Sri Lankan context,
- Identify the main GSCM practises that should be managed to obtain the necessary organizational performance that will affect the supply chain key performance indicators (KPIs),
- Find the extent to which the green practises can applied to supply chain in order to add value to the company
- Development of a framework with steps of applicable GSCM practises in Sri Lankan context which help non – green manufacturers to adopt GSCM.

The expected outcomes of the research are,

- Identification of GSCM practises in apparel manufacturing operations applicable as well as not applicable in Sri Lankan context,
- New GSCM practises which can be applied in Sri Lankan context and already used in other countries,
- A set of guidelines for non-green apparel manufacturers, as well as partially complete apparel manufacturers, to transform their supply chain into a GSC.

Literature Review

GSCM is defined as ‘integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life’ (Srivastva, 2007). It can also be defined as ‘the integration of both environmental and supply chain managements and has been identified as a proven way to reduce an organization's impact on the environment while improving business performance’ (Torielli *et al.*, 2011).

Green manufacturing and remanufacturing is a very important area within green operation. In 2008, Carvalho defined green operational practises such as reduction of redundant and unnecessary materials, reduction of replenishment frequency, integration of the reverse material and information flow in the supply chain environmental risk sharing, waste minimization, reduction of transportation lead time, and efficiency of resource consumption (Carvalho and Cruz-Machado, 2008). Furthermore, green operational practises can also be defined as product design to use reduced material/energy, with ability to reuse/recycle/recover, which ensures no/less hazardous material/process, and supports environmental regulations (Lakshmimeera et.al., 2013).

The aforementioned definitions of GSCM imply that simply 'being green' will not be adequate for modern organizations. Bowenet et. al., (2001) stated that organizations will adopt GSCM practises if they identify that such an adoption will result in specific financial and operational benefits. The 'greening' of supply chain is also influenced by the following processes' characteristics process capability to use certain materials, possibility to integrate reusable or remanufactured components into the system (which would require disassembly capacities), and design for waste minimization (energy, water, raw materials, and non-product output) (Sarkis, 2003).

Beamon (1999) identified present performance measures appropriate for the Green supply chain. These measurements are identified using International Organization for Standardization (ISO) adopted ISO 14000 Series as its international specification standard for environmental management system. The ISO 14000 Series documentation comprises of five basic components, and is structured as shown in Table 1 below;

Table 1: The ISO 14000 Series (source: International Organization for Standardization, 1996)

ISO family	Requirement
ISO 14001	Specifies minimum requirements for achieving ISO 14000 Certification
ISO 14004	Sets guidelines for developing an environmental auditing
ISO 14010	Establishes the general principles of environmental auditing
ISO 14011	Establishes auditing procedures for the auditing of Enterprise Management systems
ISO 14012	Establishes qualification criteria for environmental auditors

Corporate performance measurement and its applications continue to grow and encompass both quantitative and qualitative measurements and approaches. The variety and level of performance measures largely depend on the goal of the organization or the characteristics of individual strategic business unit. This paper has defined a list of measures and metrics which are applicable for performance measuring. Furthermore, it identifies a set of existing measurement tools for GSCM/Performance Measurement System (PMS) (Table 2).

Table 2: Comparison between GSCM performance measurement tools (*source*: *Hervani et al., 2005*)

GSCM/PMS tools	Reference	Applicability of function in concern
Life cycle analysis type tools (Faruk *et al*. 2002)	Venkatasubbaiah *et al*., 2014	Maps graphically represent the values of the environmental impacts along the supply chain. The tool can evaluate various products for comparison.
Balanced Scorecard (Kaplan and Norton , 1992, 2004)	Chen *et al*. 2008, Jalali Naini*et al*, 2011, Bhattacharya, 2013	Feedback on internal business processes and external outcomes in order tocontinuously improve strategic performance and results. Fulfils the requirement of ISO 14031, to focus on management of the organization by objectives, to use as an information system, to visualize the cause and effect relationships between different measures. BSC does not separate cause and effect over time: The time dimension is not part of the BSC (Lee *et al*., 2008, Cebeci, 2009) BSC does not provide mechanisms for selecting best measures of performance (Cebeci, 2009, Leung *et al*., 2006)
Analytical hierarchy process (Saaty 1980)	Handfield *et al*.,2002, Pineda-Henson *et al*., 2002, Sarkis., 1998, 2003	Decision support model the extension of analytical hierarchy process beyond dyadic organizational boundaries to further supply chain evaluation has not been completed.
Data envelopment analysis tool (Charnes et al.,1978)	Sarkis and Talluri, 2004	A robust quantitatively focused benchmarking and performance measurement tool Inclusion and evaluation of environmental characteristics has yet to be completed.
Analytic network process (ANP) (Saaty, 1996)	Bhattacharya, 2013	A multi-criteria decision-making tool. Strategic level decision making Focus inner dependence, and among different sets of elements, outer dependence
Game Theory	Zhu and Dou, 2007, Chen and Sheh, 2009	Strategic level decision making
Fuzzy theory	Bhattacharya, 2013	Fuzzy sets are able to resemble human decisions. Fuzzy triangular numbers transform the qualitative linguistic preferences into quantitative forms.

Extensions to the balanced scorecard to incorporate environmental performance measures have also been significantly advanced (Epstein and Wisner, 2001, Zingales *et al*., 2002) (Figure 1). In the conclusion, US Environmental Protection Agency identified the balanced scorecard approach as their methodology for deploying strategic direction, communicating expectations, and measuring progress towards agreed-to objectives (Kanji, 2003).

Financial

- Percentage of proactive vs. reactive expenditures
- Capital investments
- Operating expenditures
- Disposal costs
- Recycling revenues
- Revenues from "green" products
- Fines and penalties
- Cost avoidance from environmental actions

Customer

- Number of green products
- Product safety
- Number of recalls
- Customer returns
- Unfavourable press coverage
- Percentage of products reclaimed after use - functional product eco-efficiency

Internal process

- Percentage of production and office materials
- certified suppliers
- Number of accidents and spills
- Internal audit scores
- Energy consumption
- Percentage of facilities certified
- Percentage of product remanufactured
- Energy use
- Greenhouse gas emissions
- Hazardous material output

Learning and growth

- Percentage of employees trained
- Percentage of renewable resource use
- Number of
  - Community complaints Violations reported by employees
  - Employees with incentives related to
  - environmental goals
  - Functions with environmental responsibilities
- Emergency response programs

Figure 1: Environmentally based performance measures by the balanced scorecard categories (*source*: *Epstein and Wisner, 2001*)

Balanced scorecard can be integrated with other performance tools to evaluate the performance;

Table 3: Integration of Balanced Scorecard with other tools for performance evaluation

Tool	Reference
Fuzzy Analytic Hierarchy Process (AHP)	Lee, Chen, and Chang, 2008
Data envelopment analysis	Yuan and Chiu, 2009
Case based reasoning	Yuan and Chiu, 2009
Quality function deployment	Cohen, 2011
Multi – attribute utility theory	Steward and Mohamed, 2001
Analytic Network Process (ANP)	Ravi, Shankar, and Tiwari, 2005
Fuzzy ANP	Tseng, 2010, Yüksel and Dağdeviren, 2010
Fuzzy Delphi method and ANP	Hsu et al. 2011
Game theory	Jalali Naini *et al*., 2011

Fuzzy (AHP) with BSC approach framework provides a mechanism for calculating the relative weights for each performance measure (Wu*et al.*, 2009). While AHP is used to structure the hierarchy and relative weightings of performance perspectives, and indicators and measures (Stwart and Mohamed,

2001, Lee, Chen, and Chang, 2008) within the BSC framework, it does not consider the interdependencies, using a network, of the causal relationship meant for Green BSC (GrBSC). ANP considers the interdependencies among criteria, sub-criteria and determinants. BSC can be successfully used for managing environmental aspects of performance (Länsiluoto and Järvenpää, 2010, Wynder, 2010). ANP is a qualitative multi-attribute decision-making approach providing structured communication to address m-business problems.

Chandraker and Kumar (2013) analyse the effects of individual activities (GSCM practises) and t corresponding contribution towards economical and environment performance. In this paper MCDM (Multi Criteria decision making) model is used to determine GSCM performance, with the help of the parameters related to GSCM performance. AHP method is applied to determine the weight of all parameters.

Bhattacharya (2013) developed a collaborative decision-making approach. This paper demonstrates how a green-balanced scorecard (GrBSC) method is developed and implemented for a UK based carpet-manufacturing company in order to measure SC performance within a CDM (collaborative decision-making) environment.

Carter and Rogers (2008) and Carter and Easton (2011) describe the broad view of sustainability incorporating the concepts of economic, social, and environmental performance. It is important to know whether there is an economic advantage in adopting GSCM.

Rao *et al*., (2005) developed a model to figure out whether GSC really benefits the organization in an economic perspective. Samples were taken by ISO14001 certified companies in South East Asia. This research investigated the relationship between GSCM practises (inbound logistics, production or the internal supply chain, outbound logistics, and in some cases, reverse logistics, including and involving materials suppliers, service contractors, vendors, distributors and end users working together to reduce or eliminate adverse environmental impacts of their activities), competitiveness (improved efficiency, quality improvement, productivity improvement, and cost savings), and economic performance (new market opportunities; product price increase; profit margin; sales; and market share).

Lakshmi Meera and Palanisamy (2014) proposed a model to evaluate whether there is a positive relationship between GSCM practises and environmental performance in manufacturing industry in Tamil Nadu, India.

Method and Materials

The research is based on two approaches. First focuses on the basic research. In the basic research the GSCM practises currently used in apparel manufacturing supply chain operations in Sri Lanka are analysed. This provides an answer to the fundamental question about what GSCM practises they are practicing and their feasibility. In the second phase of the research, which is applied research, the applicability of these GSCM practises in to SME Apparel Company in Sri Lanka is investigated. Afterwards, a generic framework which gives sequence of most applicable practises to adopting traditional SC to GSC for operational process in apparel manufacturing company in Sri Lanka is developed. The research is based on scientific approach. It measures the relationship between current GSCM practises and organization performance to find out whether these practises have a positive relationship on organization performance or not. Therefore, correlational research approach will be conducted.

Following table lists the definitions required to carry out the research. The research is conducted according to these definitions (Table 3).

Table 3:Construct definitions

Construct	Definition
Green Supply chain Management	GSCM is the practise of monitoring and improving environmentalperformance in the supply chain with ISO 14001 or any EMP system)Godfrey, 1998(
Brown Supply Chain Management	Brown SCM is the SC which in introductory level of GSCM practises and monitoring without proper EMP
Operations process in Sri Lankan Apparel Industry	Inbound logistics which include Tailoring, sewing, ironing and packing function) .ShoufengJi, Yuran Jin, Campbell, 2014(
SME Apparel company in Sri Lanka	Small -Monthly Turnover)Rs. million(<5 and Number of Employees < 100 Medium -Monthly Turnover)Rs. million(between 5 – 200 and Number of Employees between 100 -500 Large -Monthly Turnover)Rs. million(>200 and Number of Employees > 500)Source :Survey data, 2012(

Since the study focused on apparel industry in Sri Lanka, all the garment factories located within the boundaries of the country belong to the survey population. Sample frame include green, brown, and non-green apparel manufacturing companies. Within this sample frame, research is conducted on three sample units.

- Sample 1: Apparel manufacturing companies with GSCM (according to definition)
- Sample 2: Apparel manufacturing companies without GSCM
- Sample 3: Brown SC companies

Since only a handful of companies are capable of implementing GSCM, the first sample includes all green apparel companies in Sri Lanka. The companies are selected according to similarities of their supply chain strategies. This sample includes only three green (manufacturing) plants. Sample 2 includes all the other garment factories in Sri Lanka. Therefore, due to practical difficulties in investigating all the elements in the population, a representative sample of 10 garment factories which have not implemented GSCM were selected through cluster sampling technique. The sample consisted of LS, MS and SS garment factories in Sri Lanka. Furthermore, sample three includes all brown SC apparel companies.

Data were gathered from both primary and secondary method. Primary data were gathered from interviews and questionnaires/ field surveys. In order to facilitate the survey, a structured questionnaire was designed and developed after a rigorous literature review. For scoring purposes, a 5 point Likert scale was employed, with the score of 1 relating to strong disagreement and 5 reflecting strong agreement. Secondary data were gathered from Central Bank Annual Report, relevant journal articles, web resources, and other forms of media.

To validate the research, an instrument was selected after the literature review. According to Hervani *et al*. (2005), balanced scorecard became the most suitable current performance measurement tool. When developing key performance indicators to measure the performance of GSCM practises, current KPI was also counted. Therefore, face and content validity were protected. Internal consistency of instruments in the questionnaire was measured using Cronbatch's Alpha coefficient. Hypotheses were developed with respect to the research questions. After finding the best practises, they were cross validated with the SME garment which did not utilize GSC, and with the brown SC companies. BSC was used again for this validation. The Kruskall Wallis test was conducted to find out the differences in the population.

Results

Interviews were carried out with general managers, quality managers, operation managers, and assistant managers in green plants, regarding waste minimization, efficiency of resource consumption, reduced carbon emission in production, energy efficient tools/machines, clean technology, biodiversity refuge, and energy conservation.

The practises already implemented in operations level were identified before.An index system that adapts to the whole performance evaluation of garment manufacturing green supply chain is constructed in the research. The system consists of 4 level indicators and 26 secondary indicators.

To determine the relative weights, managers were asked to make pairwise comparisons using a preference scale, similar to the scale in Table 4. For instance, if finance is judged to be "very strongly more important" than customer in supporting the business strategy, a score of 7 is given.

Table 4 Scale of the Preferences

Verbal judgment	**Degree of preference**
Equally preferred	1
Moderately preferred	3
Strongly preferred	5
Very strongly preferred	7
Extremely preferred	9

Note: Intermediate levels can be used to provide additional levels of discrimination

Pairwise comparison

In this comparison, AHP analysis of judgments of several people in the assessment process was taken. This is a critical issue, since determining the relative importance of the competitive priorities, and of the performance measures is normally a collective process that may involve several managers and management accountants. Therefore, to gather relevant data, the survey was distributed among general manager, quality manager, and assistant mangers of the concerned companies. In order to consider the AHP the judgments of several people to aggregate the individual paired judgments on the basis of a mathematical operator like, for instance, the geometric mean is used.

After the qualitative data were transferred to quantitative data, Figure 2 shows the decision tree for each factor. The following decision tree can be used to identify the most suitable green practise as shown in figure.

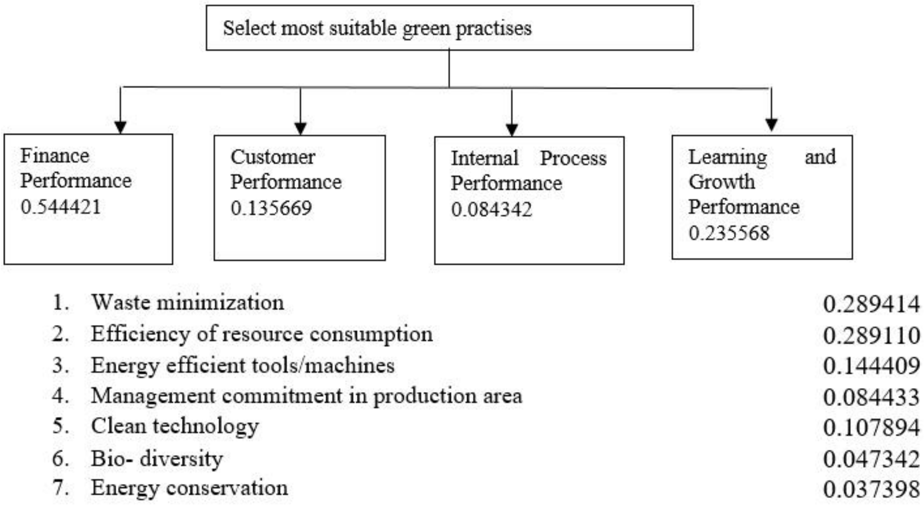

Figure 2: Calculated decision tree

Analysis of Internal Consistency

Cronbatch's Alpha coefficient was used in order to identify the internal consistency of the instruments used to measure the above green practises of GSCM. According to statistics, there is a high internal consistency in all the instruments when Cronbatch's Alpha coefficient is greater than 0.7. Following table represents the Cronbatch's Alpha values of the instruments. The result suggested that the instruments possessed a high degree of internal consistency (Table5).

Table 5: Cronbatch's Alpha values of instruments

Instrument	**Values**
Green Plant	
Waste minimization	0.792
Efficiency of resource consumption	0.704
Energy efficient tools/Machines	0.916
Management commitment in production area	0.609
Clean technology	0.789
Bio- diversity	0.849
Energy Conservation	0.951
Non-green Plant	
Waste minimization	0.696
Efficiency of resource consumption	0.702
Energy efficient tools/Machines	0.744
Management commitment in production area	0.689
Clean technology	0.869
Bio- diversity	0.756
Energy Conservation	0.802
All	0.855

Testing hypotheses for green plant

After finding the weight factors for each measurement, it is required to find the green practises performed in the plant. Therefore, hypotheses test is carried out for testing the relationship between each practise (Table 6).

Table 6: *Hypotheses for testing relationships between green practises*

Area of Concern (Hypotheses)	**Variables in Concern**
Waste minimization and green plant (H_1)	a – Finance performance
Efficiency of resource consumption and green plant (H_2)	b – Customer performance
Energy efficient tools/Machines and green plant (H_3)	c – Learning and growth performance
Management commitment in production area and green plant (H_4)	d – Internal process performance
Clean technology and green plant (H_5)	e – Overall performance
Bio – diversity and green plant (H_6)	
Energy conservation and green plant (H_7)	

Hypothesis test is done using Spearman's coefficient of rank correlation. It is described the relationship between sets of ranked data. Using SPSS Statistics 17.0 Spearman's coefficient of rank correlation was calculated for each hypothesis testing. Following shows the result of the hypothesis (Table 7)

Table 7: *Green practises with their accepted hypothesis spearmen correlation values*

Green Practise	**H_a Finance**	**H_b Customer**	**H_c L & G**	**H_d Internal**	**H_e Overall**
Waste minimization	0.858	X	X	0.621	0.782
Efficiency resource consumption	0.723		X	0.355	0.696
Energy efficient tools/machines	0.636	X	X	0.769	0.630
Management commitment in production area	0.232	X	0.5	0.921	0.644
Clean technology	0.251	0.232	0.449	0.207	0.396
Bio- diversity	0.214	0.680	X	0.487	0.210
Energy conservation	0.774	0.504	0.770	0.212	0.586

Spearman's correlation coefficient is a statistical measure of the strength of a monotonic relationship between paired data. According to Spearman's correlation, in above findings green practises are identified in three categories;

Following shows the best practises which are identified from the hypothesis (Table 8).

Table 8 Identified best practises in operations process

Type of the relationship	Green practise
Strong (best practises) (0.60 – 1.0)	Waste minimization
	Efficiency resource consumption
	Energy efficient tools/machines
	Management commitment in production area
Moderate (0.40 – 0.59)	Energy conservation
	Clean technology
Weak (0.00 – 0.39)	Bio- diversity

After considering AHP and Hypothesis values, the following framework is developed. This framework is based on green apparel manufacturing companies in Sri Lanka. It is used to evaluate the applicability of GSC practises in operation process in Sri Lanka (Figures 3 and 4).

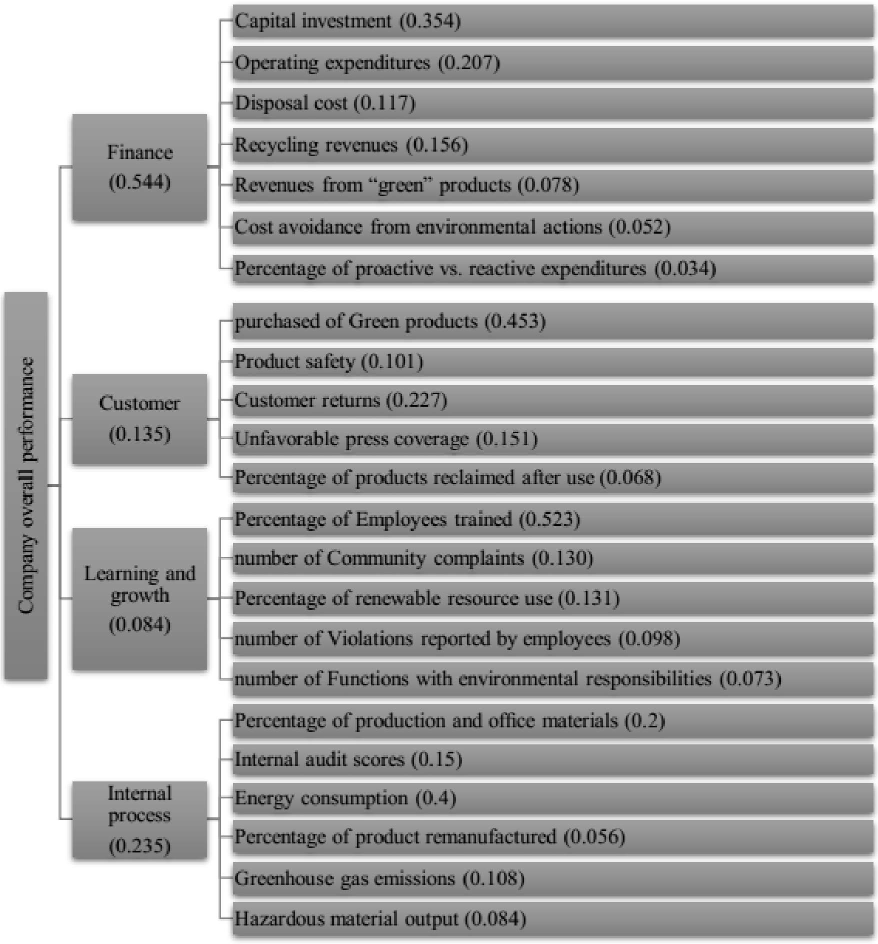

Figure 3: Model to measure the performance of the green practises performance in operation level

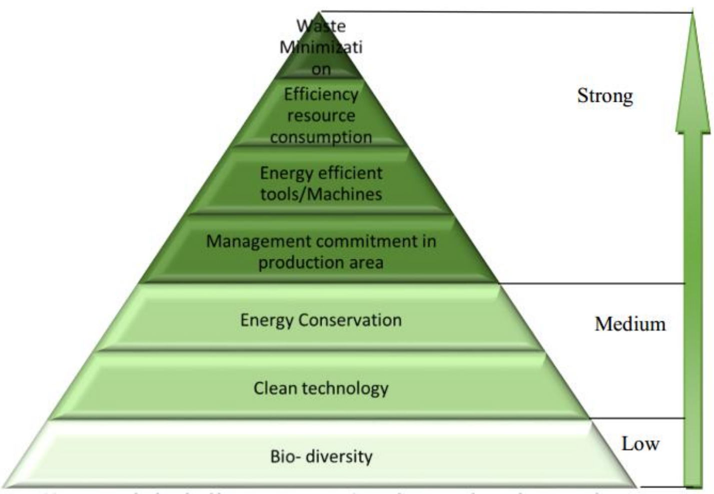

Figure 4: Framework of applicable green practises in Sri Lankan Apparel Manufacturing Industry

Another survey was distributed to validate the above framework. This survey focused upon non- green apparel companies in Sri Lanka. The sample consisted of 10 large scale apparel companies, 10 medium scale companies and 10 small scale companies. This scale is selected according to the methodology. Kruskall - Wallis test was carried out to find whether the samples originated from the same distribution through a comparison of variances by ranks. Null hypothesis (H0) : There is no difference in the population distributions and alternate hypothesis (Ha) -There is a difference in the population distributions for this test are as follows.

Number of samples are 3 and each sample consists of 10 observations. With the significance level (α) of 0.05, null hypothesis is not rejected and alternate hypothesis is rejected. Computed p-Value of H is greater than the significance level (α) or computed test statistic of H is less than critical value null hypothesis is rejected and alternate hypothesis is accepted if computed p-value of H is less than or equal to the significance level (α) or computed test statistic of H is greater than critical value.

Results show that the samples are different from each other for (null hypothesis is rejected) clean technology and biodiversity. When further categorizing, it is understood that only populations of medium and small scale companies are different from green plant population mean. Large scale companies have no difference in population with the green practises.

Discussion

The main objective of this research is to provide a framework to evaluate the applicability of green supply chain practises (operation process) in Sri Lankan apparel manufacturing industry. This research identified seven main practises related to operation level; waste minimization, efficiency resource consumption, energy efficient tools/machines, management commitment in production area, energy conservation, clean technology, and biodiversity. The overall performance of a given company is measured using predefined green balanced scorecard. A framework has been developed in order to find out the green practises applicable to Sri Lanka, and the extent to which they are applicable. Furthermore, a performance measurement model has been developed to measure performance of any upcoming green practises. Any given apparel manufacturing company can use this model to identify whether their green practises are applicable to Sri Lankan context or not.

For improved green supply chain performance, the customer needs to have a better understanding about GSC. Green products are comparatively expensive. A motivation factor should be present for the customer to spend in excess to buy a green product. It is important that an organization have good working relationships with their suppliers in order for it to successfully implement a green supply chain. Strong supplier relationships make it easier to engage with suppliers on environmental issues, to dictate instructions and standards based on environmental criteria, and to monitor suppliers using scorecards or risk assessment. Currently green practises are more focused on enhancing the finance performance and internal process performance. There are very few practises which involve with learning and growth performance. Researchers need to focus more on this area. Although finance and internal processes are more important for a particular company, it needs to consider other factors as well in order to increase the performance.

Furthermore, the research has shown that lean production has some features which positively affect the green concept. It is easier to convert lean company to green company. However, researchers are yet to discover from observation if lean production could be advantageous to GSCM. Therefore, Sri Lankan organizations involved in lean production can have the advantage of converting their SC to GSC. The company needs to focus more on reducing carbon emissions in micro level. At present this practise is only operating in macro level. However, if it also considers micro level, it will lead to the enhancement of company performance.

IT should be embedded to the operation process. IT is considered as a clean technology and it increases the efficiency of the process. Building an environment friendly platform for the industry will increase the performance of the company.

This research can be extended to cover the entire supply chain. This research focused on operation level, but it could be extended to inbound/outbound sales and marketing. It will help to extract best practises related to GSC to improve the apparel industry. The performance measurement model which is developed in this research can be used to evaluate the best practises in other functions as well. It will help to identify the issues and limitations related to SC, and this research can lead to extensive research to find out the relationship between green and lean strategy. Researchers have still not focused on this area. However, this is a research topic with high economic value. If the link between lean and green could be identified, that will be useful for garment factories which are currently following lean to adapt green practises in a shorter period.

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SIMULATION AND OPTIMIZATION-BASED APPROACHES TO ASSESS THE BEHAVIOUR OF THE RETAIL SUPPLY CHAIN NETWORK DESIGNS

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Abstract: The study focuses on using optimization and simulation-based modeling approaches to evaluate the performance to assess the viability of a Supply Chain Network Design (SCND). It enables companies to perform powerful what-if analyses leading them to make better informed decisions. The study helps companies evaluate the appropriate number, location and necessary capacities of their distribution centres (DCs) and warehouses based on projected demand and service level targets. This allows the decision makers to see the performance of the supply chain over time under various scenarios and assist them to understand the inter-relationships between different modeling components. The authors have using retail supply chains as a test bed and carried out performance evaluation under various scenarios to enhance the applicability of the SCND by varying locations, number of facilities and product combinations. The ultimate objectives of the work were to minimize total supply chain network design cost including variable cost and maximize organization's customer service potential and provides a comprehensive analysis of the firm's supply chain structure and performance through pre-defined set of scenarios.

Keywords: exact mathematical approaches; multi-echelon optimization; simulation; supply chain network design

Introduction

A world class transformational supply chain begins with a network that employs an all-encompassing view of the various business areas that manage the delivery of products to customers. The result is significant capital, operational, and tax savings while achieving optimal customer satisfaction. An increasing number of companies are asking the question: "How can my supply chain be used to maximize profits?" This is a different objective than traditional network optimization projects which define the objective as reducing costs and maintaining customer service levels. Therefore, with the current identification, maximizing profit through the supply chain network is mainly focused and attractive area in the competitive business world.

The network design problem is one of the most comprehensive strategic decision problems that need to be addressed for a long-term efficient operation of the entire supply chain. The SCND provides an optimal platform for efficient and effective supply chain management (Varasteh, 2007). In addition to that, it determines the number, location, capacity and type of plants, warehouses and DCs to be used (Altiparmak *et al*, 2006). Although there are many studies have been done on supply chain network optimization, there are only few significant studies carried out in linking with a distribution network design optimization and supply chain network.

As pointed by, Keizer *et al*, (2012), there is a need, and a challenge, to incorporate the deterioration of product quality in both design and control models. Simulation is a powerful technique to model detailed product characteristics as well as logistical control processes. Optimization techniques are able to produce new network scenarios and to optimize the flow of products throughout the network. A hybrid

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approach combining simulation and optimization is a promising research direction.

Though the most of the real world scenarios are involved with multi-product, multi-stage and multi-source approach, most of the studies haven't focused these scenarios together. So, the study is considered this all scenarios together by performing IBM CPLEX® and compared performance with simulation. Since the supply chain network design decisions are strategic, it should be optimal. So, the solving mechanism should be given the optimal solution approach. Therefore, CPLEX optimal solution is the best answer for analyzing the supply chain network.

Retail is the final stage of any economic activity. By virtue of this fact retail occupies an important place in the world economy. In the current business context, retail industries have growing demand than the other industries. In result, by blending with the optimize supply chain network retail distributors can gain competitive advantage than the rivals. Furthermore, this study supports to the decision making process on strategic planning to design and control many real world complex practical scenarios.

The remainder of this paper is organized as follows. The literature review is described in next section. Thereafter, study describes methodology and results and discussion. Conclusions are presented in last section.

Literature review

According to the Ambrosino and Scutella, (2005), while analyzing a distribution network, two factors can be distinguished such as the optimization of the flows of goods: in this case it is considered an existing distribution network, and need to optimize the flows of goods through the network; and the improvement of the existing network: in this case need to choose the best configuration of the facilities in the network in order to satisfy the goals of the company, while minimizing the overall costs. There are extensive literatures available on the analysis of supply chain coordination. Two of the most common ways of analyzing a supply chain are simulation and analytical modeling. Therefore, this study is focused with hybrid approach by combining optimization and simulation.

Truong and Azadivar, (2003) has considered about the simulation based optimization for supply chain configuration design. His new approach combines simulation, mixed integer programming and genetic algorithm. The simulation model returns the overall long run system-wide cost and customer service level of the supply chain. Reiner and Trcka, (2004) have studied a product-specific supply chain in the food industry, analyzes the effects of changes carried out and shows how demand uncertainties are dealt with. To measure and analyze the performance effects of the supply chain configuration alternatives depicted, a simulation environment has developed.

Simulation modeling and analysis has become a popular technique for analyzing the effects of these changes without actual implementation or assignment of resources. Many manufacturing systems can be easily and adequately analyzed with discrete event simulation models. However, other systems may require more complex continuous event or even combined discrete and continuous event simulation approaches in order to develop valid models (Huda and Chung, 2002).

Al-Zubaidi and Tyler, (2004), Simulation modelling work has been undertaken to gain insights into the dynamic behavior of apparel supply to retail customers. In particular, this research has looked at replenishment strategies in response to consumer demand. From an operations research point of view, Supply Chain Network Design (SCND) is the discipline used to determine the optimal location and size of facilities and the flow through the facilities (Goldsby *et al*, 2013). As recalled in Farahani *et al*, (2014), there are many models in the SCND literature. Different decisions are made in the SCND and perhaps the most critical one is locating the facilities in different tiers of the supply chain. Thus this study is focused to fill the gap of the current literature by providing the solution for distributing products with minimum distribution cost.

As the literature, most of the optimization models are limited for single stage or two stages and as pointed by Munasinghe and Rupasinghe, (2016), though the distance is playing a major role with supply chain network design cost, most of the studies have not focused distance for calculating the distribution network cost. Furthermore, it's hard to find the optimization and simulation combined approach with multi echelon supply chain network design with current literature and it has proved by Table 1 which is elaborated by Munasinghe and Rupasinghe,(2016).

Table 1:Summary of the systematic review (Source: Munasinghe and Rupasinghe, (2016)

Study	**Application Area**	**Decision Variables**	**Number of Stages**	**Multi-Product**	**Multi-Source**
Altiparmak *et al*, (2006)	The model aims to select the suppliers, determine the subsets of plants and DCs to be opened and design the distribution network strategy that will satisfy all capacities and demand requirement for the product imposed by customers	The quantity of raw material shipped from supplier to plant The quantity of the product shipped from plant to DC and DC to customer	Three		×
Keskin and Uster, (2007)	The model determines where to locate DCs and how many of each product to be transported from plants to DCs and from DCs to retailers in such a way that the total fixed location costs and transportation costs in the system are minimized	Number of products transported from DC to customer Number of product transported from plant to DC	Two	×	×
Altiparmak *et al*, (2009)	Determines the subsets of plants and DCs to be opened and to design the distribution network strategy that will satisfy all capacities and demand requirements for each product requested by the customer at a minimum cost	The quantity of raw material shipped from supplier to plant The quantity of the product shipped from plant to DC and DC to customer	Three		×
Golmohammadi *et al*, (2010)	Determines the optimal distributing strategy from the plants to the warehouses and from the warehouses to the customers	Quantity of demand from customer zone delivered from warehouse Shipments from plant to warehouse	Two		×
Machado *et al*, (2016)	Determines the set of DCs to be open so that the company can fully meet the demands of its customers at the lowest possible cost	Quantity of product shipped from factory to DC Quantity of raw material shipped from vendor to factory	Three	×	

According to the literature, most of the studies are limited to single source, single product and single stage approach. Furthermore, the distribution network design has gained a very limited consideration. Therefore, the authors have considered the multi-echelon supply chain network design as the test bed to optimize the distribution cost. Summary of the literature is depicted in Table 2.

Table 2 Summary of the modeling approaches literature review

Title	**Study**	**Description of the modeling approach**
Simulation based optimization for supply chain configuration design	Truong and Azadivar, (2003)	Develop a hybrid optimization approach to address the Supply Chain Configuration Design problem. The new approach combines simulation, mixed integer programming and genetic algorithm
Customized supply chain design: Problems and alternatives for a production company in the food industry. A simulation based analysis	Reiner and Trcka, (2004)	Suggest an improvement model that helps enhance the performance of a specific supply chain
Simulation modeling and analysis issues for high-speed combined continuous and discrete food industry manufacturing processes	Huda and Chung, (2002)	Illustrate some of the issues associated with a real world example of a combined continuous and discrete event high-speed food processing simulation model
Simulation of Supply-Chain Networks: A Source of Innovation and Competitive Advantage for Small and Medium-Sized Enterprises	Liotta, (2012)	Emphasize the relevance of simulation for the design and management of supply-chain networks from the perspective of small and medium-sized firms
Simulation modelling for food supply chain redesign; Integrated decision making on product quality, sustainability and logistics	van der Vorst *et al*, (2009)	Propose a new integrated approach towards logistics, sustainability and food quality analysis, and implement the approach by introducing a new simulation environment
Optimizing Coordination Strategies in a Real Supply Chain: Simulation Approach	Ingenieur, (2007)	Develop new coordination distribution strategies that coordinate the inventory and transportation activities and optimize the performance of the supply chain.

Methodology

The study focuses on optimizing the retail supply chain network design cost with hybrid optimization and simulation approach. As the methodology, first and foremost the study is come up with a literature survey to find out the approaches and gaps of the existing literature related to supply chain network. Through the literature survey identified the current need for the optimization-simulation approach with supply chain network design.

In this study, the authors use an optimization-simulation based approach on the latest supply chain network design model development by Munasinghe and Rupasinghe, (2016).With that model development authors have come up with new mathematical approach to minimize the total SCND cost considering in a multi-echelon network where multi suppliers, multi, warehouses, multi, DCs, multi retailer, and multi products are taken into consideration and the model is depicted in below.

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{x=1}^{X} C_{ijx}\, Q1_{xij}\, d_{ij} + \sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{x=1}^{X} C_{jkx}\, Q2_{xjk}\, d_{jk} + \sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{x=1}^{X} C_{klx}\, Q3_{xkl}\, d_{kl}$$
$$+ \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{x=1}^{X} C_{ilx}\, Q4_{xil}\, d_{il} + \sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{x=1}^{X} C_{ikx}\, Q5_{xik}\, d_{ik}$$
$$+ \sum_{j=1}^{J}\sum_{l=1}^{L}\sum_{x=1}^{X} C_{jlx}\, Q6_{xjl}\, d_{jl}$$

[Source: Munasinghe and Rupasinghe, 2016]

To evaluate this model, some numerical analysis was conducted using the CPLEX solver with RSC literature test cases and presented performance analysis with simulation. The study approach is depicted in Figure 1.

The methodology of this study is focused on determining the most profitable combination of supplier-warehouse-DC-retail mapping for product flow combinations. As depicted in the figure 1, optimization is performed through IBM CPLEX® software and what-if analyses were performed through the simulation approach using the Supply Chain Guru® software. Considered supply chain network design is depicted in Figure 2.

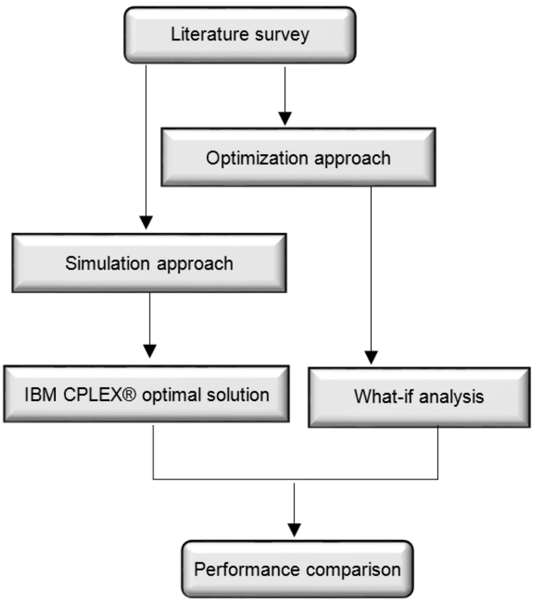

Figure 1 Research methodology of the simulation and optimization-based approach

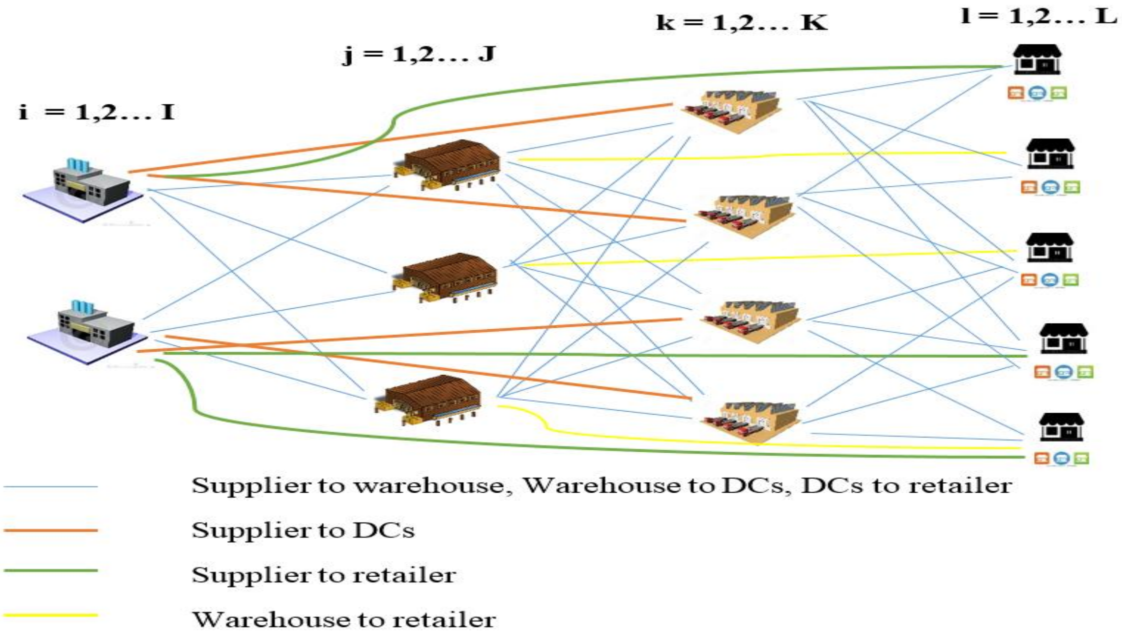

Figure 2 Supply chain network design

Results and discussion

Simulation-based Approach

Computer simulation is an especially effective tool to help investigate and analyze complex problems. Because it can be applied to operational problems that are too difficult to model and solve analytically. Moreover, mathematical models require too many simplifications and assumptions to model coordination strategies in realistic supply chain problems. Discrete event simulation permits complex logistics systems to be modeled more realistically (Terzi and Cavalieri, 2004). Therefore. The authors are focused with simulation model to perform the powerful what-if analyses with Supply Chain Guru®. It has considered the six main model elements to develop the simulated network design such as product, site, demand, inventory policies, transportation policies and sourcing policies. These elements combine to provide the nodes of the network, the links between the nodes, and the relationships created by these links.

The simulation-based scenarios have been created using the model developed by Munasinghe and Rupasinghe, (2016). As discussed in the methodology, this is used to analyze the behavior of supply chain network design which is then optimized using IBM CPLEX® optimal solution.

As explained in Ding *et al*, (2007), it has been stated that optimization is hardly used independently in industries. Comparing to optimization techniques, simulation is more suitable for the evaluation of complex industrial systems given a limited number of candidate scenarios. Also, it’s provided answer for deciding that if it is changed the network design, how it will influence the performance of the supply chain network. Also, it can be used to analyze the single sourcing and multi-sourcing influence for the SCND. Not only that but also it is supported to analyze the facility variation with demand.

This simulation is evaluated through 16 different kind of scenarios. Data table is depicted in Table 3.

S- Supplier, W- Warehouse, DC- Distribution Centre, R- Retailer, X- Products

Table 3 Data of the simulation analysis

	Number of facilities							
	Single facility consideration				Multi facility consideration			
	Single supplier	Single warehouse	Single DC	Single retailer	Multi supplier	Multi warehouse	Multi DC	Multi retailer
Single product	S=1, W=3, DC=4, R=13	S=2, W=1, DC=4, R=13	S=2, W=3, DC=1, R=13	S=2, W=3, DC=4, R=1	S=3, W=3, DC=4, R=13	S=2, W=4, DC=4, R=13	S=2, W=3, DC=5, R=13	S=2, W=3, DC=4, R=14
Multi product	S=1, W=3, DC=4, R=13	S=2, W=1, DC=4, R=13,	S=2, W=3, DC=1, R=13	S=2, W=3, DC=4, R=1	S=3, W=3, DC=4, R=13	S=2, W=4, DC=4, R=13	S=2, W=3, DC=5, R=13	S=2, W=3, DC=4, R=14

According to the above data table scenarios have been created to run the simulations and the total cost obtained is depicted as comparison to the base-case scenario. This is depicted in Table 4 and profit comparison depicted in Table 5.

Table 4 Simulated model results for cost

Scenario	**Total cost**	**Changed cost percentage**
Baseline scenario	2, 350, 873, 446.7150	
Single product- Single supplier	2, 104, 684, 982.9513	-10.47 %
Single product- Single warehouse	2, 269, 540, 167.1588	-3.45 %
Single product- Single DC	1, 943, 066, 302.1636	-17.34 %
Single product- Single retailer	159, 738, 869.6922	-93.21 %
Multi product- Single supplier	2142446900.2794	-8.86 %
Multi product- Single warehouse	2, 301, 039, 520.5871	-2.11 %
Multi product- Single DC	1, 970, 801, 887.5816	-16.16 %
Multi product- Single retailer	159, 738, 869.6922	-93.20 %
Single product- Multi supplier	2, 138, 298, 804.9216	-9.04 %
Single product- Multi warehouse	2, 234, 326, 486.5906	-4.96 %
Single product- Multi DC	2, 234, 593, 270.5906	-4.95 %
Single product- Multi retailer	2, 284, 470, 489.2035	-2.82 %
Multi product- Multi supplier	2140428720.9216	-8.95 %
Multi product- Multi warehouse	2, 238, 283, 354.3906	-4.79 %
Multi product- Multi DC	2, 238, 771, 559.5906	-4.77 %
Multi product- Multi retailer	2, 289, 478, 489.2035	-2.61 %

Table 5 Simulated model results for profit

Scenario	**Total profit**	**Changed profit percentage**
Baseline scenario	2, 625, 244, 073.2850	
Single product- Single supplier	2, 871, 432, 537.0487	9.38 %
Single product- Single warehouse	2, 706, 577, 352.8412	3.09 %
Single product- Single DC	3, 033, 051, 217.8364	15.53 %
Single product- Single retailer	41, 792, 130.3078	-98.41 %
Multi product- Single supplier	2, 904, 539, 119.7206	10.63 %
Multi product- Single warehouse	2, 736, 856, 499.4129	4.25 %
Multi product- Single DC	3, 062, 857, 132.4184	16.66 %
Multi product- Single retailer	41, 999, 890.3078	-98.40 %
Single product- Multi supplier	2, 837, 818, 715.0784	8.09 %
Single product- Multi warehouse	2, 739, 448, 033.4094	4.35 %
Single product- Multi DC	2, 739, 049, 249.4094	4.33 %
Single product- Multi retailer	2, 816, 964, 530.7965	7.30 %
Multi product- Multi supplier	2, 844, 372, 799.0784	8.34 %
Multi product- Multi warehouse	2, 744, 721, 365.6094	4.55 %
Multi product- Multi DC	2, 743, 871, 960.4094	4.51 %
Multi product- Multi retailer	2, 828, 964, 930.7965	7.76 %

Simulation-based approach is enhanced the understandability of the SCND behavior by applying multi-product and single product scenarios with multiple facility combinations in separately. Thus, it is easy to carry out a performance analysis and interpret the appropriate supplier to retail mapping with different kinds of products.

When compared with the baseline scenario, multi-products with single DC scenario gives the highest profit. Furthermore, it is evident that this can be used to evaluate each different scenario and take managerial strategic decisions. The Supply Chain Guru®, profit comparison is depicted as in Figure 3 and total cost comparison is depicted in Figure 4.

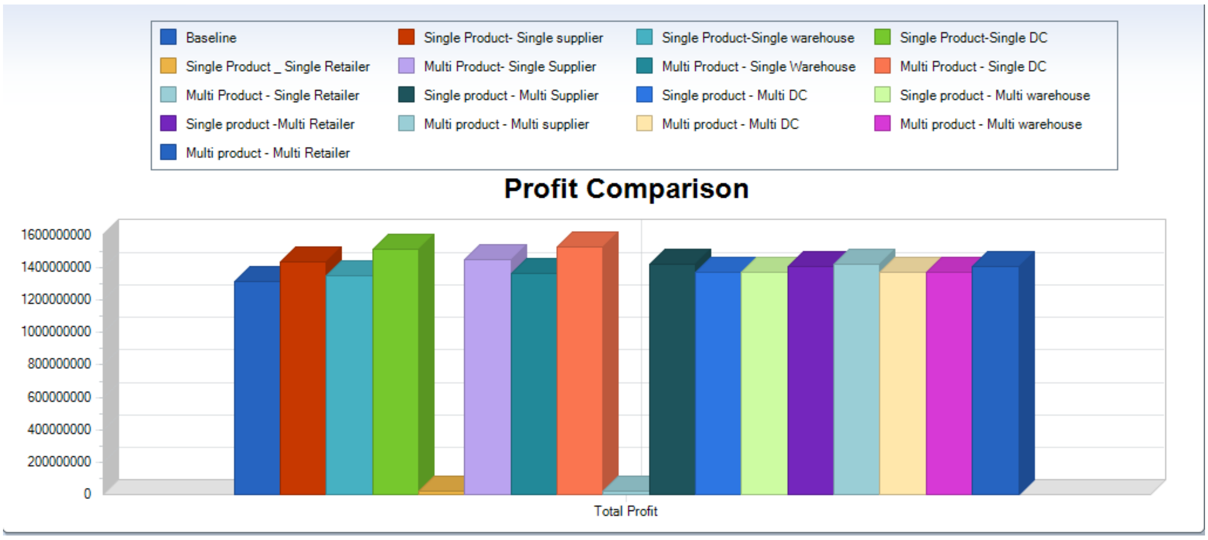

Figure 3 Profit comparison of the simulated model

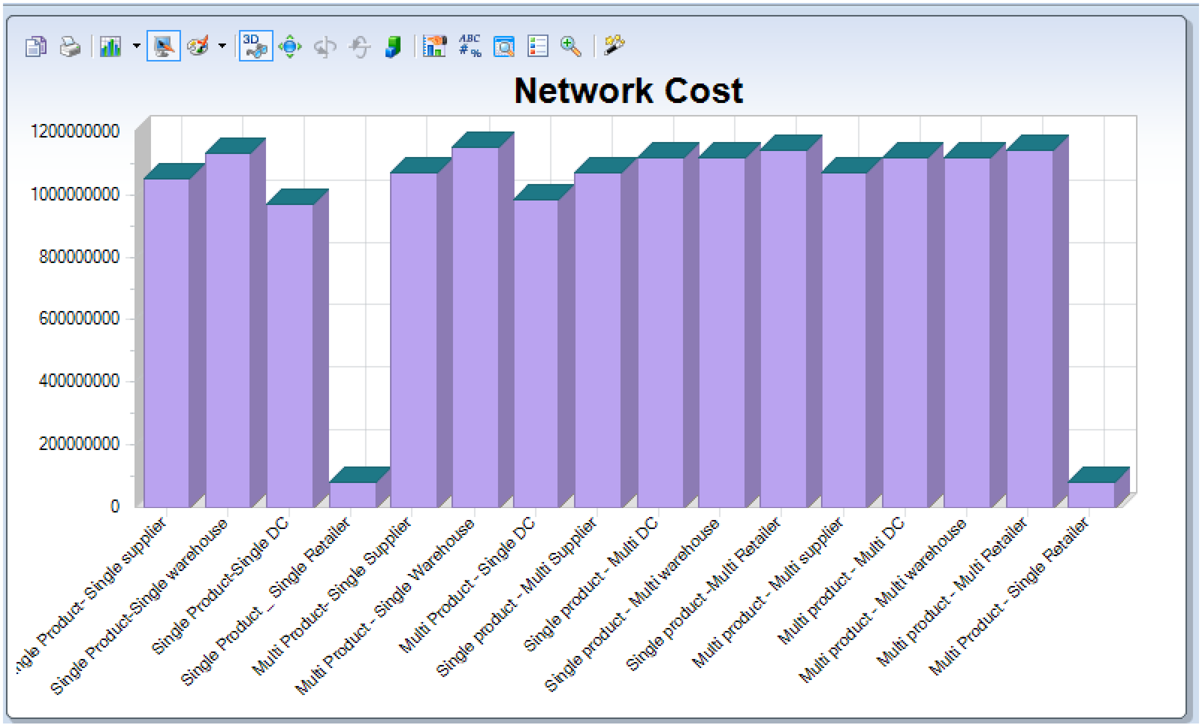

Figure 4 Cost comparison of the simulated model

Finally, it can be concluded that the above simulation approach supports the strategic decision making on a typical SCND. It supports the performance evaluation of the designed network and the scenarios well explain the multi-product, multi-echelon, multi-source, multi-stage SCND by providing better inner visibility to the supply chain network.

Optimization-based Approach

In the present competitive era, logistics and supply chain network plays a vital role towards the economic growth of a country (Biswas and Samanta, 2016). IBM CPLEX optimal solution is a state-of-the-art software tool which provides the ability to solve any complex Mixed Integer Programming (MIP) formulation optimally with a reasonable time.

The SCND decisions are strategic decisions and most of the cases optimal solution plays an important role. By using the IBM CPLEX toolkit the optimal solutions were found with the most profitable supplier-warehouse-DC-retailer mapping for product flows. However, the obstacle is, the execution time of CPLEX increases with the problem size. However, finding an optimal solution is important for the strategic decisions as those decisions can't be dynamically changed. This study utilizes the IBM CPLEX solver for solving the optimal design with respect to different scenarios as depicted in the Table 6. Due to the long the execution times, the comparison analysis only considers small size problems and this sample problems are formulated taking inside from real world business scenarios.

Table 6 Sample scenarios with different dimensions

Sample problem	Supplier	Warehouse	DC	Retailer	Products
1	2	2	2	3	3
2	2	1	3	4	3
3	2	1	2	5	3
4	1	2	2	4	3
5	1	2	3	5	3
6	1	2	3	6	3
7	2	2	2	3	4
8	2	1	3	4	4
9	2	1	2	5	4
10	1	2	2	4	4
11	1	2	3	5	4
12	1	2	3	6	4

According to the sample problems, the study is carried out by changing number of facilities and number of products to find the optimal solution. Furthermore, this sample problems help to understand the network design and analyze performance with different cases to design the network as profitable way.

Developed CPLEX solution pseudo code is depicted in Figure 5 and Figure 6.

```
Begin
input X,I,J,K,L
    for each j In J do
    input Volume of Warehouse
    end for

    for each k In K do
    input Volume of DCs
    end for

    for each x In X do
        for each i In I do
            for each j In J do
            input unit transportation cost for product x from Si to Wj
            end for
        end for
        for each j In J do
            for each k In K do
            input unit transportation cost for product x from Wj to Dk
            end for
        end for

        for each k In K do
            for each l In L do
            input unit transportation cost for product x from Dk to Rl
            end for
        end for

for each i In I do
            for each l In L do
            input unit transportation cost for product x from Si to Rl
            end for
        end for

        for each i In I do
            for each k In K do
            input unit transportation cost for product x from Si to Dk
            end for
        end for

        for each j In J do
            for each l In L do
            input unit transportation cost for product x from Wj to Rl
            end for
        end for
    end for

for each x In X do
        for each i In I do
            Input total output of suppliers i for product x
        end for

        for each l In L do
            Input demand of retailer l for product x
        end for

        for each j In J do
            Input maximum capacity of warehouse Wj for product x
        end for

        for each k In K do
            Input maximum capacity of DC Dk for product x
        end for
    end for
for each i In I
        for each j In J
            Input distance from Si to Wj
        end for
    end for
    for each j In J
        for each k In K
            Input distance from Wj to Dk
        end for
    end for
    for each k In K
        for each l In L
            Input distance from Dk to Rl
        end for
    end for
    for each i In I
        for each l In L
            Input distance from Si to Rl
        end for
    end for
    for each i In I
        for each k In K
            Input distance from Si to Dk
        end for
    end for
    for each j In J
        for each r In R
            Input distance from Wj to Rl
        end for
    end for
```

Figure 5 CPLEX solution pseudo code part 1

```
//Objective Function

minimize sum(iV in Suppliers,jV in Warehouses,xV in Products)
 (Unit transportation cost for product xV from iV to jV)
* (Quantity of product xV shipped from iV to jV) * (Distance from iV to jV) +

   sum(jV in Warehouses,kV in DCs,xV in Products
(Unit transportation cost for product xV from jV to kV)
* (Quantity of product xV shipped from jV to kV) *(Distance from jV to kV) +

   sum(kV in DCs,lV in Retailers,xV in Products)
(Unit transportation cost for product xV from kV to lV)
* (Quantity of product xV shipped from kV to lV) * (Distance from kV to lV) +

   sum(iV in Suppliers,lV in Retailers,xV in Products)
 (Unit transportation cost for product xV from iV to lV)
* (Quantity of product xV shipped from iV to lV) * (Distance from iV to lV) +

   sum(iV in Suppliers,kV in DCs,xV in Products)
(Unit transportation cost for product xV from iV to kV)
* (Quantity of product xV shipped from iV to kV) * (Distance from iV to kV) +

   sum(jV in Warehouses,lV in Retailers,xV in Products)
(Unit transportation cost for product xV from jV to lV)
* (Quantity of product xV shipped from jV to lV) * (Distance from jV to lV) +

//Subject to

  for each x In X

     for each i In I
        Calculate total distributing quantity from supplier
     end for
     for each l In L
        Calculate retailers demand
     end for
     for each j In J
        Calculate used capacity of the warehouse
        Check maximum capacity of the warehouse
     end for
     for each k In K
        Calculate used capacity of the DCs
        Check maximum capacity of the DCs
     end for
     for each i In I
        for each j In J
           Calculate total incoming quantity from Warehouse and
           Supplier
           Check total incoming quantity from Warehouse and
           Supplier
        end for
     end for
     for each i In I
        Calculate total incoming quantity form Supplier:
     end for
     for each i In I
        for each j In J
           Check distance from Supplier to Warehouse for positive
           value
        end for
     end for

  for each j In J
        for each k In K
           Check distance from Warehouse to DCs for positive value
        end for
     end for
     for each k In K
        for each l In L
           Check distance from DCs to Retailer for positive value
        end for
     end for
     for each i In I
        for each l In L
           Check distance from Supplier to Retailer for positive
           value
        end for
     end for
     for each i In I
        for each k In K
           Check distance from Supplier to DCs for positive value
        end for
     end for
     for each j In J
        for each l In L
           Check distance from Warehouse to Retailer  for
           positive value
        end for
     end for
  end for

End
```

Figure 6 CPLEX solution pseudo code part 2

By using the above pseudo code, the optimal solution results which are obtained from IBM CPLEX are depicted in Table 7. As explained before the execution time increased as the size of the problem increases.

Table 7 Result of the CPLEX optimal solution

Sample Problem	No. of variables	Optimal solution
01	90	11, 520, 880
02	105	19, 248, 380
03	99	33, 589, 850
04	84	14, 755, 220
05	123	18, 655, 860
06	141	20, 331, 350
07	120	16, 713, 430
08	140	26, 237, 330
09	132	48, 681, 050
10	112	26, 362, 970
11	164	32, 202, 610
12	188	34, 942, 930

Conclusions

The level of competitiveness across all industrial sectors has increased in the last few years due to the globalization. This increased level of competitiveness is pushing companies to achieve further optimization of their business processes and particularly to collaborate with their direct logistics entities in supply chain network. Therefore, this study yields the need of using optimization and simulation-based approaches to better understand supply chain networks.

Though the SCND have been thoroughly researched in the literature, most of the cases have ignored the multi-echelon SCND approach. In this study the authors' review, optimization and simulation-based approaches and how these approaches be used in assessing dynamics of the supply chain behavior. The literature belongs to either optimization or simulation. A few of the studies have explored hybrid methods which include both optimization and simulation together. However, most of the studies have not examined multi-product, multi-stage and multi-source considerations together in order to minimize the total distribution network cost. Furthermore, multi-echelon supply chain network design considerations have filled the gap in this domain as pointed by Munasinghe and Rupasinghe, (2016). Therefore, this paper presents an optimization and simulation approach to capture and design the real scenario of retail supply chain network design with multi-product, multi-source.

With optimization approach alone, ignores the behavior of the network design and simulation modelling facilitates to evaluate the performance of the supply chain network design much more dynamic nature. With the exact mathematical modelling approach the solution yielded through CPLEX, provides the optimal network design and the quantities to be transferred from facility to facility while minimizing the total distribution network cost. Furthermore, simulation analysis supports the evaluation of the behavior of supply chain network design.

Finally, this study is more beneficial for strategic decisions with respect to retail supply chain networks and the numerical analyses are carried out for small-sized problem instances. Therefore, future studies can be proposed to alleviate this limitation to better assess a much more generalized multi-echelon supply chain networks.

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AN ANALYTICAL MODELLING APPROACH TO OPTIMIZE SAFETY STOCK OF WINERY SUPPLY CHAINS (WSC)

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Abstract: Winery Supply Chains (WSC) are more cash sensitive as a considerable portion of inventory is kept and financed throughout the WSC due to the long production process, distances from suppliers/markets and the importance of having the correct finished goods for orders. Hence, Inventory Optimization (IO) is one of the most critical areas in a WSC. This paper is framed on introducing a Genetic Algorithm (GA) incorporating a mathematical model that integrates selected external and internal characteristics of WSCs together with demand uncertainties specific to WSC, developed by the authors to optimize the most critical type of inventory, the safety stock level of WSC. This paper further compares three main types of inventory policies, the continuous review, the periodic review policy and a hybrid of both policies, which analyze their impact on selected Key Performance Indicators (KPI). The developed simulation models incorporating the comparison, integrates demand specific for wine products to a distributor in a Winery Supply Chain. This paper fulfils a larger knowledge gap in the arena of IO for WSC and presents the foundation for larger research projects in IO for WSC. Thus, the generic safety stock model would enable the WSCs achieve higher performance leading to competitive advantage.

Keywords: Demand Uncertainties, Genetic Algorithm, Safety Stock, Simulation, Winery Supply Chains

Introduction

The major cause for the existence of inventory in a supply chain (SC) is the mismatch of demand and supply. The overstock of inventory is not suitable due to the higher investment on it and the costs associated. The non-availability or the shortage of inventory would result in disturbance of the production process as well as poor customer satisfaction levels. Though inventory has been invented in to SCs to tackle uncertainty, existence of tradeoffs has brought out the attention of the corporates to find the appropriate inventory policy that specifies 1) when an order for additional items should be placed and 2) how many items should be ordered each time [Heizer, J. & Render, B., 1999] and [Lipman, B., 1975]. Under the assumption that the manufacturing world is deterministic and is with adequate capacity, only pipeline stocks and cycle stocks would only be needed that can be easily predicted. But today, it is not the case. The most significant is the decision on the inventory more than the pipeline and cycle stock. According to [Graves, 1988], safety stock is the "excess" inventories held beyond the minimum inventory level that would be possible in a deterministic and incapacitated world. This is needed in the manufacturing systems due to the uncertainties depicted above. Thus, this study focuses on the "inventory that is maintained explicitly to protect the organization just in case one or more of these problems occur is called buffer inventory or safety stock" [Chapman, 2006]. In simple terms, safety stock is mainly the inventory kept in to minimize the stock outs. This paper introduces an efficient GA to solve the safety stock optimization mathematical model under demand uncertainties for WSC developed by the authors in which internal & external characteristics specific for WSC have been integrated, such as storage factors, wine constituents, inflation and tax rates [De Zoysa, D.L. and Rupasinghe, T.D., 2016]. This GA development is followed by a Design of Experiment (DoE) to tune

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the algorithm that enables the users undertake better parameter fixing to receive near optimal values for the level of safety stock that should be maintained. Further, this study compares selected inventory policies out of the many different types of inventory policies that would enable corporates identify the most appropriate answers for the two questions mentioned above. However, most of these models are restricted to certain restrictions such as constant demand. In this study, the three simulated models for each of the selected three inventory policies would integrate variation or uncertainty in demand for a distributor in a highly uncertain and cash sensitive SC, the WSC. The modelling has been performed using the Arena simulation package.

Methodology

This study is performed in order to fill the knowledge gap pertaining in the area of safety stock optimization for winery supply chains. An easily solvable safety stock optimization model would enable the winery businesses to reduce their cost of inventory and increase customer service levels by ensuring that the optimal amount of stock is kept within the supply chain to avoid stock out or shortages.

After a review of literature, a mathematical model for safety stock optimization is developed integrating selected intrinsic and extrinsic characteristics of the wine products and the WSC [De Zoysa, D.L. and Rupasinghe, T.D., 2016]. Then meta-heuristic algorithms using GA has been developed to solve the mathematical model with computational efficiency. Then the developed GA has been tuned performing a Design of Experiment (DoE). Further, the study has been expanded in to modelling selected inventory policies for WSC to assess the effect of them for the selected inventory policies, bringing out the importance of maintaining the optimum level of safety stock. The Table 1 provides a summary of the review of literature on safety stocks [De Zoysa, D.L. and Rupasinghe, T.D., 2016].

Table 1 Summary of the Literature Review

References	Summary
[Funaki, K., 2012]	Application Area: Optimization model for safety stock placement in a SC network for an assembly SC. Objective: Minimizing the total cost including the processing and transit cost with stock holding cost.
[Lesnaia, E. et al., 2004]	Application Area: Placement of safety stock in a general network SC. Objective: Maintaining the required service level.
[Graves, S. C., & Willems, S. P., 2003]	Application Area: Placement of safety stocks in a SC. Objective: Minimize the total supply chain cost.
[Boulaksil, Y. et al., 2009]	Application Area: Determination of safety stocks in multi-item, multi-stage inventory systems that face demand uncertainties considering constraints such as batch sizes, capacity and material constraints. Objective: Minimize the total supply chain cost.
[Simchi-Levi, D., & Zhao, Y., 2005]	Application Area: Numerical and analytical insights have been developed in the recursive equations with respect to safety stock positioning with stochastic lead times. Objective: Minimize the total supply chain cost.
[Heath, D., & Jackson, P., 1994]	Application Area: A simulation model is developed to analyze the safety stock levels for a multiproduct/plant production system with stochastic demand. Objective: Find the economic safety stock factor.
[Inderfurth, K., & Vogelgesang, S., 2013]	Application Area: analyze the safety stock levels for a multiproduct/plant production system with stochastic demand. Objective: Minimize the logistic cost.

Results

Development of a Safety Stock Optimizing Genetic Algorithm

A Genetic Algorithm is developed to optimize the safety stock level of WSCs incorporating the mathematical model of optimizing the safety stock level [De Zoysa, D.L. and Rupasinghe, T.D., 2016]. The objective of this model (10), is to find the close-to-optimal values for n, K and SS while minimizing the total variable cost of inventory (TC), where i = 1, … n [i = 1; product 1] and at the same time minimizing the safety stock level for each product in the portfolio, maintaining the required capacity constraints (11), where Kapi = capacity of product i and Kapmaxi = maximum capacity of product i and service level constraints (12), where SLi > 0. Equations, (13) and (14) depict the non-negativity constraints.

$$\text{Min}\left[\sum_{i=1}^{n}\{TC_i(n,K),SS_i\}\right] \tag{10}$$

$$Kap_i \le Kapmax_i \tag{11}$$

$$SL_i \ge SLexpected_i \tag{12}$$

$$SS_i \ge 0 \tag{13}$$

$$i,j \ge 0 \tag{14}$$

Genetic algorithm is a population based meta-heuristic technique. It starts with the current population. Selection is applied to the current population to create an intermediate population. Then crossover and mutation are applied to the intermediate population to create the next population. The process of going from the current population to the next population constitutes one generation in the execution of a genetic algorithm. The genetic algorithm is developed using java. Since this is the first instance of using genetic algorithms on the problem of safety stock optimization under high demand uncertainties, specific for WSCs there are no direct implementations to be found which can be compared to our implementation. The pseudocode for the developed genetic algorithm is depicted below.

Input
Read array of demand to be served for each quarter {P1, P2, P3, P4, P5, P6}
Population size (p)
Number of generations (G)
//Initialization
Create a chromosome with a random set {gene for each product (safety stock, tax rate, Inflation1, Inflation2, aging factor)}
Check for capacity constraints
Check for demand constraints
Check for no shortages
Do this for p times to create a population
Get the best chromosome from the population
Save as the elite
Initial TC = total cost (TC) of the fittest chromosome in first population
//Genetic Algorithm
//Run for n times
Loop1 {
//Run for p times
Loop2 {
//Tournament selection
Select a random set of tours from the population
Get the fittest and return
//Crossover
Parent1 = tournament selection ()
Parent2 = tournament selection ()
Child = Crossover (Parent1, Parent2)
//Mutation
Swap random two columns in the child
} endLoop2
//New population is created
Get the fittest
Replace previous elite if fittest is better than elite
} endLoop1
Get the elite
Final TC = TC of elite
Reduction of TC = (initial TC-final TC)
Print "Reduction of TC"

Test Case Formulation

A hypothetical test case for a set of six products, has been developed to demonstrate how this model can be used. Assume that the fixed period in which the standard deviation of the demand that tends to be small enough for the EOQ model to be used under stochastic demand is 20 quarters and 4 orders are placed during the fixed period. The external purchase cost per unit, the internal ordering cost, internal and external inflation rates, internal and external holding costs and shortage cost per unit item per unit time, service level and capacity for the product, total lead time, time increment used in calculating the standard deviation for demand needs to be identified for each product in the portfolio. Most importantly, the relationship of wine constituents and storage factors for the amelioration of wine needs to be identified by analyzing industry data. In the hypothetical test case, it is being assumed that the distributor holds the inventory in an internal warehouse, so that only the internal inflation rates would be applicable and the lead time is deterministic. The same discount rate (11%) and the same replenishment cycle and reorder quantity is applied for each of the six products in the portfolio. The Table 2 depicts the hypothetical cost values for each of the six products in the portfolio in developing the hypothetical test case that is incorporated in developing the GA.

Table 2 Cost Components used for Test Case Formulation

Cost $	Product Portfolio					
	P1	P2	P3	P4	P5	P6
c_{11}	40.5	45.0	55.0	42.5	43.0	55.0
c_{21}	35.0	35.0	38.0	48.0	40.0	48.0
A	30.0	35.0	40.0	50.0	45.0	55.0
p	35.0	55.0	53.0	43.0	58.0	60.0

Results of the Design of Experiments (DoE)

To analyze the performance of GA, the experiment has been designed as follows in the Table 3.

Table 3 DoE Parameters

Crossover Rates	0.3	0.8
Replications	10 per one crossover rate, per one population size, per one set of generations	
No. in Population	50	
No.of Generations	100	1000

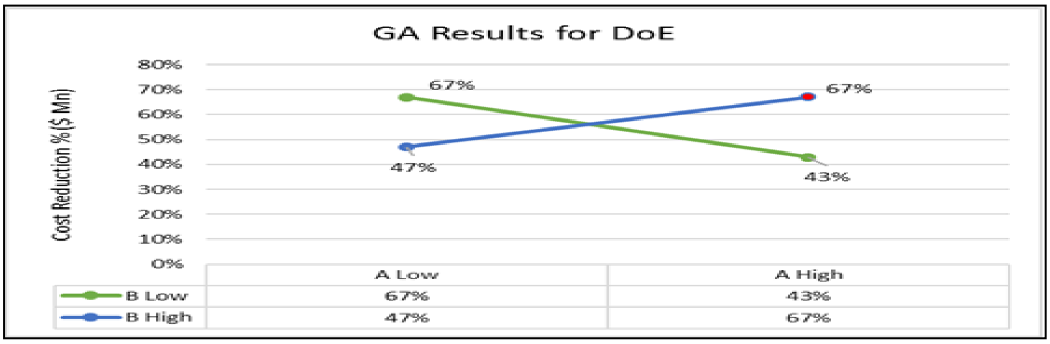

Figure 1 Results of the Genetic Algorithm for DoE

Note that these crossover rates, size of the population and number of generations are the most widely used values found on the literature. The outcome of GA is cost reduction compared to initial total cost (TC) of the elite chromosome for the product portfolio. The data points for each cross over rates can be seen in the Table 4 below.

Table 4 GA Results for each Crossover Rates

Crossover Rate = 0.3 ($Mn)	Crossover Rate = 0.8 ($Mn)
6.69	0.00
23.99	28.67
11.31	10.80
12.44	17.17
11.98	3.20
0.00	4.50
14.96	8.13
11.32	0.00
8.40	9.01
19.03	0.00
12.67	0.32
7.82	16.43
5.82	7.73
5.70	9.44
15.64	8.30
12.96	31.83

1.48	16.40
9.52	18.55
17.75	5.17
16.30	5.98

The below Table 4 depicts the full factorial design for the DoE for each two factors (size of generations and crossover rate) with two levels (High and Low).

Table 5 Full Factorial Design of the Experiments

Factor Name	Factor Name	Low Setting	High Setting
Size of Generations	A	100	1000
Crossover Rates	B	0.3	0.8

The following Table 6, depicts the results of the GA for each parameter experiment.

Table 6 Results of the Genetic Algorithm

Selected Parameter	Values for the Parameter of the GA			
Size of the Population	50			
Size of Generations	100		1000	
Crossover Rates	0.3	0.8	0.3	0.8
Average TC Reduction %	67%	47%	43%	67%

According to the above Table 5 and Figure 1, the highest average cost reduction is arrived at when the size of the generation is 1000 and the crossover rate is 0.8 for the population size of 100.After tuning the GA using the design of experiments, the tuned GA is run to get the results. The following Table 7 below depicts the results of the tuned GA.

Table 7 Results of the tuned Genetic Algorithm

Product	P1	P2	P3	P4	P5	P6
Average Safety Stock	34.05	9.6	43.3	16.85	26.5	34.1
Average Inventory	130.6	136	139.25	131.4	130.45	129.05
Safety Stock %	26.1	7.1	31.1	12.8	20.3	26.4

Simulation Models

This The simulation software, the student version of Arena is used to construct the inventory management system of a Distribution Centre (DC) in a WSC. In each policy, the DC would place orders evaluating its inventory level only. The simulation would be run for 365 days (a year). The general operations for the inventory models would be as follows.

1.The DC receives the orders for wine cases from retailers, weekly, each case of 12, 750ml bottles.

2.The DC receives deliveries from the Filler (bottler) in a WSC that was ordered L (constant lead time) periods ago.

3.The DC fulfills its customer orders (plus backorders if any) with the inventory on hand and the safety stock available. If there are not enough inventories, the unfulfilled quantity will be backordered. Note that the retailers will wait until the DC can fulfill the order.

4.In the continuous review, the DC monitors the inventory on hand each time an order arrives and backordering and follows a (r, Q) policy.

5.In the periodic review, the inventory on hand is reviewed in a fixed time interval T and follows (s, S) policy.

6.In the hybrid model both (r, Q) and (s, S) is followed. The safety stock is continuously reviewed and updated.

Following figures would depict the Arena models developed for each inventory policy. Figure 2 depicts the continuous review model where replenishment order is placed when the inventory on hand is up to or below the reorder point r and a fixed quantity of Q is ordered in each replenishment order. During the lead time for the replenishment, the demand is satisfied using safety stocks or else are queued in backorders.

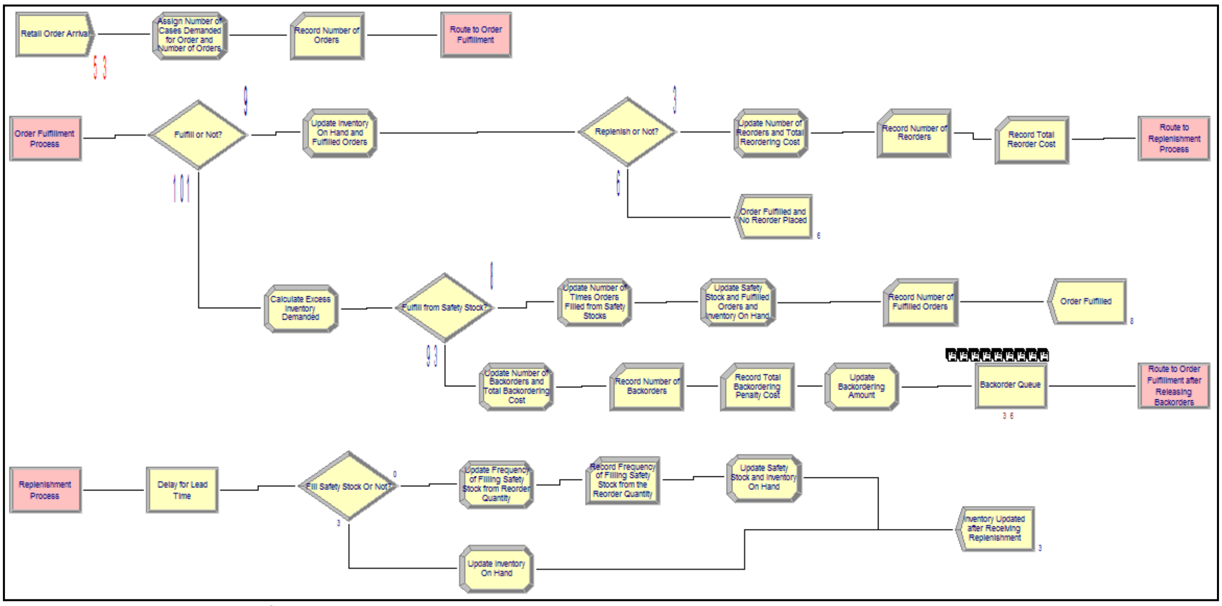

Figure 2 Arena Model for Continuous Review Policy

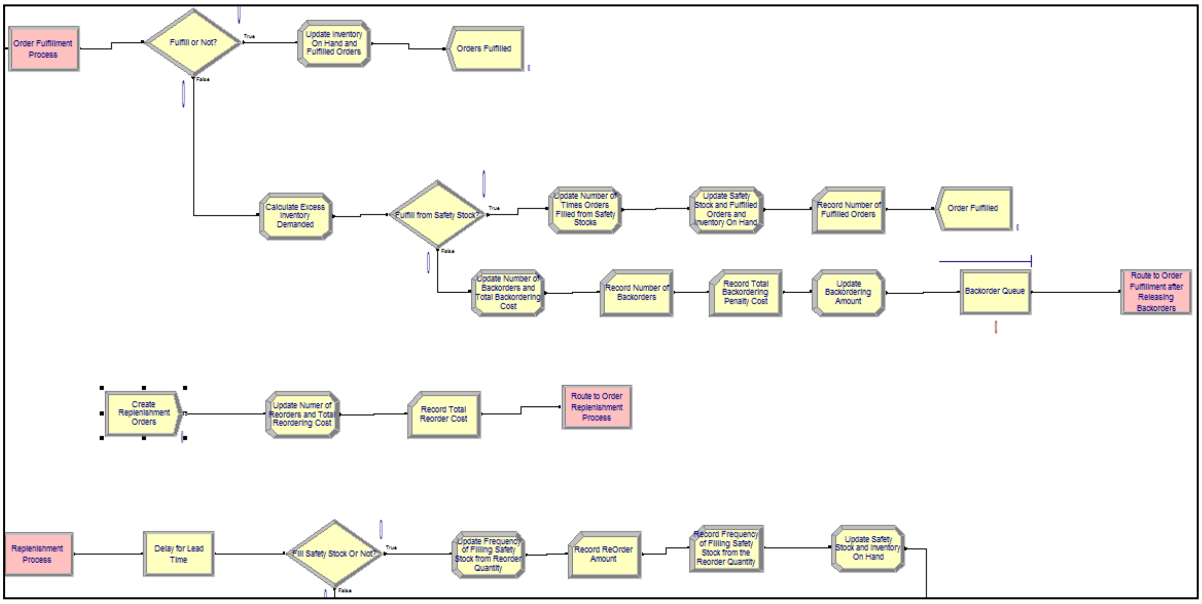

Figure 3 Arena Model for Periodic Review Policy

As soon as the replenishment order arrives, safety stock is filled up to the fixed level and the backorders are satisfied. Figure 3 Depicts the periodic review model where a replenishment order is placed every T time period, with the quantity to maintain the target inventory level. During that time, shortage inventory would be taken from the safety stock or else are queued in backorders.

The hybrid model that incorporates characteristics of both the previous models depicted in Figure 4 reviews the inventory level during a fixed time interval T greater than the normal periodic time but a reorder point for the safety stock level is fixed and each time the safety stock falls below that, a replenishment order is placed. Following Table 8 depicts the initial values for the variables in each inventory model.

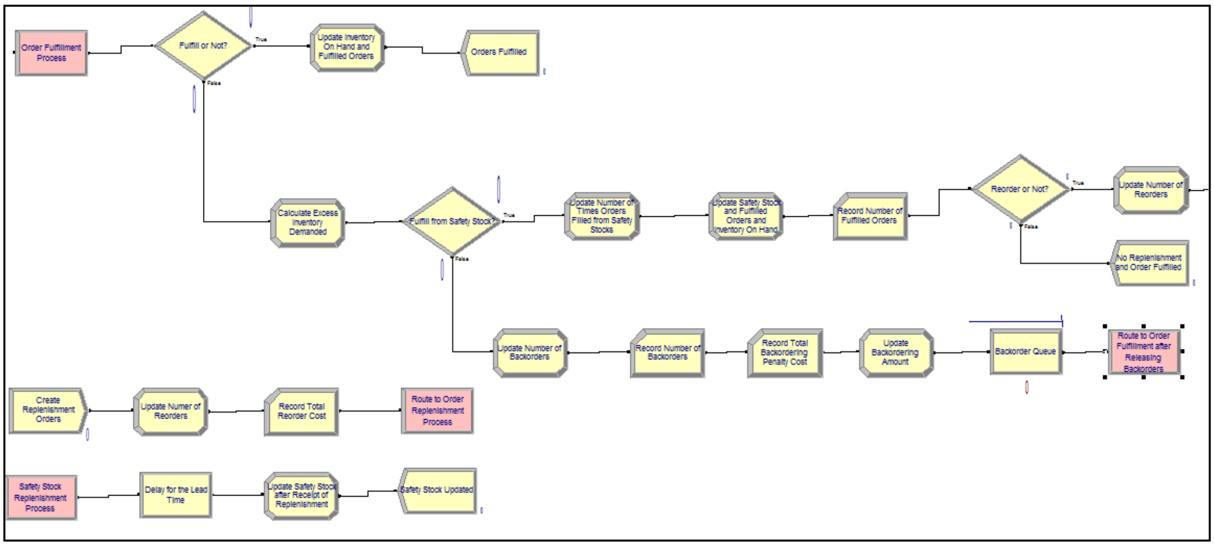

Figure 4 Arena Model for the Hybrid Model

Data Generation for Simulation Models

Demand for wine is generated using the instrumental variable (IV) regression formula (1), introduced by [Cuellar, S. S., & Huffman, R., 2009], where the wine demand vary for price and income changes for the period. Random data are generated for the price and income using the Research Randomizer, a random number generator.

Table 8 Initial values for model variables

Variables	Value
Inventory on Hand	10000
Reorder Point	5000
Fixed Safety Stock	3000
Reorder Quantity	1000
Target Inventory Level	10000
Lead Time	5 days
Review Time Interval (Periodic Review)	30 days
Review Time Interval (Hybrid)	60 days
Reorder Point for Safety Stock	1000

$$\text{Cases}_{jt} = \beta_0 + \beta_1\text{Price}_{jt} + \beta_2\text{Income}_{jt} \qquad (1)$$

where; j = 1, 2, n weeks of year t=1, 2, n

Weekly demand for wine cases is taken as a fit for the normal distribution of a mean of 1430 with a 95% confidence level. To depict the effect of the unstable and variable demand, to demand distributions with the same mean demand but with two different coefficients of variance (CV) are considered.

Performance Measures

Each modelled inventory policy is measured for its performance against the below selected KPIs in terms of inventory depicted in Table 9.

Table 9 Key Performance Indicators

KPIs	Calculations
Fill Rate	$\frac{\text{Number of Fulfilled Orders}}{\text{Number of Orders Received}} \times 100\%$
Avg Reordering Cost per Week	$\frac{\text{Total Reordering Cost}}{\text{Number of Weeks for the Simulation Run}}$
Avg Backordering Penalty Cost per Week	$\frac{\text{Total Backordering Cost}}{\text{Number of Weeks for the Simulation Run}}$
Number of Stock Outs per Week	$\frac{\text{Total Number of Backorders}}{\text{Number of Weeks for the Simulation Run}}$

As depicted in Table 9, Fill Rate and the Number of Stock Outs per Week would show the level of customer satisfaction while the other cost based KPIs show the cost hidden in inventory decisions for each inventory policy. The backordering penalty cost per order is taken as $ 10000 and the reordering cost per reorder is taken as $ 20000 for simulation purposes. In each simulation run for each inventory policy model for the two CVs of wine demand, another specific variable is measured, the number of times orders are fulfilled the existing safety stock available in the DC.

Results of the Simulation Study

For each of the models the wine demand is of a 1430 mean per week and the replication length is 365 days. The two CVs for the two types of demand variability, high and low are 0.98 and 0.07 respectively. Results obtained from the simulation runs for each type of variability in demand for each three types of inventory policy models are depicted in Table 10, Table 11 and Table 12 below.

Table 10 Results for Continuous Review Model

KPIs and Variables	CV = 0.07	CV = 0.98
Avg Backorder Cost per Week	2547.95	2547.95
Avg Reorder Cost per Week	164.38	164.38
Fill rate	28.3%	32.1%
Number of Stock Outs per Week	1.79	1.79
Number of Times Orders Fulfilled from Safety Stock	6	8

According to the results for the continuous review model in Table 10, it is seen that there is no effect on the backorders and the reorders against the demand variation. But the under the high demand variations, the number of times orders are fulfilled from the safety stocks are high depicting the importance of availability of safety stocks in maintaining or achieving higher fill rates during high demand uncertainty.

Table 11 Results for the Periodic Review Model

KPIs and Variables	CV = 0.07	CV = 0.98
Avg Backorder Cost per Week	27.40	54.79
Avg Reorder Cost per Week	657.53	657.53
Fill rate	100.0%	100.0%
Number of Stock Outs per Week	0.02	0.04
Number of Times Orders Fulfilled from Safety Stock	2	4

Table 12 Results for the Hybrid Model

KPIs and Variables	CV = 0.07	CV = 0.98
Avg Backorder Cost per Week	0.00	82.19
Avg Reorder Cost per Week	328.77	328.77
Fill rate	100.0%	100.0%
Number of Stock Outs per Week	0	0.06
Number of Times Orders Fulfilled from Safety Stock	12	20

According to the results in Table 11 for the periodic review, it is seen under high demand variability, backorders have increased resulting in increase of backordering cost and the stock outs per week. It is also seen that the increment on the number of times orders are fulfilled from safety stocks have increased and that is the reason for maintaining higher fill rates under demand uncertainty. Increase in the number of stock outs have increased in high demand variation in the hybrid model as well and it is seen that the increment of the number of times the orders are filled using safety stocks have resulted in maintaining higher fill rates. This may be due to the continuous replenishment of the safety stock level in the hybrid model that has enabled fulfilling orders without stock outs despite the fact that the review period is higher than the periodic review model. According to the below Table 13, the inventory policy type that gives the favorable values for the two variables are depicted. It is seen that during the high demand variability, the hybrid model has been able to fulfill orders from the safety stock, while the periodic review has been able to reduce number of stock outs per week, both resulting in higher fill rate.

Table 13 Analysis of the Variables

Variables	Low Demand Variability	High Demand Variability
Number of Stock Outs per Week	Hybrid	Periodic
Number of Times Orders Fulfilled from Safety Stock	Hybrid	Hybrid

Conclusion

This paper shows the effect of the different inventory policies for the performance of WSCs, both in low and high demand variability through simulation. For the better management of the cost and the service level tradeoffs of inventory, the most appropriate inventory policies should be adopted. It is seen that, in demand uncertainties for WSCs, integration of both the continuous and periodic review policies could result in policies that present better performance than merely adopting one policy alone.

It is also concluded that the availability of safety stock is of higher importance under high demand uncertainties in WSCs to achieve a higher customer satisfaction level or fill rate. As the safety stock is not available for free, optimization of safety stock for WSCs under high demand uncertainties is highly important.

Further, this study while filling a vast knowledge gap for WSCs, enables the WSCs achieve one of the key objectives, reducing the cost of logistics activities by optimizing the level of the excess stock that is needed to be held within the supply chain under high demand uncertainties, introducing a computationally efficient GA with defined best parameters to solve the mathematical model for a product portfolio and most eminently, this study is the first instance of introducing a tuned GA focusing specifically on optimizing the safety stock level for a WSC. The tuned GA proposes that the average level of the safety stock to be maintained is about 20% of the average inventory for the developed test case. Thus the performance of WSCs is improved, leading to competitive advantage.

One suggestion for future research would be to integrate supplier and process uncertainties as well for this model as this study is only taking demand uncertainty in to consideration. Another way to enhance this study is to integrate more intrinsic and extrinsic characteristics of WSCs apart from the ones considered in this model.

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MULTI OBJECTIVE SUPPLY CHAIN NETWORK RECONFIGURATION UNDER DISRUPTIONS

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Abstract: Disruption in today's complex and global supply chain network (SCN) results in a negative impact on business performance. Companies try to manage disruptions by shifting the production/sourcing to undisrupted facilities, expanding the capacity at selected facilities, re-routing transportation and outsourcing the unmet demands. Models and methods to find a cost effective SCN reconfiguration to deal with disruption need attention. In this work, a SCN reconfiguration in a dynamic planning horizon under facility disruption is modelled mathematically with the objectives of minimizing the expected total cost and delivery time. The augmented ε-constraint method is proposed as a solution approach to obtain a set of Pareto optimal solutions. Numerical illustration with disruption scenarios is presented and our results show that facility with minimum distance to most customers serve majority of total customer demand. During disruption onset period, unmet demands are shifted to least utilised facility. During recovery periods, the facility with minimum distance to most customers is expanded to satisfy unmet demands. More capacity expansion occurred in minimum cost solution than in minimum time solution as more number of facilities are opened in latter than in former. The capacity utilization of facilities in minimum cost solutions are higher compared to that of minimum time solution.

Keywords: Supply chain network reconfiguration, facility disruption, capacity expansion, p-robust, multi-objective, multi-period

Introduction

Modern supply chains are cost oriented and many fail to consider the need for investing in disruption recovery management as they decrease the net profit. Past research in supply chain disruptions (refer Tang 2006 and Snyder et al., 2016) have focussed mainly on proactive mitigation approaches. It is difficult to justify the investments made in proactive disruption management from supply chain manager's perspective (Ghadge et al., 2015 and Dani, 2008).Reconfiguring the supply chain network (SCN) by managing with the available resources and restoring to normal working condition is a reactive disruption mitigation strategy (Blackhurst et al., 2005; Tang, 2006 and Baymout, 2014). Supply chain network reconfiguration (SCNR) under disruption includes strategies such as shifting the production to undisrupted facilities, capacity expansion at selected facilities, opening new facilities, inventory allocation, transportation rerouting and outsourcing unmet demand(Wilhelm et al., 2013; Thanh et al., 2008 and Melo et al., 2006). Recent reviews on facility location dynamics suggest that network reconfiguration under facility disruption risk as a high scope problem (Seyedhosseini et al., 2016 and Arabani & Farahani, 2012).Past SCNR models deal mainly with operational risks such as demand, supply, commodity price fluctuation, exchange rate and import tariff risks (Cortinhal et al., 2015; Pimentel et al., 2013; Melo et al., 2012, 2006 and Thanh et al., 2011). However, in practise the loss due to low probable catastrophic disruptions are significant as compared to repetitive operational risks. Ivanov et al., (2016) have presented a multi-stage SC re-planning model under facility and transportation disruptions considering gradual capacity recovery and disruption duration. The optimal proactive SC structure and recovery policies (such as opening new back-up suppliers, depots and transportation channels/modes and use of inventory and capacity buffers) against disruptions are determined using System dynamics and linear programming. Kristianto et al., (2014) developed a two stage stochastic program for designing a reconfigurable supply chain network under disruptions by optimal inventory allocation and transportation routing. Klibi & Martel, (2013) incorporated operational response and structural adaptation decisions (such as additional expediting, backorder and overtime recourse decisions) in each SC planning period and developed a multi-criteria design evaluation approach to select the most effective and robust SCND among candidate solutions. Summarizing from literature, clearly SCNR models considering facility disruption received limited attention (Ivanov et al., 2016, Kristianto et al., 2014 and Klibi & Martel, 2013). Motivated by this clear research gap, we develop a multi-objective multi-period SCNR model under facility disruptions. In particular, our model answers the following issues:

- Which facilities to open at the beginning of the planning period such that the expected cost of reconfiguration is restricted by a user- defined threshold i.e. p-robustness criteria(Snyder and Daskin, 2006 and Peng et al., 2011)
- How the material flow in SC should be directed in each planning period in the event of facility disruptions such that demand requirements are satisfied while minimizing cost and delivery time?
- When and which undisrupted facilities should be selected for capacity expansion?
- When and which customer's unmet demand should be outsourced?

Following the work of Peng et al., (2011),a p-robust mixed integer linear programming (MIP) model is developed with the objectives of minimizing the expected cost of reconfiguration and delivery time. The proposed model differs from the existing literature on SCNR in some directions. First, the existing models typically discuss proactive strategies such as backup suppliers, backup depots and transportation channels/ modes, inventory and capacity buffers and facility fortification against disruption. Whereas our model addresses recovery strategies like shifting production/ sourcing to undisrupted facilities, expanding capacity of undisrupted facilities and outsourcing demand to external facility. Second, our model incorporates a set of reconfiguration planning periods among the planning horizon following an onset of disruption during which the material flow is reassigned and SC structural adaptation decisions are made. To the best of our knowledge except the work of Klibi & Martel, (2013), all the above cited literature on SCNR models assume that SC structural adaptation decisions can be made anytime within the planning horizon to tackle the operational and disruption risks which are highly impractical. Third, most of the above mentioned reconfiguration models are single objective dealing either with SC cost minimization or profit maximization. Whereas our multi-objective recovery model finds a trade-off between minimising the expected cost of reconfiguration after the onset of a facility disruption while meeting the customer service level. Furthermore, SCNR models in literature use expected measures like expected cost, expected service level, etc. and mean-variance measures (Klibi & Martel, 2013) like Conditional Value-At-Risk and Value-At-Risk of the expected cost of the SC and cost variance. Models with robust measures like p-robustness, min-max cost and minimizing relative regret are limited. Our model minimizes expected cost and time such that the expected cost of reconfiguration is restricted in each disruption scenario by a user- defined threshold through p-robustness measure in the constraint (Peng et al., 2011).Thereby a robust SCND is generated before realization of any scenario that will perform efficiently under any disruption scenario after reconfiguring with optimal reactive strategy.

Finally, a number of solution approaches to the SCNR models have been proposed: commercial mathematical programming software (Melo et al., 2006), branch and bound (Huang & Goetschalckx, 2014), Benders decomposition (Kristianto et al., 2014), Lagrangian relaxation [22,29] and heuristics (Melo et al., 2012). Since commercial solvers are highly suitable for small and medium problem instances and heuristics and meta-heuristics are preferred for large scale problems to reduce computational time (Bashiri et al., 2012), our model uses the augmented ε-constraint method (Mavrotas & Florios, 2013) coded in GAMS 23.5 as a solution approach. The rest of the paper is organised as follows. In section 2, a multi-objective SCNR model is formulated. An illustrative example is presented in section 3. The results obtained using the augmented ε-constraint method is detailed in section 4. In section 5, conclusions and future research are discussed.

Problem description and model formulation

We model a three echelon supply chain network consisting of plants, transhipments and customers where a single product is delivered to various demand points over a finite planning horizon and the network is subjected to facility disruptions (Peng et al, 2011). Simultaneous facility disruptions are rare enough to be negligible (Schmitt, 2011). Disruption of single facility at a time is considered in our work. It is assumed that disruption is complete and once a facility is disrupted it doesn't recover. The planning horizon is assumed to cover a set of period t∈ (0, 1, 2… T). Along this horizon disruption may occur and reconfiguration decisions are made only in the planning periods $td^t \in T$. This disruption reconfiguration planning periods are assumed to be three periods following the works of Hendricks & Singhal, (2005), Losada et al., (2010, 2012), Sahebjamnia et al., (2015) and Torabi et al., (2015). The first period within reconfiguration planning horizon when disruption occurs is termed as 'onset period' and the remaining two periods are termed as 'recovery periods' as shown in figure 1.As our problem is long term strategic in nature where each period may represent one or more years, inventory decisions do not provide representative information and are not considered in the model i.e. material inflow at a facility is equal to its outflow (Pimentel et al., 2010).

The facility location decisions are made at the beginning of planning horizon (t_0) and remain unchanged. When the network is disrupted at period td^1, optimal reactive reconfiguration is arrived. Within reconfiguration planning horizon, unmet demands are satisfied either by shifting sourcing/ production to different undisrupted facilities, or by expanding capacity at selected facilities or by outsourcing to external facility. Outsourced products are directly delivered to customers. The capacity of external facility is assumed to be infinite (Cortinhal et al., 2015; Thanh et al., 2011, 2010,2008; Hinojosa et al., 2008).Capacity expansion at undisrupted facilities is not permitted during disruption onset period td^1 as it is not practically feasible to implement structural changes in short term immediately after the disruption (Melo etal., 2006 and Ivanov et al., 2016).

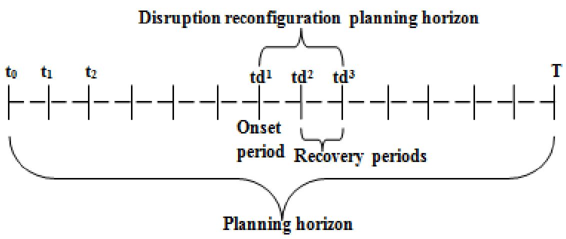

Figure 1: SCN reconfiguration and planning horizon

The specifications of the model are given below.

Indices

p Plants (p= 1,2,….P)

i Transhipment (i=1,2,….I)

l Customers (l= 1,2,….L)

t Planning horizon(t= 1,2,….T)

s Scenarios (s= 1,2,….S)

$\boldsymbol{pd_s^p}$ Set of disrupted plants 'p' in scenario's'

$\boldsymbol{id_s^i}$ Set of disrupted transhipments 'i' in scenario's'

$\boldsymbol{td_s^t}$ Set of disruption reconfiguration planning periods't' in scenario's'

$\boldsymbol{tr_s^t}$ Set of recovery periods't' in scenario's' $(\boldsymbol{tr_s^t \subset td_s^t})$

Parameters

$\boldsymbol{D_{tl}}$ Demand at customer l in period t

$\boldsymbol{\bar{K}_p}$ Initial capacity of plant p

$\boldsymbol{\bar{K}_i}$ Initial capacity of transhipment i

$\boldsymbol{\bar{\bar{K}}_p}$ Maximum allowed capacity at plant p

$\boldsymbol{\bar{\bar{K}}_i}$ Maximum allowed capacity at transhipment i

$\boldsymbol{q_s}$ Probability of scenario s

$\boldsymbol{f_p}$ Fixed cost of plant p

$\boldsymbol{f_i}$ Fixed cost of transhipment i

$\boldsymbol{Ct_{pi}}$ Unit transportation cost from plant p to transhipment i

$\boldsymbol{Ct_{il}}$ Unit transportation cost from transhipment i to customer l

$\boldsymbol{Cpt_l}$ Unit transportation cost from external facility to customer l

$\boldsymbol{Cn_{tp}}$ Unit new capacity addition cost at plant p in period t

$\boldsymbol{Cn_{ti}}$ Unit new capacity addition cost at transhipment i in period t

$\boldsymbol{Tt_{pi}}$ Transportation time from plant p to transhipment i

$\boldsymbol{Tt_{il}}$ Transportation time from transhipment i to customer l

$\boldsymbol{Tt_{l}}$ Transportation time from external facility to customer l

$\boldsymbol{fs_{stp}}$ Failure state of plant p in period t and in scenario s $\begin{cases} 1, & \text{if plant p disrupted} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{fs_{sti}}$ Failure state of transhipment i in period t and in scenario s $\begin{cases} 1, & \text{if transshipment i disrupted} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{maxt_{tpi}}, \boldsymbol{mint_{tpi}}$ Maximum and minimum limit of quantity of shipped from p to i in period t

$\boldsymbol{maxt_{til}}, \boldsymbol{mint_{til}}$ Maximum and minimum limit of quantity of shipped from i to l in period t

$\boldsymbol{maxn_{tp}}$, $\boldsymbol{minn_{tp}}$ Maximum and minimum limit of adding capacity at plant p in period t

$\boldsymbol{maxn_{ti}}$, $\boldsymbol{minn_{ti}}$ Maximum and minimum adding capacity at transhipment i in period t

$\boldsymbol{me_{p}}$, $\boldsymbol{me_{i}}$ Minimum capacity utilisation for a facility p /i if opened

Decision Variables

$\boldsymbol{Qt_{stpi}}$ Quantity transported from plant p to transhipment i in period t and in scenario s

$\boldsymbol{Qt_{stil}}$ Quantity transported from transhipment i to customer l in period t and in scenario s

$\boldsymbol{Qn_{stp}}$ Quantity of capacity added at plant p in period t under scenario s

$\boldsymbol{Qn_{sti}}$ Quantity of capacity added at transhipment i in period t under scenario s

$\boldsymbol{Qp_{stl}}$ Quantity supplied by external facility for customer l in period t in scenario s

$\boldsymbol{x_p} \begin{cases} 1, & \text{if plant p opens} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{x_i} \begin{cases} 1, & \text{if transhipment i opens} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{qt_{stpi}} \begin{cases} 1, & \text{if plant p transports to transshipment i in period t and scenario s} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{qt_{stil}} \begin{cases} 1, & \text{if transhipment i transports to customer l in period t and scenario s} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{qn_{stp}} \begin{cases} 1, & \text{if new capacity is built at plant p in period t and scenario s} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{qn_{sti}} \begin{cases} 1, & \text{if new capacity is built at transshipment i in period t and scenario s} \\ 0, & Otherwise \end{cases}$

$\boldsymbol{qp_{stl}} \begin{cases} 1, & \text{if demand of customer l is met by external facility in period t and scenario s} \\ 0, & Otherwise \end{cases}$

Mathematical model

Minimise

$$\sum_{p\in P} f_p x_p + \sum_{i\in I} f_i x_i + \sum_{s\in S} q_s \Bigg(\sum_{t\in T}\sum_{p\in P}\sum_{i\in I} Qt_{stpi}\, Ct_{pi} + \sum_{t\in T}\sum_{i\in I}\sum_{l\in L} Qt_{stil}\, Ct_{il} + \sum_{t\in T}\sum_{p\in P} Qn_{stp}\, Cn_{tp} + \sum_{t\in T}\sum_{i\in I} Qn_{sti}\, Cn_{ti} + \sum_{t\in T}\sum_{l\in L} Qp_{stl}\, Cp_{tl} \Bigg) \quad (\mathbf{1})$$

Minimise

$$\sum_{s\in S} q_s \Bigg(\sum_{t\in T}\sum_{p\in P}\sum_{i\in I} Tt_{pi}\, qt_{stpi} + \sum_{t\in T}\sum_{i\in I}\sum_{l\in L} Tt_{il}\, qt_{stil} + \sum_{t\in T}\sum_{l\in L} Tt_{l}\, qp_{stl} \Bigg) \quad (\mathbf{2})$$

Subjected to constraints

$$\sum_{p\in P} f_p x_p + \sum_{i\in I} f_i x_i + \sum_{t\in T}\sum_{p\in P}\sum_{i\in I} Qt_{stpi}\, Ct_{pi} + \sum_{t\in T}\sum_{i\in I}\sum_{l\in L} Qt_{stil}\, Ct_{il} + \sum_{t\in T}\sum_{p\in P} Qn_{stp} + \sum_{t\in T}\sum_{i\in I} Qn_{sti}\, Cn_{ti} + \sum_{t\in T}\sum_{l\in L} Qp_{stl}\, Cp_{tl} \le (1+p)C_s^* \forall \boldsymbol{s} \quad (\mathbf{3})$$

$$\sum_{i\in I} Qt_{stil} + Qp_{stl} = D_{tl} \forall\, \boldsymbol{s} \in \boldsymbol{S}, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{l} \in \boldsymbol{L} \quad (\mathbf{4})$$

$$\sum_{i\in I} Qt_{stpi} \le \left(\bar{K}_p x_p + \sum_{\tau=1}^{t} Qn_{s\tau p} \right)\left(1 - fs_{stp}\right) \quad \forall\, \boldsymbol{s} \in \boldsymbol{S}, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{p} \in \boldsymbol{P} \quad (\mathbf{5})$$

$$\sum_{i\in I} Qt_{stpi} \ge Me_p \left(\bar{K}_p x_p + \sum_{\tau=1}^{t} Qn_{s\tau p} \right)\left(1 - fs_{stp}\right) \quad \forall\, \boldsymbol{s} \in \boldsymbol{S}, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{p} \in \boldsymbol{P} \quad (\mathbf{6})$$

$$\sum_{l\in L} Qt_{stil} \le \left(\bar{K}_i x_i + \sum_{\tau=1}^{t} Qn_{s\tau i} \right)\left(1 - fs_{sti}\right) \quad \forall \boldsymbol{s} \in \boldsymbol{S}, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{i} \in \boldsymbol{I} \quad (\mathbf{7})$$

$$\sum_{l\in L} Qt_{stil} \geq Me_i\left(\bar{K}_i x_i + \sum_{\tau=1}^{t} Qn_{s\tau i}\right)(1 - fs_{sti}) \quad \forall\, \boldsymbol{s \in S, t \in T\ i \in I} \quad \mathbf{(8)}$$

$$\sum_{l\in L} Qt_{stil} = \sum_{p\in P} Qt_{stpi}\ \forall\, \boldsymbol{s \in S, t \in T, i \in I} \quad \mathbf{(9)}$$

$$Qn_{stp} = 0 \quad \forall\, \boldsymbol{s \in S, t \in T, p \in pd_s^p} \quad \mathbf{(10)}$$

$$Qn_{sti} = 0 \quad \forall\, \boldsymbol{s \in S, t \in T, i \in\ id_s^i} \quad \mathbf{(11)}$$

$$Qn_{stp} = 0 \quad \forall\, \boldsymbol{s \in S, t \in T \setminus tr_s^t, p \in P} \quad \mathbf{(12)}$$

$$Qn_{sti} = 0\ \forall\, \boldsymbol{s \in S, t \in T \setminus tr_s^t, i \in I} \quad \mathbf{(13)}$$

$$Qp_{stl} = 0 \quad \forall\, \boldsymbol{s \in S, t \in T \setminus td_s^t, l \in L} \quad \mathbf{(14)}$$

$$Qt_{stpi} \leq maxt_{tpi}\, qt_{stpi} \quad \forall \boldsymbol{s \in S, t \in T, p \in P, i \in I} \quad \mathbf{(15)}$$

$$Qt_{stpi} \geq mint_{tpi}\, qt_{stpi} \quad \forall \boldsymbol{s \in S, t \in T, p \in P, i \in I} \quad \mathbf{(16)}$$

$$Qt_{stil} \leq maxt_{til}\, qt_{stil} \quad \forall \boldsymbol{s \in S, t \in T, i \in I, l \in L} \quad \mathbf{(17)}$$

$$Qt_{stil} \geq mint_{til}\, qt_{stil} \quad \forall \boldsymbol{s \in S, t \in T, i \in I, l \in L} \quad \mathbf{(18)}$$

$$Qn_{stp} \leq maxn_{tp}\ qn_{stp} \quad \forall \boldsymbol{s \in S, t \in T, p \in P} \quad \mathbf{(19)}$$

$$Qn_{stp} \geq minn_{tp}\, qn_{stp} \quad \forall \boldsymbol{s \in S, t \in T, p \in P} \quad \mathbf{(20)}$$

$$Qn_{sti} \leq maxn_{ti}\ qn_{sti} \quad \forall \boldsymbol{s \in S, t \in T, i \in I} \quad \mathbf{(21)}$$

$$Qn_{sti} \geq minn_{ti}\, qn_{sti} \quad \forall\, \boldsymbol{s \in S, t \in T, i \in I} \quad \mathbf{(22)}$$

$$Qp_{stl} \leq D_{tl}\ qn_{stl} \quad \forall \boldsymbol{s \in S, t \in T, l \in L} \quad \mathbf{(23)}$$

$$qt_{stpi} \leq x_p \forall\, \boldsymbol{s \in S, t \in T, p \in P, i \in I}\ \mathbf{(24)}$$

$$qt_{stil} \leq x_i \forall \boldsymbol{s \in S, t \in T, i \in I, l \in L} \quad \mathbf{(25)}$$

$$qn_{stp} \leq x_p \forall \boldsymbol{s \in S, t \in T, p \in P} \quad \mathbf{(26)}$$

$$qn_{sti} \leq x_i\ \forall\, \boldsymbol{s \in S, t \in T, i \in I} \quad \mathbf{(27)}$$

$$Qt_{stpi}, Qt_{stil}, Qn_{stp}, Qn_{sti} \geq 0 \quad \forall\, \boldsymbol{s \in S, t \in T, p \in P, i \in I} \quad \mathbf{(28)}$$

$$qt_{stpi}, qt_{stil},\ qn_{stp},\ qn_{sti} \in 1{,}0 \quad \forall \boldsymbol{s \in S, t \in T, p \in P, i \in I} \quad \mathbf{(29)}$$

The objective function (1) minimizes the expected SCNR cost which consists of fixed costs of plants and transhipments, transportation costs from plants to transhipments and from transhipments to customers, capacity expansion cost and cost of outsourcing from external facility. Among the cost components, only the fixed cost of plants and transhipments are scenario and time independent. Objective function (2) minimizes the expected delivery time consisting of transportation time from plants to transhipments, from transhipments to customers and from external facility to customers. Transportation times between echelons are independent of quantity transported. Constraint (3) enforce the p-robustness criterion, requiring that the relative regret for scenario‘s’ may not be more than p % of deterministic optimal scenario cost. Let O(s) be the deterministic cost minimisation problem for each scenario‘s’ given in appendix A1 and C_s^* be the corresponding objective value for the problem. Constraint (4) states that customer demand can be met using products from the plants and outsourcing from external facility. Constraints (5 and 7) ensure that the total out-flow from a facility (plant and transhipment) does not exceed its capacity when opened and undisrupted in that scenario, and prevent any flow when it is closed or disrupted. Further, the second term on right side indicates the added new capacity after expansion. The set $'\tau'$ is an alias of set ‘t’. Constraints (6 and 8) ensure that a facility (plant and transhipment)is opened only if a least specified capacity is used. Constraint (9) ensures the material flow constraint for transhipment nodes. Constraint set (10 and 11) restricts adding new capacity at disrupted facility (plant and transhipment)and Constraint set (12 and 13) restricts adding new capacity during the planning periods other than disruption recovery periods. Constraint 14 ensures that outsourcing is not opted outside the reconfiguration planning horizon. Constraints (15-18 and 19-22) restrict the transportation arc capacity and capacity addition per period at facilities. Constraint 23 restricts maximum outsourced quantity to be less than corresponding customer’s demand. Constraint set (24-27) ensures that product flow and capacity expansion occur only in opened facilities. Constraints (28) and (29) are standard integrity and non negativity constraints.

Numerical example

We now demonstrate the proposed model, using data drawn from the literature where possible and available. A 3 echelon SC with 5 plants, 7 transshipments and 20 customers is considered. The planning horizon is assumed to have seven periods ($t_0$to t_6). The disruption scenarios are assumed to occur at period t_2 and hence reconfiguration planning periods include periodst_2 to t_4. A set of twelve scenarios with single facility disruption are generated. Scenarios s1-s5 considers plant disruption and scenarios s6-s12 consider transshipment disruptions.

The probabilities of scenarios are uniformly generated between (0,1).

Following Peng et al., (2011), each customer demand is uniformly drawn from (50,110). We calculate the total customer demands in the first period. This sum demand is then divided by |i| to determine average required supply from transshipments. The initial capacity of transshipment node is drawn uniformly from (2.5,3) of average required supply. Same procedure is followed for calculating initial capacity of plants. Following Thanh et al., 2008, the fixed cost for a facility is uniformly drawn from (60, 65) of initial capacity. The capacity expansion cost per unit (Melo et al., 2006) takes a value uniformly between (25, 50).The distance between facilities is drawn uniformly from (1,250).The transportation is assumed by road and the average transportation cost is assumed as INR Rs. 2/unit distance/unit quantity. The delivery time between source and destination nodes is assumed to be proportional to the distance between them.

Maximum allowable facility capacity after expansion is restricted to 1.5 times the initial capacity. Each facility per period can add no more than and no less than1/4 and 1/12 of its initial capacity (Thanh et al., 2008). The minimum capacity utilization for a facility to be opened is assumed as 20% (Badri et al., 2013). The outsourcing cost and time are given a large value of INR 2500 and 500 days respectively (Peng et al., 2011).The value of ‘p’ in robustness constraint is user-defined and is set as 0.22.

Results and discussions

The proposed model is solved using augmented ε-constraint method (Mavrotas, 2006) and is coded using GAMS 23.5.The Pareto front obtained is shown in figure 2.

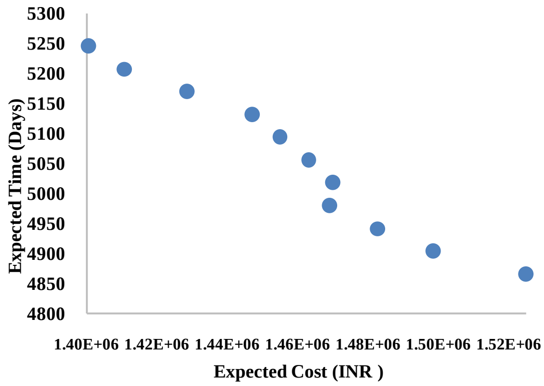

Fig. 2: The Pareto Front for the problem

The nominal scenario cost and time are INR 1458202 and 5159 days respectively. The results are further reported in terms of choice and capacity utilization of opened facilities after disruption with respect to generated Pareto solutions.

The Pareto solutions with the details of opened facilities are shown in table 1. In the obtained Pareto solutions, all plants ‘p1-p4’are opened except in the minimum cost solution and in a solution closer to ideal solution (1405793, 5207.09) identified following the work of Prasanna Venkatesan and Kumanan (2012). Similarly in all the solutions the transshipments ‘i1’-‘i7’ are opened.

Table 1: Pareto solutions with choice of facilities

Expected		Facilities opened	
Cost (INR)	**Time (Days)**	**Plants**	**Transshipment**
1395584	5244.89	2,3,4	1,2,3,4,5,6,7
1519998	4865.38	1,2,3,4	1,2,3,4,5,6,7
1405793	5207.09	2,3,4	1,2,3,4,5,6,7
1423687	5169	1,2,3,4	1,2,3,4,5,6,7
1442111	5131.08	1,2,3,4	1,2,3,4,5,6,7
1449894	5093	1,2,3,4	1,2,3,4,5,6,7
1458064	5055.29	1,2,3,4	1,2,3,4,5,6,7
1465111	5017.38	1,2,3,4	1,2,3,4,5,6,7
1464141	4979.4	1,2,3,4	1,2,3,4,5,6,7
1477787	4941.45	1,2,3,4	1,2,3,4,5,6,7
1493654	4903.5	1,2,3,4	1,2,3,4,5,6,7

The percentage of customer demand allocated to opened facilities and their capacity utilization during period ‘t_0’ in nominal scenario ‘s0’ are show in table 2for extreme solutions and solution closer to ideal point respectively. It is observed from table 2 that nearly 50% of customer’s total demand is satisfied by plant ‘p3’ at nominal scenario in all the three solutions. This is due to the fact that ‘p3’ is closer to all transshipment nodes and hence the variable transportation cost and delivery time are minimized.

Table 2: Percentage customer demand allocated to opened facilities and their capacity utilization during period 't_0' in nominal scenario 's0' for MC, MT and IP solutions

Pareto solutions	**MC**				**MT**				**IP**			
Periods	**Location with percentage of customer demand allocation of opened**		**Capacity Utilization of opened**		**Location with percentage of customer demand allocation of opened**		**Capacity Utilization of opened**		**Location with percentage of customer demand allocation of opened**		**Capacity Utilization of opened**	
	Plants	**Transshipments**	**Plants**	**Transshipments**	**Plants**	**Transshipments**	**Plants**	**Transshipments**	**Plants**	**Transshipments**	**Plants**	**Transshipments**
t_0	p2-19.3	i1-9.1	p2-0.366	i1-0.242	p1-17.9	i1-17.9	p1-0.296	i1-0.475	p2-19.3	i1-9.1	p2-0.366	i1-0.242
		i2- 12.8		i2-0.333		i2-12.8		i2-0.333		i2- 12.8		i2-0.333
	p3-55.7	i3-14.3	p3-0.974	i3-0.38	p2-10.6	i3--10	p2-0.201	i3-0.266	p3-55.7	i3-14.3	p3-0.974	i3-0.38
		i4-19.3		i4-0.507		i4-10.6		i4-0.279		i4-19.3		i4-0.507
	p4-25	i5-10.5	p4-0.428	i5-0.257	p3-42.3 p4-29.2	i5-10.5	p3-0.739 p4-0.52	i5-0.257	p4-25	i5-10.5	p4-0.428	i5-0.257
		i6-21.8		i6-0.523		i6-21.8		i6-0.523		i6-21.8		i6-0.523
		i7-12.2		i7-0.33		i7-17.5		i7-0.476		i7-12.2		i7-0.33
t_2	p2-20.8	i1-10.1	p2-0.372	i1-0.253	p1-19.5	i1-19.5	p1-0.305	i1-0.488	p2-11.2	i1-16.1	p2-0.201	i1-0.401
		i2-9.4		i2-0.232		i2-9.4		i2-0.232		i2-9.4		i2-0.232
	p3-59.2	i3-12	p3-0.975	i3-0.302	p2-11.4	i3-8.6	p2-0.205	i3-0.214	p3-59	i3-12	p3-0.97	i3-0.302
		i4-20.8		i4-0.516		i4-11.4		i4-0.284		i4-0		i4-0
	p4-19.9	i5-9.7	p4-0.322	i5-0.223	p3-45.6 p4-23.4	i5-9.7	p3-0.751 p4-0.377	i5-0.223	p4-29.8	i5-14.7	p4-0.481	i5-0.339
		i6--27.4		i6-0.62		i6-27.4		i6-0.62		i6-27.4		i6-0.62
		i7-10.5		i7-.269		i7-13.9		i7-0.356		i7-20.3		i7-0.521
t_3	p2-20.5	i1-8.8	p2-0.358	i1-0.214	p1-21.2	i1-21.2	p1-0.322	i1-0.515	p2-11.5	i1-14.6	p2-0.201	i1-0.356
		i2-10.1		i2-0.241		i2-10.1		i2-0.241		i2-10.1		i2-0.241
	p3- 59.8	i3-17.4	p3-0.958	i3-0.424	p2- 11.5	i3-10.9	p2-0.201	i3-0.265	p3-57.8	i3-17.4	p3-0.926	i3-0.424
		i4-20.5		i4-0.496		i4-11.5		i4-0.279		i4-0		i4-0
	p4-19.7	i5-9.4	p4-0.309	i5-0.211	p3-44.5 p4-24.1	i5-9.4	p3-0.713 p4-0.379	i5-0.211	p4-30.7	i5-13.1	p4-482	i5-0.294
		i6-24.2		i6-0.533		i6-24.2		i6-0.533		i6-24.2		i6-0.533
		i7-9.6		i7-.238		i7-14		i7-0.349		i7-20.5		i7-0.512
t_4	p2-24.1	i1-7.9	p2-0.437	i1-0.201	p1-23.3	i1-23.3	p1-0.367	i1-0.589	p2-11.1	i1-18	p2-0.201	i1-0.455
		i2- 8.1		i2-0.2		i2-8.1		i2-0.2		i2-8.1		i2-0.2
	p3- 58.9	i3-14	p3-0.98	i3-0.353	p2-11.1	i3-10.4	p2-0.201	i3-0.263	p3-63.6	i3-15.7	p3-1.059	i3-0.397
		i4-24.1		i4-0.605		i4-11.1		i4-0.279		i4-0		i4-0
	p4- 17.2	i5-12.2	p4-0.281	i5-0.284	p3-47.4 p4-20.7	i5-12.2	p3-0.789 p4-0.338	i5-0.284	p4-25.5	i5-16.3	p4-0.416	i5-0.379
		i6-24.8		i6-0.568		i6-24.8		i6-0.568		i6-24.8		i6-0.568
		i7-9.1		i7-0.236		i7-12.6		i7-0.327		i7-17.4		i7-0.45

During the disruption onset period ‘t_2’ where capacity expansion is not feasible, the unmet demands are fulfilled mainly by shifting them to least utilized facilities considering the transportation cost and delivery time. For example, in the minimum time solution, when plant ‘p4’ gets disrupted the under-utilized facilities ‘p1’ and ‘p2’ serves the disrupted facility’s demand (23.4% of total demand). It is found that the undisrupted facility ‘p1’ serves 20% of the demand while ‘p2’ serves the remaining 3.4% considering the transportation cost and delivery time. Also it is observed that during the recovery periods ‘t_3’ and ‘t_4’, capacity expansion occurs at facility ‘p3’ which is close to all transshipment nodes. More capacity expansion occurred in minimum cost solution as more number of facilities are opened in minimum time solution than minimum cost solution. Similarly the capacity utilization of facilities in minimum cost solutions are higher compared to that of minimum time solution.

Conclusion

We have developed a multi-objective SCN reconfiguration in a dynamic planning horizon under facility disruptions. The reconfiguration decisions considered are shifting customer demands to undisrupted facilities, outsourcing to external facility and capacity expansion at undisrupted facilities. The augmented ε-constraint method is proposed as a solution approach to obtain a set of Pareto optimal solutions of minimised expected network cost and delivery time. Numerical illustrations with findings are presented. One possible extension of our model is to study the reconfiguration decisions of more than one facility disruptions. Another direction for improvement could be consideration of partial facility disruptions and capacity recovery of disrupted facilities over a time period.

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Appendix

A1: The optimal scenario costs C_s^* are calculated by solving the model O(s) for each of the scenario‘s’.

O(s)

C_s^*= **Minimise**

$$\sum_{p\in P} f_p x_p + \sum_{i\in I} f_i x_i + \sum_{t\in T}\sum_{p\in P}\sum_{i\in I} Qt_{stpi}\, Ct_{pi} + \sum_{t\in T}\sum_{i\in I}\sum_{l\in L} Qt_{stil}\, Ct_{il} + \sum_{t\in T}\sum_{p\in P} Qn_{stp}\, Cn_{tp} + \sum_{t\in T}\sum_{i\in I} Qn_{sti}\, Cn_{ti} + \sum_{t\in T}\sum_{l\in L} Qp_{stl}\, Cp_{tl} \quad (30)$$

Subjected to constraints

$$\sum_{i\in I} Qt_{stil} + Qp_{stl} = D_{tl} \;\forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{l} \in \boldsymbol{L} \quad (31)$$

$$\sum_{i\in I} Qt_{stpi} \le \left(\bar{K}_p x_p + \sum_{\tau=1}^{t} Qn_{s\tau p}\right)\left(1 - fs_{stp}\right) \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{p} \in \boldsymbol{P} \quad (32)$$

$$\sum_{i\in I} Qt_{stpi} \ge Me_p\left(\bar{K}_p x_p + \sum_{\tau=1}^{t} Qn_{s\tau p}\right)\left(1 - fs_{stp}\right) \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{p} \in \boldsymbol{P} \quad (33)$$

$$\sum_{l\in L} Qt_{stil} \le \left(\bar{K}_i x_i + \sum_{\tau=1}^{t} Qn_{s\tau i}\right)\left(1 - fs_{sti}\right) \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{i} \in \boldsymbol{I} \quad (34)$$

$$\sum_{l\in L} Qt_{stil} \ge Me_i\left(\bar{K}_i x_i + \sum_{\tau=1}^{t} Qn_{s\tau i}\right)\left(1 - fs_{sti}\right) \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{i} \in \boldsymbol{I} \quad (35)$$

$$\sum_{l\in L} Qt_{stil} = \sum_{p\in P} Qt_{stpi} \;\forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{i} \in \boldsymbol{I} \quad (36)$$

$$Qn_{stp} = 0 \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{p} \in \boldsymbol{pd_s^p} \quad (37)$$

$$Qn_{sti} = 0 \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}\, \boldsymbol{i} \in \boldsymbol{id_s^i} \quad (38)$$

$$Qn_{stp} = 0 \quad \forall\, \boldsymbol{t} \in \boldsymbol{T} \setminus \boldsymbol{tr_s^t}, \boldsymbol{p} \in \boldsymbol{P} \quad (39)$$

$$Qn_{sti} = 0 \quad \forall\, \boldsymbol{t} \in \boldsymbol{T} \setminus \boldsymbol{tr_s^t}, \boldsymbol{i} \in \boldsymbol{I} \quad (40)$$

$$Qp_{stl} = 0 \;\forall\, \boldsymbol{t} \in \boldsymbol{T} \setminus \boldsymbol{td_s^t}, \boldsymbol{l} \in \boldsymbol{L} \quad (41)$$

$$Qt_{stpi} \le maxt_{tpi}\, qt_{stpi} \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P}, \boldsymbol{i} \in \boldsymbol{I} \quad (42)$$

$$Qt_{stpi} \ge mint_{tpi}\, qt_{stpi} \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P}, \boldsymbol{i} \in \boldsymbol{I} \quad (43)$$

$$Qt_{stil} \le maxt_{til}\, qt_{stil} \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{i} \in \boldsymbol{I}, \boldsymbol{l} \in \boldsymbol{L} \quad (44)$$

$$Qt_{stil} \ge mint_{til}\, qt_{stil} \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{i} \in \boldsymbol{I}, \boldsymbol{l} \in \boldsymbol{L} \quad (45)$$

$$Qn_{stp} \le maxn_{tp}\, qn_{stp} \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P} \quad (46)$$

$$Qn_{stp} \ge minn_{tp}\, qn_{stp} \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P} \quad (47)$$

$$Qn_{sti} \le maxn_{ti}\, qn_{sti} \quad \forall \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{i} \in \boldsymbol{I} \quad (48)$$

$$Qn_{sti} \ge minn_{ti}\, qn_{sti} \quad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{i} \in \boldsymbol{I} \quad (49)$$

$$Qp_{stl} \leq D_{tl}\, qn_{stl} \qquad \forall \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{l} \in \boldsymbol{L} \qquad (\mathbf{50})$$

$$qt_{stpi} \leq x_p \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P}, \boldsymbol{i} \in \boldsymbol{I} \qquad \mathbf{(51)}$$

$$qt_{stil} \leq x_i \forall \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{i} \in \boldsymbol{I}, \boldsymbol{l} \in \boldsymbol{L} \qquad \mathbf{(52)}$$

$$qn_{stp} \leq x_p \forall \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P} \qquad \mathbf{(53)}$$

$$qn_{sti} \leq x_i \; \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{i} \in \boldsymbol{I} \qquad \mathbf{(54)}$$

$$Qt_{stpi}, Qt_{stil}, Qn_{stp}, Qn_{sti} \geq 0 \qquad \forall\; \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P}, \boldsymbol{i} \in \boldsymbol{I} \qquad (\mathbf{55})$$

$$qt_{stpi}, qt_{stil}, qn_{stp}, qn_{sti} \in 1,0 \qquad \forall\, \boldsymbol{t} \in \boldsymbol{T}, \boldsymbol{p} \in \boldsymbol{P}, \boldsymbol{i} \in \boldsymbol{I} \qquad (\mathbf{56})$$

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USING AUTOMATION TECHNOLOGY AND IOT BASED DATA CAPTURING TO ENSURE HIGH QUALITY LAST MILE LOGISTICS

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Abstract: The customer facing leg, i.e. the Last Mile (LM), and field executive (FE) for any logistics company play a pivotal role in establishing a brand among its customers. It is imperative to have a robust and closely controlled LM for longevity of a company in the market. In the following paper, we present various sense-&-respond concepts and technologies that can be used to track and, in-turn, enhance the performance of individual LM resources. Sense-&-respond systems can lead to well-defined action plan enabling an efficient LM service, thus improving customer experience, curtailing unnecessary costs and improving safety of all stakeholders. The different modular and customizable solutions conceptualized and evaluated below include multiple IOT technologies, like camera based solutions, BLE beacons, GPS, and recorders, that can be employed to have a multi-point sensing in LM delivery service. We cover aspects, ranging from FE attendance, FE's disposition, track and trace of FEs in turn shipments, and route optimization, customers' and FEs' interaction and a feedback mechanism to allow for continuous improvement of customers' and FEs' experience.

Keywords: Last Mile (LM), Field Executive (FE), IOT, Sense-&-Respond

Introduction

Last Mile(LM) is the final leg in logistics, delivering the goods to the customer. The forward part starts from the local distribution centres and culminates at the customers' doorstep. There is also reverse logistics of picking up shipments from customers and dropping at the distribution centres for further processing. Due to factors like traffic congestion, multiple drop points, and low shipment density per customer, LM is often the most expensive(as shown in Fig 1.) and least efficient link in the supply chain, yet one of the most crucial as there is direct interaction with the customer. Any customer impression made in LM by the service or the interaction with the FE can impact future business from the particular customer. Having a swift, reliable, and customer friendly, yet cost effective LM service is critical for any logistics company looking for long term sustainability.

Morgan Stanley estimates the e-commerce market, in India, to grow over $100 Billion by 2020[2], with around 30% share of e-retailers, and over 300 million users. In the frenzy to capture the largest market share, most e-commerce companies are offering heavy discounts, leading to losses. To curb these losses, companies cut down operational costs. Customer experience centric initiatives, seem as additional costs in the short term, are often relatively neglected in such logistics companies.

It should be remembered that a firm may be cost efficient by optimally using its resources in producing a given mix of outputs. Despite being cost efficient, this firm may not realize maximum possible profits if it fails to estimate market demand correctly and, thus, produces outputs that do not effectively match customer needs (Krasnikov, Jayachand-ran, & Kumar, 2009[3]). To address this issue, profit efficiency was introduced as a more inclusive concept than cost efficiency (Berger, Cummins, and Weiss 1995[4]). Profit efficiency focuses on unobserved differences in the extent to which the output of different firms meets customer needs, and it accounts for the notion that some firms may incur additional costs in providing superior services and products but are rewarded for these efforts through higher revenues. In effect, the profit efficiency concept captures the cost of inputs required to produce a certain level of outputs and the additional revenues generated by producing outputs that are best suited to meeting customer needs. Following the same philosophy, proposed IOT based sense-and-respond methods will require cost investment by the firms but will over-time incentivise the firms by maximising their profits, through greater customer satisfaction and retention, and minimizing their losses, by enabling better trace and track capabilities.

Since LM delivery is a manual-labour intensive process, with FEs picking and dropping shipments between distribution centres and customers, it brings along multiple inefficacies and shrinkages accrued with manual processes. In developing economies, unstructured manpower accentuates theft related problems such as theft and intentional mistakes. With IOT based sense-and-respond systems, we can monitor the entire LM activity and material flow, and actively take corrective actions to maintain a strong LM service. Via this paper, we propose technologies to monitor and improve productivity of FEs, reduce misconduct, decrease FE related escalations, and improve FEs and customers' safety. In the next section, we realize what are some of the current metrics for the large players in the supply chain industry, focussed on Indian markets, and in the following section possible solutions are offered that may be employed to improve these metrics.

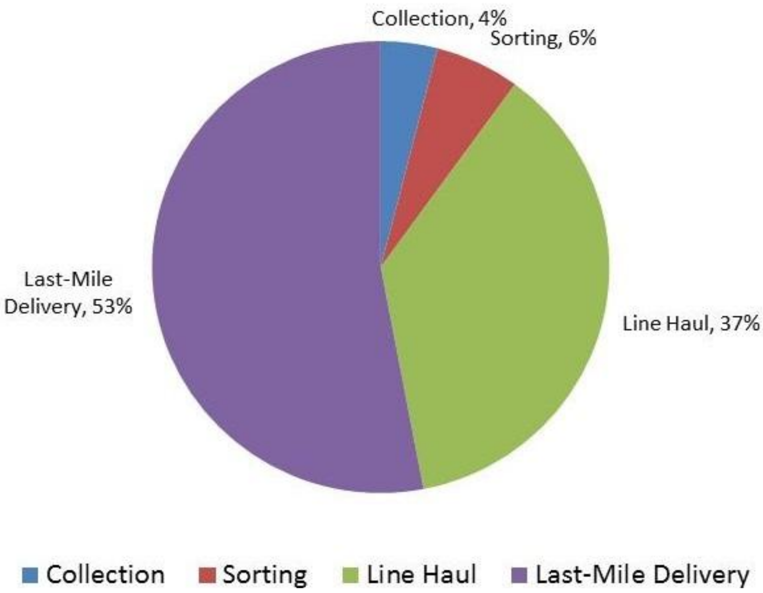

Figure 1. Industry wide cost breakup of logistics companies (Millar, 2005)[1]

Customer Relationship – The elusive challenge

"One thing Amazon [U.S.] has done very successfully [is that] they've owned the entire value chain. They've owned the last mile, the moment that matters - when the package arrives. Once you can own [that], you build a loyal customer base." – Sucharita Mulpuru, Forrester Research

Studies point that LM employees' performance can increase not only brand value but also regain/improve customer trust in the brand (Kuehner-Herbert, 2009[5]; Ind, 2004[6]), thus ensuring FEs' code of conduct is a priority for companies. Thompson and Maoz, 2005[7] suggest that 70% of spending for customer relationship in the coming years will be justified by its potential to increase efficiency. Customer specific initiatives requires additional resources. Profit efficient initiatives although, generate revenue that exceeds the additional costs. In effect, such initiatives enable firms to generate higher-quality products and services, possibly at higher costs. The proposed technologies, among other existing methods, facilitate efficient information flow between a firm and its customers by capturing and routing of relevant information to appropriate channels. Firms that have better relationships with customers enjoy higher profitability (e.g., Bolton 1998[8]; Reinartz, Thomas, and Kumar 2005[9]). With companies that maintains and executes better communication with their customers, their customers are likely to stay longer in the relationship with them, purchase more often, and show lower propensity to switch to competitors (Johnson and Selnes 2004[10]).

In developing economies like that of India, e-commerce is in a nascent stage, majorly due to reduced internet reach and the legacy of brick and mortar stores that offer a personal connect. Tangibility of the items in offline stored allows customers to experience the items before purchasing them. Due to this factor, online stores had to come up with lenient return policies and cash-on-delivery (COD) option. Currently around 80% of customers opt for COD. It leads to slower delivery service as each transaction takes extra time to complete. Companies set up customer care centers to guide customers and assay the escalations that could relate to FEs' attitude or product errors. A reliable delivery could provide confidence to customers to opt for pre-payment and curb call center costs.

In this study, we have targeted improving customer relationship through provision of efficient and reliable delivery, along with measures towards safety of both participants, i.e. FEs and customers.

Customer Experience

Withincreasing urbanization, changing customer priorities and propensity to spend, and increasing number of competitors, customer experience can prove to be a differentiator for companies wanting to stay in the business for long. Moreover, it can be a marketing tool through word of mouth and ways as described later. As per Cadwallader et al, 2010[11], customer perception of a brand depends on front line employees/administration behaviour, and attitude.

Given the large expanse of India and high population density, companies often prefer to locate distribution centers as close to the customers as possible. This is to limit customer per FE, hence, speedier and relatively easier for managing orders. Flip-side of such a highly distributed network is that since there are innumerable employees in the LM of a large logistics company, it is laborious and next to impossible to maintain a standard quality of operations through-out the network. Multiple firms have close-to-customer hubs or service centres with person in-charge to monitor 10-50 people under him / her. Beyond a certain configuration, it can be an arduous task for the hub in-charge and often leads to unintended lax or oversights. Moreover, on-the-field monitoring of FE's performance remains an almost impossible challenge to tackle. Through multiple surveys, scalations related to FE generally fall under:

- Unprofessional behaviour and dress
- Asking for tip
- FE denies coming to doorstep
- Delivers to wrong person (eg. security or relative) and does not record the same

Currently there is no evidence in case for conflict resolution. As it will be made clear in the following sections, technology can put eyes and ears on site and provide visibility through the entire LM leg.

Reliable Delivery

E-commerce thrives on convenience of shopping and getting items delivered at doorstep with just a few clicks. An unreliable LM service, with uncertainties in arrival time, making the customer wait or even pursue the delivery service can cause the e-retailers to lose customers. A reliable delivery service on the other hand offers tracking of the shipments, as well as, at the next level, assures slotted delivery, i.e. within the time slot decided with the customer.

Currently it takes on an average 6-7 days by Indian e-commerce companies (4-6 days for Flipkart shipments) [Red Seer Consulting report, 2016]. For most services, customer is unaware as to when the shipment is planned to arrive within the day and might not be available when the FE arrives. Besides, often the customer, due to either ignorance or intent, enters wrong pin codes in the address, which throws off the delivery service. The inability to perfectly coordinate with the FE and erroneous address details, leads to, at best, less productive LM, and, at worst, multiple failed attempts and even return of shipments that costs a company, across India e-commerce industry, directly around Rs. 49 per attempt [Red Seer Consulting report, 2016]. Add to that indirect costs such as customer escalations, for which a customer care must be set-up, and reduction of reorders.

A major contributor to the cost, and companies' troubles is failed and invalid attempts. As per various articles published in reputed newspapers, percentage of failed attempts can be between 15-20% in major cities and, even 30-40% in smaller towns[12,13,14]. IOT can help track FEs and in verifying the customer – FE interactions.

Safety

In multiple recent incidences, safety concerns have been raised for customers and even FEs (as they are put to harm's way if someone tries to steal the merchandize[15,16,17]). Once again companies feel help -less when it comes to tracking the event or collecting evidences.

Unwarranted delays, suspicious interactions and dubious transactions, can be recorded and monitored with IOT devices. They can assist in developing the back-end data analytics to proactively prevent any undesired incidences and alleviate the concerns.

Technology to the aid

Information drives decisions and policies. Without extensive data, any policy is merely a shot in the dark. Internet of things, through omnipresent network of sensors, bridges these gaps, connecting the entire network. The explosion of connected devices combined with central processing ecommerce platforms and adoption of common standards will only intensify the growth of IoT-enabled capabilities across the retail industry. Various sensors and systems can be employed to effectuate a reliable and customer centric LM logistics. Following list explores such sense-and-respond systems, through the LM delivery, focusing on the human element. Shipment tracking techno-logy such as RFID etc.

Vision based Attendance and Grooming Check

Cognizance of the attendance for the day is a basic requirement for any labour intensive company and is needed for a reliable delivery service. In LM, it allows planning the routes and responsibility for the FEs and disbursing salaries correctly. Often companies use either fingerprint based biometric machines, card readers or record it manually. Most reliable of course is biometric machine.

“Good grooming is integral and impeccable style is a must. If you don’t look the part, no one will want to give you time or money.” – Daymond John

In an internal survey, around 50% customers considered FE grooming as an important factor for perfect delivery, as it establishes trust on the FE. The FE for any company is not just some service or delivery personnel but is the customer facing brand ambassador. A positive demeanour and grooming inspires trust and respect for the person and the company tag he / she carries. Realizing this fact, companies often set grooming standards and uniforms to FEs.

Flipkart, like many other customer facing logistics companies, defines grooming parameters for the FEs. The norms encompass FE t-shirt, jacket, facial hair, and shoes, for a professional appearance. Accordingly, uniforms are provided to the FEs that project the brand. To ensure compliance, team leader appraises the FEs before assigning them tasks. It can take considerable amount of time (1-2 min per FE) to complete the associated task-list, and record data. Team leadersalso have considerable responsibility to control the LM of his / her area, Thus, due to lack of time or negligence, grooming check takes a back seat, leading to erroneous data.

To expedite the process, automated vision based attendance and grooming is being piloted at Flipkart distribution hubs where an FE is identified and his / her grooming score is generated based on the above-mentioned parameters. The scores are linked with the FE’s identity, in the ERP. Aside from savings on the biometric machines (which are often expensive), it can help reduce the operational costs by up to 10-12% per team (depending on the team size) a month.

Multiple options were explored to take the photos, using fixed cameras of different resolutions as well as mobile cameras. Each option entails associated complexities. Pilot yielded 100% accuracy in facial recognition and dress code check, and based on the chosen method, 70% - 99.8%accuracy for facial hair recognition(roof mounted 2MP camera being the least accurate, and selfie being the highest). The selfie based solution is easily scalable and has an expected payback period of 9 months.

GPS

All deliveries happen on either bikes or vans. GPS capability in the vehicles offers irrefutable benefits in logistics via asset tracking. GPS tracking helps in improving all three fronts – reliability, safety and customer experience thanks to following potentials:

1.<u>Route planning and monitoring</u>: First and foremost, mapping and en-route asset visibility allows real time route planning. This is exceptionally useful for short delivery services like food delivery, and multiple concierge services. Business model of cab services like Ola and Uber thrives on GPS enablement. Moreover, any deviations can be monitored and flagged. The outliers can be identified and respective actions can be initiated.

2. <u>Fleet management</u>: Real time positioning, allows coordinating FEs on road. Thus, re-routing, and task sharing is made possible by having GPS capability.

3. <u>Estimate time of delivery& real time updates</u>: Based on route planning and current position of the FE, prior intimations can be made to the customer and route can be re-planned in case of any issue. Customer can be ready in case on delivery or free

his/her schedule accordingly. This saves customers', as well as, FEs' time, hence positively impacts customer experience and FE productivity.

4. Fuel consumption: Fuel cost is a high contributor to total LM cost. Payments are often made per km. It has been observed that many vehicle owners manipulate odometers to display more than actual distances, by as much as 20%. Any such deviations can be tracked, and expected fuel consumption on the route can be compared with actual to reckon any fuel theft as well as control costs.

5. Address verification: In multiple incidences, customers intentionally, erroneously, or by ignorance, or enter wrong addresses or pin codes and call up the FE to follow a different route. This impacts FEs performance, and the following route and deliveries, hence adversely affecting the customer experience. By event based GPS pings, exact delivery locations can be marked for future reference and even analysing customer behaviour.

6. Vehicle and driver safety: As per Ministry of Road Transport & Highway, a serious road accident occurs every minute in India. Through real time visibility any events like over-speeding or unexpected delays can be tracked. Driving patterns can be recorded and appropriate action taken. It even enables theft capturing, of shipments (as for unexpected stops), and the vehicle.This can lead to 5-15% saving of insurance costs[18].

7. Evidence in case of delivery disputes: Escalations like False Attempts (e.g. FE did not arrive, customer absent etc.) can be resolved.

GPS capabilities and back end analytics can impact multiple aspects of transport logistics and are elevating from a luxury to a necessity. These capabilities positively impact LM planning, customer experience, maintaining FE performance, and other indirect cost savings.

Considering the many benefits, most of the logistics companies across the world have already employed GPS in their heavy vehicles. GPS capabilities have been tested and phase wise implementation is under progress in Flipkart. First phase was leveraging the GPS capabilities of FE mobile phones that has LM app. For regular delivery service, GPS ping is triggered during important events such as deliveries. For short pick-&-drop services such as food delivery, regular every minute ping was enabled, to allow complete route visibility to the customers.

Due to limited batteries, mobile devices, although, cannot be used for high accuracy GPS pings for continuous 8hours of operation. Pilots conducted showed a regular mobile phone can last about 6-7 hours at high accuracy GPS phone, with the most basic apps running. The duration gets reduced as the number of apps increase and the phones get older. As per tests, the accuracy of mobile phone GPS can range between 30m-50m on road. This encouraged us to test a standalone pocket GPS, with a long battery and 10m accuracy. Such GPS devices can be obtained off-the shelf at low cost and give an offline download of the entire route taken be the FE. Costs increase if GPRS is desired for live information.

Certainly, it is desirable to have asset free solution, that does not add any discomfort to the FE, but allows constant and real time information at high accuracy. This encouraged us to explore en-route charging option, as detailed under:

On the go Charging

Given the shift from paper based deliveries, to smart device based deliveries, with route-mapping, delivery schedules, taking signatures with time stamps etc, it is desired that the FE be connected all the time and his device can perform throughout the working hours. With multiple sensors like GPS (as mentioned above), BLE, accelerometers etc, it is becoming increasingly difficult to sustain the battery for such durations. This raises a requirement of either additional power banks or a method to keep the devices live. Power-banks, although, have limit-ations such as limited number of charging cycles and possible oversight in charging by the FE.

Almost 80% of the LM deliveries, in India, happen via motor bikes. Moreover, these bikes are owned by the FEs themselves. This pushes for the requirement of easily pluggable devices on the bikes

1. Battery adaptor: One of the possible solutions is a USB charger connected to the bike battery. Such economical chargers can be purchased easily.

2. Dynamo: In an internal survey, it was realized that many FEs were uncomfortable in withdrawing extra connections from their bike batteries. This led us to explore another economic yet reliable method to charge phones during movement, a bike mounted dynamo that converts rotational energy of wheels or the transmission system in the bike into electrical energy to charge the phone. Well-

designed dynamos can be easily mounted on the bikes before the shift and removed right after.

There are multiple variants available in the market for dynamos. A control circuit has been designed to use dynamos for charging phones and the entire system under exploration and tests. The hardware cost slower than INR 300 and is easy to maintain.

BLE

GPS cannot be used in indoor environments, and, as mentioned, is battery intensive. In such cases, BLE technology can be leveraged as a location signature for a building or location, to maintain a reliable LM. This is especially useful for short distance pick and drop, concierge and food deliveries where the FE must confirm his presence at the location.

BLE beacons' range varies between 10-12 m and distance between receiver and emitter can be computed using RSSI (Recieved Signal Strength Indicator) data. Due to this precision, BLE is being used by multiple retail stores across the world for area specific advertisements and discounts to shoppers. Moreover, they are used for localization of assets within the facility.

Today every delivery person carries a smart phone with Bluetooth connectivity. Inexpensive BLE beacons of around INR 700 can be installed at the vendors' locations and relevant information and orders can be pushed to the FE and the network, even if FE is unable to access internet on mobile device. This helps in optimizing information sharing and elimination of fake attempts and claims by FEs and vendors. Additionally, the beacons can be used to push advertisements and offers for the e-commerce sites or vendors to customers in vicinity of beacons, thus bring additional dimension of marketing and thus providing an alternate revenue source.

Voice Recorder

In all *customer - FE* interaction related escalations, companies find themselves at the receiving end, as the error or misconduct cannot be attributed to either the FE, or the customer. Moreover, in case of any safety concern or a crime, it becomes difficult to identify the wrong doer due to lack of evidence.

It is a regular practice to record call centre calls for training purposes and more. Similarly, a recording device with the FE that monitors the conversations and can raise flags during conversations can help identify unpleasant situations and provide evidence in case of any conflict. For handling large data, voice analytics software is used to identify tonalities, pitch, keywords etc and flag relevant conversations for further analysis. If implemented, multiple issues can be solved by monitoring the field conversations:

1. Reduction of Customer Escalations and improved CSAT (Customer SATisfaction) score: By setting conversational standards and using the recordings for training, customer-FE interaction can be made more professional and pleasant for the customers.
2. Shrinkage Capture: By analysing GPS data and recordings in tandem, point of theft and culprits involved can be identified. Through legal action, items may also be retrieved.
3. Customer retention: A customer happy with the service, who got the items he received as good condition, is more likely to re-order from the website
4. Safety of the FEs: If the recordings are being analysed in real time, unpleasant incidences can be identified as they happen. This can provide just enough time to take appropriate action.
5. Reduction in call centre costs: With reduced number of escalations, call centres can be offloaded.
6. Incident evidences - Legal advantages: In case of an unpleasant incident, ranging from arguments to safety concerns, recording of the incident can help implicate the culprit and take due action.

Legal approvals and customer consent must be considered before recording the conversations. We at Flipkart are currently exploring the legal implications of voice recorders thatwill be handled by local delivery centres.

Smart Lockers

Considering customers' privacy, unavailability of customers at mutually convenient time, and ease of package drops and retrievals, lockers are becoming a sensation in LM across the industry. They allow timely and assured delivery, affecting reliability and customer experience. Lockers can strategically be placed at various locations like shopping centres, metro and bus stations, grocery stores etc. and payment gateways can be enabled to facilitate even COD services. Customers can take the items at their convenience and, also, return them through these lockers. Through constantly changing locker pass codes, shipment security is maintained (Montreuil, and Faugere, 2016[19]).

During the testing phase, multiple features were tested. Some of the important parameters, but not limited to, that are advised to exist in the smart lockers, are :

- Constant CCTV camera monitoring
- Lan or 3G connectivity
- Parcel security measures including weight capture, door opening sensor
- As fail-safe, internal battery and option for offline information storage of customer and passcode information
- Possibility for cash-on-delivery through debit / credit card
- User friendly GUI for even amateur users
- NFC connectivity (future possibility)

Additionally, this serves as real estate for marketing and helps in increasing foot-fall in respective stores, thus a mutually beneficial scenario for all parties involved. Almost all major delivery companies across the world, including postal services, Amazon, Wall Mart, DHL, UPS etc., are investing heavily in smart lockers. In India, companies, like QikPod, Smart Box plan to have at least 50,000 lockers installed in India's 10 biggest cities. Use of Smart Lockers can reduce failed attempts, improve productivity of FEs by providing a single drop point for multiple shipments, allow users to receive shipments at their own convenience and allays their privacy concerns, and thus, reduce operational costs.

Conclusion

In this paper, we identified few of the existing inefficiencies, in the LM of any logistics, especially in Indian environments. that arise due to subjectivity of the customers and the tasks being highly labour intensive. These inefficacies can lead to shrinkages, inability to have a well-defined delivery plan, reduced customer satisfaction and trust, and reduced sales. To alleviate them, various technology solutions are explored and some case studies presented from different companies, including Flipkart.

The presented solutions are modular in nature and can work in parallel or in conjunction to bring the desired benefits. Based on their existing problems, and current status quo, supply chain companies, can pick and choose whichever solution gives most benefit. A simple heuristic approach is to pick and choose a custom solution relevant to the respective organization. For example, a nascent and relatively capital deprived company can start with only GPS and Smart Lockers as capabilities. As the strength and propensity to spend increases, the company can focus more on customer centric initiatives. Table 1 presents mapping of presented solutions to the issues that LM of a logistics company suffers.

Table 1: Solutions Summary

Category	**Problem**	**Possible Solutions**
Customer Experience	Undelivered packages	Smart Locker
	Rude behaviour	Voice recorder
	Unprofessional attitude	Voice recorder
	Unprofessional grooming	Auto Grooming Check
Reliability	Shipment to the wrong person	Voice recorder
	Fake attempts and incorrect delivery data	GPS BLE
	Erroneous customer address	GPS
	Low FE productivity	GPS Smart Locker
Safety	Accidents	GPS
	Theft or worse crimes	GPS Voice recorder

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LOGISTICS COLLABORATION SOLUTIONS TO IMPROVE SHORT FOOD SUPPLY CHAIN SOLUTION PERFORMANCE

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Abstract: In recent years, new forms of consumption alternative to conventional food systems have emerged across the world. These consumption patterns advocate consumption of local products, quality and the distribution with maximum one intermediary between the producer and the consumer or ideally nil. The objective of these consumption patterns, which is distributed through short food supply chain, is to reduce the externalities caused by conventional consumption modes. Many authors have shown, through analysis of case studies that the consumption of local products is not reducing automatically the negative externalities. The short food supply chain still faces many challenges in order to constitute a real alternative to the globalized food model. Among these challenges, the logistics is currently the main bottleneck for the development of this sector. The logistics become even more complex when it occurs in urban areas.

The objective of this paper is to understand the specificities and the constraints of the short food supply chain in order to design suitable logistic solutions to improve short food supply chain performance.

Keywords: local food system, short food system, performance

Introduction

Over the last few years, the conventional food system has been subject to much criticism. The criticisms include the negative impact of this system on the environment and on health, fears about food security, and the low pay of small-scale farmers (T. Bosona, 2013; Green & Phillips, 2014). In addition, consumers are demanding greater quality and traceability (Bantham & Oldham, 2003; T. G. Bosona & Gebresenbet, 2011). In recent years, new forms of consumption that are alternatives to the conventional food system have emerged across the world. Interest in local food has increased significantly. Kneafsey et al., 2013) cites a recent survey of European consumers, 90% of respondents (26,713 respondents) agreed to buy more local food (DG AGRI, 2011). However, more than half noted the difficulty of obtaining such products.

The objective of these alternative modes of consumption, which are distributed through the short food supply chain, is to reduce the externalities caused by conventional consumption modes. These new patterns allow consumers and producers to build relationships of trust (Policy Commission, 2002). It also supports small-scale farmers to diversify production, increasing value added, and ensuring more stable incomes. However, many authors have shown through analysis of case studies that the consumption of local products is not automatically reducing the negative externalities (Martinez, 2010; Mastronardi, Marino, Cavallo, & Giannelli, 2015; Renting et al., 2003) and did not contribute to improve economic and social performance. Some authors argue that this is because the local food system is characterised by small business with limited resources in terms of finance and knowledge. The short food supply chain still faces many challenges in order to constitute a real alternative to the globalised food model: the cost of logistics, the difficulty of complying with regulations, the difficulty to meet the requirements of customers in terms of quality, responsiveness, product availability and administrative burdens, etc. Among these challenges, logistics is currently the main bottleneck for the development of this sector (Ljungberg, Juriado, & Gebresenbet, 2013). Logistics becomes even more complex in urban areas. The conventional food chain has shown that logistics was a lever to improve supply chain performance. To optimise logistics, it has long since adopted the best practices such as third-party logistics solutions, Just-In-Time delivery, supply chain integration and electronic communication systems, transportation coordination, route optimisation and logistics integration (T. G. Bosona & Gebresenbet, 2011; Engelseth, 2016; Lacombe, 2013; Ljungberg et al., 2013).

Research question

The objective of this paper is to understand the specificities and the constraints of the short food supply chain and then, identify and analyse existing logistics collaboration solutions. From this research, authors propose a framework with a key factors to consider in setting up an effective collaborative system for short food supply chain.

This article will be organised as follows: first, the article focuses on reviewing literature on local food systems and the short food supply chain. This literature review allows us to understand the concept and the constraints of short food supply chain. Second, the paper identifies and describes collaboration logistic solutions applied in local food systems through desk research and semi-structured interviews conducted with stakeholders involved in the short food supply chain. Finally, the paper proposes a framework to establish an effective logistics collaboration in short food supply chain.

Literature review

Definition of short food supply chain and local food systems

Presently, there is no consensus regarding the exact definition of local food systems among academics, practitioners and politicians (Abate-Kassa & Peterson, 2011; Blanquart et al., 2010; Duault, 2014a; GONCALVES & ZEROUAL, 2014; Kneafsey et al., 2013). Several definitions of local food systems coexist in the literature. In this section, three main definitions are detailed, one based on the geographical location, the other on the number of intermediaries and the last on the proximity between the producer and the consumer.

Geographical location

This definition of the local food system focuses mainly on the geographical aspect of production and consumption, which must take place in the same area (Kneafsey et al., 2013). The main criticism of this definition is the fact that there is no consensus regarding geographical radius. This varies from 20 to 100 km depending on the region, the population density, but also the type of products. For fresh and perishable products, the distance must be as small as possible to ensure freshness and food safety (EC, 2013; Kneafsey et al., 2013; Martinez, 2010). Some other authors propose to use administrative delimitation such as the region, country, state and province rather than distance (Pinchot, 2014). In Anglo-Saxon countries, we often find reference of 100 miles, referring to movement 100-miles Diet (Merle & Mathilde, 2011).

Number of Intermediaries

Some authors define a local food system as a system by which the distribution is made with a supply chain composed by a maximum of one intermediary. This supply chain is called « Short food supply chain » (Marsden, Banks, & Bristow, 2000; Renting et al., 2003). This definition involves defining the concept of intermediaries. Some stakeholders such as logistics service providers do not see themselves as intermediaries since they do not own the products. (Marsden et al., 2000). This definition does not address the fact that the products were produced in a defined radius, but that the products have sufficiently clear and complete information on the area of production (producer, origin, quality, ect...). The quality of the product is more important than the geographical area of production. The reduced number of intermediaries guarantees consumers better reliability of such information.

Relationship between consumers and producers (proximity)

Other authors use the concept of "proximity between producers and consumers"to define a local food system. This concept of proposes a vision based on the existing relationship between producers and consumers. Prigent-Simonin (2012), proposed four dimensions to define the concept of proximity. (1) Geographic proximity: In addition to the notion of distance, they also cite the concept of time and ease of access. (2) Identity proximity: share the same values as the producers (protection of biodiversity, environmental protection, support small farmers). (3) Relational proximity: Exchange of product information, production and processing methods. (4) Process proximity: Knowledge of food production reinforces consumer's thoughts of product quality.

This research will adopt the definition of the local food system as a system in which, the distances and intermediaries are reduced as much as possible while keeping in mind the importance of the area of production, but also the need to establish social relationships between producers and consumers.

Potential Benefit of short food supply chain

Many benefits of local food systems have been identified in numerous studies (CoR, 2011). These benefits were observed in a social, economic as well as environmental dimension. (CoR, 2011; Kneafsey et al., 2013; Malandrin & Dvortsin, 2015)

Social benefits of local food systems

There are many social benefits associated with the emergence of local food systems. These benefits include improving social cohesion between producers and consumers, maintaining local farms, contributing to the development of local employment, promotion of the farming profession, improving the welfare of farmers and the independence of farmers. Nevertheless, some studies also show that the local food system can lead to a form of social exclusion. The local food system does not reach the entire population especially for the population who receive a low income. The high price of local food is the main cause (Duault, 2014b; Kneafsey et al., 2013)(Chiffoleau, Gauche, & Ollivier, 2013). (Brown et al ; 2009 Macias 2008).

Economic benefits of local food systems

Many studies have highlighted the economic impact of the development of the local food system. It has been shown through the multiplier effect that the local economy is boosted by the development of a local food system by increasing revenues of producers and creating local jobs (Pinchot, 2014). Buying locally increases sales, which has the effect of increased spending on other local sectors (transport, shopping and tourism). Finally, in the employment sector, jobs are created either directly in the agricultural sector or in other sectors (transport, local shops and commodities).

A study on the potential for job creation in the region of Brussels (Belgium) estimated that the development of a local food system in the Brussels-Capital Region could lead to the creation of more than 7000 jobs in the food sector (approximately 3000 currently) (Verdonck, Taymans, Chapelle, Dartevelle, & Zaoui, 2014).

Environmental benefits of local food systems

The environmental benefits refer to the efforts put in place to reduce the ecological footprint of food in a region. It is recognised that the food industry is responsible for numerous environmental externalities. Several studies have shown that the production process is the one that generates the most impact in terms of emissions of greenhouse gases (57%) compared to 17% for the distribution process, which can be higher if non-optimisation of distribution (low fill rate, empty returns, storage, ect…) is taken into account (Duault, 2014a).

The results of the environmental benefits of local food systems are highly variable depending on the products analysed, the agricultural mode, transportation mode, the data used, but also the scope of the study (Edwards-Jones et al., 2008). Some authors believe that the local food system reduces environmental impact through the reduction of GHG (Van Hauwermeiren et al. 2007; Pelletier et al. 2011) while others estimated that it has no positive effect on the environment due to the low volume (Kneafsey et al., 2013), (Duault, 2014a). Moreover, Lacombe, (2013) highlights that empty returns of trucks, consumer movements to the point of sale and the increase of cold rooms for many local food system does not allow stakeholders to significantly reduce GHG. These inefficiencies result primarily from the absence of formal logistics and a lack of optimisation of logistics activities (Blanquart et al., 2010).

As shown in the literature, there are real benefits to the development of a local food system, but it is not always obvious to highlight these benefits due to lack of accurate data. The impact assessment carried out on a social, economic and environmental level shows that better optimisation of logistics is a key factor to improve performance for the short food supply chain.

Methodologies

To identify collaboration logistic solutions in the short food supply chain, two approaches were used: First, a "top-down" approach which consists of identifying in the literature, logistics solutions applied in short food supply chains. Second, a "Bottom-up" approach which consists of analysing local food initiatives in order to highlight logistics practices. These tasks will provide an overview of the existing logistics solutions in the short food supply chain.

Scope of the study

This study focuses only on logistics activities dedicated to the distribution of finished food products from the producer to the consumer. This implies that this study will not focus on upstream harvesting activities. The main reason is that these activities come under agronomy studies. In addition, this study does not cover food processing activities. The reason is the existence of the great diversity of practices. This study will focus on the finished product released from the food processors. Case study analysis and interviews with stakeholders will be mainly based on the European experience of local food systems with a special focus on Belgium and France.

Stakeholders description

Before analysing the logistics solutions applied in the short food supply chain, this article identifies the main stakeholders in the sector. It is proposed to group the stakeholders of local food into four categories: (1) Shippers (2) Intermediaries (3) Third Party logistics and (4) Receivers. There are other stakeholders involved indirectly in the short food supply chain, for example public authorities (regulations, laws), regulatory agencies (regulations, controls), research centres (Research & Development), financial institutions (financing). Despite the importance of these actors, they are not the subject of analysis in this paper (Nomathemba, 2010)(Schiefer, 2011)(Christy, Mabaya, Mutambatsere, & Mhlanga, 2009).

Shippers

By definition, shippers are stakeholders who entrust their own product to other stakeholders to ensure delivery to the final destination. In the SFSC, they are all stakeholders who produce local food. These are commonly called "*producers*".

Among the producers, it is possible to distinguish local farmers (mainly vegetable producers and fruit growers), livestock farmers (poultry, meat and fish) and processors (bakers, beverages and dairy products) (Chandrasekaran & Raghuram, 2014; Rao, 2006; Srinivas, Ramanathan, Ayireddy, Taneja, & Sitaram, 2009). Included in this category are producer cooperatives.

Intermediaries

Intermediaries are defined as stakeholders who make purchases from producers and resell them to other stakeholders (mainly business customers). In the local food system, intermediaries are mainly food wholesalers or distributors (Dooley & Foltz, 2012).

Receivers

By definition, receivers are stakeholders who receive food products they ordered from producers or wholesalers. Trienekens & al., (2008) indicate that their position gives them some power over other supply chain stakeholders in the sense that they have access to crucial information about the needs of end consumers. In this category, there are, for example, Community-supported agriculture groups (CSA), grocery stores, conventional supermarkets, restaurants and collective restaurants.

Third Party Logistics

These stakeholders offer logistics services (inventory, transport, order management, ect…) to other companies. In the SFSC, the logistics service providers pay particular attention to offering services that meet the needs of this sector by providing eco-friendly services (low-emission vehicles, recyclable packaging, cyclocargo, ect…) with a positive social impact and tailored to small business.

Typologies of short food supply chain

In a SFSC, consumers are reached through different distribution channels. In this work, the classification proposed by Chiffoleau et al., (2013) is adopted. This classification is based on the one hand, on either the absence or presence of an intermediary between the producer and consumer, respectively direct and indirect distribution. Then, the authors distinguish within each category, an individual or collective dimension of the distribution. Four distribution channels of local food systems are identified each distribution channel has very specific characteristics, challenges and needs in terms of logistics organisation (Aubry, Bressoud, & Petit, 2011).

Direct Distribution – individual

This category includes all the direct distribution to the end consumers (e.g. Farmers' Markets, Internet sales and individual baskets). The volumes sold through this distribution are generally quite low. Consumers who buy through this channel mainly want to meet producers and know more about the production process. This is for them a guarantee of good quality products. There are no formal logistics for this type of distribution.

Indirect Distribution – individual

This channel provides local food to consumers through collective organisations. (Consumer or producer organisations). This channel of distribution generates greater volumes since there is a scale effect in the grouping of orders by those organisations. Receivers in this channel are looking to buy a wider range of local products at a more affordable price. Moreover, they expect some flexibility in terms of distribution according to their availability (evenings or weekends). Logistics activities in this channel are relatively informal and characterised by high inefficiency (Aubry et al., 2011).

Indirect distribution – individual

This type of distribution is performed through intermediaries who sell local products to the final consumers. Those intermediaries are mainly stores, grocery stores, supermarkets and wholesalers. The final consumers who buy local food through this channel are looking for good quality products and need to be regularly supplied to prevent stock-outs. The retail sector is more demanding regarding the respect of delivery schedules to ensure complex planning in this sector.

Indirect distribution – collective

This is a distribution channel via collective intermediaries as HORECA and collective restaurants (private and public canteens). These intermediaries require large volumes, a wide range of products and at low prices (Bresson, 2012). Moreover, they require from producers, very strict compliance with food hygiene standards. In terms of logistics performance, regularity and punctuality of deliveries are needed to prepare meals on time. Table 1 shows the characteristics of each distribution channel in terms of volume, product diversity, flexibility, logistics and the purchase price (Duault, 2014a).

Table 1: Characteristics of local food system distribution channel (Adapted from Duault, 2014a)

Distribution Channel		Volume	Diversity	Flexibility	Price
Direct Distribution	Individual	Low	High	High	High
	Collective	Mid	High	High	Mid
Indirect Distribution	Individual	Mid	Mid	Mid	Mid
	Collective	High	Low	Low	Low

Collaboration logistics solutions used in short food system

Below the paper proposes an analysis of the various collaborationlogistic solutions used in the SFSC. These solutions have been identified in the literature and from discussions with the stakeholders of the local food system.

Much research has already been carried out on the potential for collaboration to improve logistics in the short food supply chain (BLANQUART, Gonçalves, Raton, & Vaillant, 2015; Duault, 2014a). This research has clearly shown interest in collaboration in terms of cost reduction, reduction of externalities and the impact on competitiveness (Christopher, 1999). Case analysis of a logistics collaborative study on the conventional supply chain was able to show that it is possible to reduce on average 30% of logistics costs (Guinouet, Jordans, & Cruijssen, 2012; Lacombe, 2013).

The surveys of farmers show that they are generally reluctant to collaborate. The main reasons include lack of trust between stakeholders, fear of loss of their independence, singularity of their distribution network, lack of tools and cost-sharing methods (BLANQUART et al., 2015; Duault, 2014a).

There are two types of collaboration: (1) horizontal collaboration in which several players, having the characteristics, as competitors, collaborate in order to improve overall logistics performance of each actor involved in this collaboration (collaboration in increasing purchasing volumes and infrastructure sharing). (2) Vertical collaboration which is between the actors within the same supply chain. This mainly concerns the sharing of information between the actors involved in this collaboration (Ozener, 2008).

Horizontal collaboration between producers

In the literature there are several forms of collaboration between producers. This collaboration mainly covers sharing of logistics infrastructure (vehicles, storage and management tools).

Logistics facilities sharing can be done in several processes (storage, transport and sales). The main reason for sharing logistics facilities is the underutilisation of available capacity and the high-cost investment and management of these facilities (Gonzalez-Feliu & Morana, 2011).

Collaborative Warehouse

Storage is a critical process in logistics performance. It is one of the largest sources of costs in the supply chain. It is estimated to represent 20% to 30% of costs through the cost of ownership of inventory. This is especially important when it concerns perishable products that require temperature-controlled storage conditions. Moreover, improved inventory management avoids stockouts and thereby improves customer satisfaction. Sharing storage space is a collaboration solution that enables actors to reduce costs and improve the supply chain performance of actors involved. There are many forms of storage space sharing (cross-dock, regional platforms, urban consolidation centres or urban logistics spaces). Nevertheless, Gonzalez-Feliu & Morana (2011) stress the importance of the availability of reliable, updated and complete information as a key success factor of a logistics partnership and as well as trust between actors involved in the collaboration.

In local food systems, inventories can be found at all levels of the supply chain, from the producer (storage of harvested products) to point of sale (storage of products to sales). Given the cost and complexity associated with managing a stock, more collaboration solutions have emerged. Two main practices were identified. First, the producer who offers to other producers their unused storage space. This is usually a form of informal collaboration between producers who are located in the same region and know one another very well. The second solution is the sharing of storage space belonging to a cooperative. This collaboration for storage has the advantage of reducing inventory and compliance costs (MESSMER, 2013).

Collaboration in the Transport and distribution system

The main benefit of transport collaboration is increasing vehicle fill rates and thus reducing transport costs (Ozener, 2008). Transportation and distribution management remain the most expensive and complicated process for the actors of the SFSC. Some studies show that these processes can represent over 40% of turnover, while on average in the food sector they are more than 10% to 15% (Raton et al., 2015). Many actors, especially farmers, do not calculate the costs of transport (MESSMER, 2013). Therefore, they have no idea of these costs, so they cannot undertake this process. To improve transport performance, collaboration is the solution most cited in the literature. On average a 30% reduction in kilometres travelled compared to individual transport is observed (Lacombe, 2013). There are many forms of collaboration in transport for producers. These range from sharing a vehicle under-exploited with other producers to the joint purchase and management of a vehicle by a farmers' cooperative (BLANQUART et al., 2015).

Sharing a Vehicle

Sharing a vehicle involves using a vehicle belonging to a farmer to transport products from other farmers. Either a farmer makes a tour to get products from other farmers or everyone brings products to the farmer-carrier. This type of collaboration requires effective organisation and the implementation of cost-sharing methods to avoid potential conflicts and ensure sustainability of this system. Moreover, this system is only possible for farmers who are in the same area and are confident enough to avoid competition problems.

When a third person transports goods that do not belong them, it is a transport for hire or reward. This type of transport is governed by most national legislation (Regulation (EC) No 1071/2009 and the Belgium Law of 15 July 2013). To avoid administrative burdens and encourage collaboration, an exemption has been established for the local food system. This allows producers to transport products to third parties without profit (they can request compensation to cover the costs), without complying with transportation regulations related to transport for hire or reward (AFSCA, 2015a). Special attention should be given to the transportation of incompatible products. The regulations required to ensure effective separation so that there is no risk of cross contamination during transportation.

Jointly purchase a vehicle

This form of transport under collaboration consists of the acquisition of a transport vehicle by a cooperative or group of farmers. In France and Belgium, this form of jointly purchased agricultural equipment is called CUMA (Coopérative d'Utilisation de Matériel). One of the main advantages is that this collaboration can benefit from public aid. In the Wallonia Region (Belgium), this aid is equal to 25% of eligible investments (Wallonie Élevages, 2012).

At the organisational level, farmers can use the vehicle in turn or go further by hiring a driver as in the case of CUMA "Terroirs sur la route" in the Loire-Atlantique in France. This CUMA acquire a truck and hire an employee driver for the transport of goods of farmers who are members of this CUMA (Terroirs44, 2016)(Lacombe, 2013). The latter organisation is more complicated to implement, because it requires a management system to be set up taking into account the constraints of each member. Other advantages are: a faster return on investment, the offloading of transport activities for the farmer (if the CUMA hires a driver). However, to succeed, lessons learned from other experiences show that it is necessary to establish information flow management systems to establish precise timetables and vehicle usage monitoring. This avoids conflicts of use and results in better cost allocation.

Horizontal collaboration between producers

From the receiver’s side, there are also different forms of logistics collaboration. This collaboration takes place mainly on sourcing processes. In this process, the collaboration focuses on the management of orders and storage of products received from suppliers (producers, processors or wholesalers).

Storage

Receivers must ensure the storage of products they receive until consumers come to take or buy them. The management of storage space and more particularly a refrigerated storage represents high costs. Pooling of storage spaces reduces storage costs for receivers, but also facilitates the work of producers who can deliver to one delivery point. From this deposit point, other receivers can pick up their products with eco-friendlier means of transport (cycling and walking). This type of collaboration has the advantage of reducing costs related to the management and total cost of ownership. Moreover, delivery of the last mile is facilitated by the grouping of products in one place. However, this collaboration is only possible with good coordination between receivers and setting up tools to share costs and risks.

Order management

Collaboration on order management involves pooling orders in order to reduce the costs of placing orders. Some actors involved support small producers, such as groups of CSA, through this collaboration the market improves for producers. This solution contributes to reducing administrative tasks related to orders.

Transport

Some receivers like shops, grocery stores…pick up the products themselves because producers don't have means of transport or that because the order quantity is not sufficient for the producer to make the delivery. Receivers can organise to pool the transportation of products they buy from the same producer.

Vertical collaboration between stakeholders

As explained above, vertical collaboration occurs when stakeholders in the same supply chain collaborate. This collaboration involves the sharing of information of logistics flows to improve logistics performance. In local food systems, information shared focuses on consumer demand, producers' offers and information about the distribution network.

Consumers' demand

In terms of demand, some producers use internet (websites, social media, ect…) to gather and understand consumers' needs. These systems have the advantage of being easy to use for consumers (Lacombe, 2013). Consumers groups like CSA, establish long-term contracts with producers. Members of these groups order products in advance for periods ranging from 3 to 6 months. This practice also allows the producer to ensure stable income for a greater period of time.

Producers' offer

To improve their market opportunities, producers are marketing their products on the internet (website, social media) to a greater extent. On these platforms, consumers can find product descriptions, prices and sometimes an online payment system. While these tools are easy to use for consumers, they represent an investment for the installation, maintenance, and time to regularly update the website. To overcome these issues, several businesses have emerged. They offer common online marketplaces and allow reduced costs and reach a larger number of consumers. "la Ruche qui dit OUI", "topino" and "Efarmz" are some examples. Despite the benefit related to the sharing of these catalogues, some criticise these initiatives due to the lack of transparency in the margins applied, but also the lack of commitment to ensure stable revenues for the producers (De La Héronnière, 2016).

Sharing of information related to distribution network

The sharing of information on the distribution network (customers, orders, tours, date and frequency of deliveries) allows better visibility of logistics flows and facilitates logistics collaboration between local food system's stakeholders. This type of data sharing is more complicated to implement because it involves sensitive information which can constitute a competitive advantage. Substantial work in upstream is needed in order to raise awareness of the benefits of sharing these types of information and establish a reliable platform that allows stakeholders to share information safely. The "Open Food Network" platform is an example that proposes a system in which producers, food hubs and consumers can share information in order to stimulate logistics collaboration.

Table 2: Overview of logistics collaboration solutions from the literature review

	Type	Solution	Examples
Vertical collaboration	Consumer’s demand	website, Social media,	Farmer’s websites and social media
	Producer’s offers	marketplaces, websites	Ruche qui dit Oui (BE, FR); Topino (BE); Efarmz (BE)
	Logistics information’s	digital platform	OpenFood Network (AU, FR, UK,…)
Horizontal collaboration	Between producers	collaborative warehouse	Agricovert (BE)
		transport and distribution collaboration	Association Manger-Fermier (FR)
		sharing vehicle	n.a
		jointly purchased vehicle	Cuma des Terroirs Mayennais (FR)
	Between receivers	sharing storage space	Heureux Nouveau (BE)
		bulk purchase	GASAP (BE)
		transportation collaboration	Beescoop (BE)

Analysis of logistics solutions

Table 2 shows the analysis of the relevance of each logistic solution with respect to different distribution channels. Horizontal collaboration between producers (HC/P) is a solution that requires a lot of coordination, but could meet the needs of all distribution channels, especially in direct distribution where logistics facilities (vehicles and stock) are underused due to low volume or inefficiency of logistics. Horizontal collaboration between receivers is suitable for consumers or consumer groups (CSA) because the issues related to confidentiality or competition are lower in these categories. Vertical collaboration (VC) is an appropriate solution for all distribution channels. The sharing of information is important to enable all other collaboration solutions. However, to share information in an efficient manner, a reliable information system is needed.

This paper is aware that this analysis based on classification provided by (Chiffoleau et al., 2013) can obscure details of some specific actors who have special needs such as sales through the internet platform such as « *Ruche qui dit OUI* », the distribution of the HORECA and distribution to supermarkets. These are important and need to be considered in future research, particularly through quantitative and qualitative surveys of stakeholders of local food systems. From the collected data, a multi-criteria and multi-actor analysis is required to confirm the analysispresented in this article but also to quantify the relevance of the solutions according to each actor.

Table 3: Relevance of logistics solutions regarding the distribution channel (+Adequate,+++ Very Adequate, ,+++ Strongly Adequate)

		H.C/P	H.C/R	V.C
Direct distribution	Individual (e.g. : Baskets…)	+++	+++	++
	Collective (e.g.: CSA..)	+++	++	+++
Indirect distribution	Individual (e.g. : Grocery..)	++	+	+++
	Collective (e.g.: HORECA...)	++	+	+++

Collaboration framework in the short food supply chain

This analysis has been used in the "Choud'Brussels project" which is a research project supported by the Brussels Region. It's aimed to set up a collaborative logistics solutions suit for distribution of local food in the Brussels-Capital Region in order to reduce logistics costs as well as the negative impact of transportation activities in Brussels. So far, several meetings and workshops were held with stakeholders. The first results have highlighted the main key factors to consider in setting up an effective collaborative system especially between producers.

Vertical collaboration key factors

The main difficulty encountered in the exchange of information between stakeholders in short food supply chain is the lack of knowledge of producers in the usage of digital solutions. Indeed, since they are at the origin information flows, it is important that they provide reliable information to other stakeholders in the supply chain. Today, as demonstrated the analysis of this paper, producers are led to manage a multitude of tools to exchange information with other stakeholders (marketplaces, telephones, mail, websites, social media...). In order to set up an effective information exchange system, producers need a tool which allows to centralize all information flow (orders, deliveries, availability of products, etc.). Moreover, to facilitate the adoption of such a tool, it must include other functionalities which help producers to manage its internal processes (Forecasting, delivery management, returns management, ...). However, this tool should not be an additional burden for producers, but rather a means of reducing administrative tasks (standardized information and documents).

In addition, particular attention must be paid to the usability of this tool. Indeed, due to the fact that producers are not used to digital solutions and don't want to spend more time in the handling of this tool, it is essential to design this tool as user-friendly as possible.

Horizontal collaboration key success factors

In our investigation, we noticed that several local producers were willing to collaborate but did not know how to identify the right partner. This is due to a lack of visibility and a lack of information exchange between producers. At the same time, producers have expressed their need to keep control of their processes and also a lack of confidence in others producers.It is therefore important to build bonds of trust between potential partners.

In Choud'Bruxelles project, an intermediate phase has been planned. its consists of designing the collaboration during which partners learn to know each other, their needs as well as their constraints. At the end of this phase, a collaboration agreement is established. This agreement must contain answers to all partners' questions relating to collaboration such as the purpose of collaboration, duration, organization, sharing costs and risks associated with the collaboration. To establish this agreement, tools must be made available to potential partners in order to validate this agreement. These tools can be simulation tools to assess the accuracy of the agreement in terms of cost sharing, compliance with the planning...When a collaboration agreement has been found, it can be implemented. Finally, it is necessary to monitor collaboration through pre-defined performance indicators.

Conclusion and further research

The local food system, which has many advantages in social, economic and environmental aspects, is characterised by a very low level of logistics performance. This research highlighted the existence of many logistics practices in the short food supply chain from informal to advanced ones. Among these solutions, some are more suited to certain distribution channels due to the particular constraints and needs of each distribution channel identified in this research. However, it is necessary to go further in identifying the characteristics, needs and constraints of the local food systems' actors to better design effective logistic solutions.

This research also identified the opportunity for the collaboration solutions as a key to improve logistics performance of the short food supply court and the need to share information through an effective vertical collaboration between the actor.

This research should go further in quantifying performance logistics solutions regarding to key performance indicators. Moreover, to assess the relevance of these solutions to different distribution channels, multi-criteria and multi-actor analysis should be conducted.

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APPLYING THE SUPPLY CHAIN OPERATIONS REFERENCE (SCOR) MODEL FOR THE EVALUATION OF SEVERAL URBAN CONSOLIDATION CENTRE OPERATING MODELS

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Abstract: Urban Consolidation Centres (UCCs) are a popular measure in city logistics, but many of the UCC projects are granted only a short life. These facilities are often view as creating benefits for the society and costs for the private sector. Recent research and experiences show however that additional value-added activities performed in these platforms are able to increase the attractiveness of these city logistics schemes. This paper proposes the application of the Supply Chain Operations Reference (SCOR) model in order to assess the impact of the UCCs on the overall supply chain performance. Authors first perform a review of current evaluation techniques for the UCC projects and highlight the relevance of a supply chain focused approach. They present the Supply Chain Operations Reference (SCOR) model and discuss its relevance for the evaluation of UCC projects. They then analyse 10 recent UCC case studies which leads to highlighting the existence of three distinct operating models. Finally, they apply the SCOR model to the different UCC operating models. The study confirms the UCCs on the reliability, responsiveness and agility of the supply chains. This brings an innovative aspect to the UCC projects evaluation which traditionally only focuses on cost, environmental or asset utilisation related metrics.

Keywords: *Urban Freight Transport; City Logistics; Urban Consolidation Centres; Evaluation; Supply Chain Operations Reference Model; SCOR*

Introduction

Urban consolidation centres (UCCs) are a popular measure in city logistics (Verlinde et al., 2012; Ville et al., 2012). They have been subject to many trial projects and implementation cases. Allen et al. (2012) identifies 114 UCC schemes in 17 countries that have been the subject of either a feasibility study, trial or a fully operational scheme in the last 40 years. However, many of the UCC projects are granted only a short life (Verlinde, 2015). (Lebeau et al., 2015a) demonstrate that a large majority of the UCCs that were operating in the previous decades have failed. In a European review of 75 UCC initiatives, Morana et al. (2014) find that only 30 (or around 40%) of the considered schemes are still operational. This figure is however to take with caution since it accounts for UCCs whose start dates extend through a long time period.

UCC schemes are traditionally seen as creating benefits for the society, but creating an additional cost for the private sector. On one hand, Verlinde (2015) performs a systematic review of 93 unique UCCs impact assessments and find a positive on the urban freight vehicle kilometres (79% of the ex-ante assessments and 100% of the ex-post assessments observed a decrease), confirming their potential to decrease the environmental impact of the urban freight transport. On the other hand, there is a general consensus that the transhipment operations introduce an additional cost in the transport chain (e.g. Allen et al., 2012; Browne et al., 2005; Marcucci and Danielis, 2008; Verlinde et al., 2012) and the failure of the UCC schemes in the past has therefore resulted in significant concerns with regards to their financial viability (Quak and Tavasszy, 2011). This specific vision on the UCC projects results in the necessity of introducing public subsidies that aim in offsetting additional costs for the private sector while maintaining the societal benefits. Browne et al. (2005) find that there is no strong evidence that any truly self-financing schemes and indicates that the success of the UCCs is dependant on the availability of public funding whereas Van Duin (2009) mentions the existence of subsidies as one of the major success factors for UCC operations.

Most of the existing evaluation techniques used for assessing the UCC projects reflect this specific vision. Browne et al. (2005) summarize the metrics that are typically used in UCC evaluations. We can put these in two following categories: measures affecting the environmental impact of urban freight transport (changes in the number of vehicle trips, changes in the number of vehicle kilometres, changes in the number of vehicles, changes in parking time and frequency, changes in total fuel consumed, changes in vehicle emissions) and measures effecting the efficiency of the last mile operations (changes in travel time, goods delivered per delivery point, vehicle load factor, changes in operating costs).

Recent research contributions and recent UCC experiences show that UCC projects can bring benefits that go beyond the environmental impact. UCCs can create value further in the supply chain and improve the overall supply chain performance. This is particularly relevant for some novel UCCs operating models. In fact, the purpose and design of the UCCs schemes has evolved over time (Allen et al., 2012). In the 70’s, UCCs were seen as simple transhipment points (Allen et al., 2012) – however, transhipment operations do not add any value to the cargo and generally create an additional cost, resulting in a negative economic impact. However, recent UCCs experiences offer a range of additional value-added services that go beyond the consolidation and cross-docking (Panero et al., 2011; Triantafyllou et al., 2014; Allen et al., 2012) and that can increase the attractiveness of these logistical platforms. For example, Allen et al. (2012) and Björklund and Abrahamsson (2015) find that the implementation of an UCC can result in value added retail and logistics activities for the receiver and enhance the supply chain efficiency.

In order to account for this effect, several authors (e.g. Browne et al., 2005; Marinov et al., 2008) highlight the importance of assessing the costs and benefits of these initiatives in a wider context and analysing the integration of these initiatives into the larger supply chains.

In this framework, this paper aims in analysing the potential impacts of the UCC schemes on the overall supply chain performance. Authors first perform a review of current evaluation techniques for the UCC projects and highlight the relevance of a supply chain focused approach. They present the Supply Chain Operations Reference (SCOR) model and discuss its relevance for the evaluation of UCC projects. They then analyse 10 recent UCC case studies in order to highlight the existence of three distinct operating models. Finally, they apply the SCOR model to the different UCC operating models and conclude with regards their impact on the overall chain performance.

Using SCOR model for UCC projects evaluation

Current evaluation techniques for the UCC projects

Evaluating the city logistics initiatives is a crucial task for the scientific community (Danielis et al., 2015). The evaluation of city logistics schemes involves consideration of a wide range of benefits and costs for both the public and private sectors (Thompson, 2014). It also brings some specific challenges such as the diversity of the stakeholders and objectives, the difficulty of assessing the costs and benefits, the lack of definition the problem owner, the lack of data or the diversity of context (Balm et al., 2014). The variety of approaches for the evaluation of city logistics initiatives documented in the literature reflects this complexity.

City logistics initiatives evaluation techniques can vary according to a number of factors. They can be ex or post evaluations. They can be categorized as either single (monetary) criterion or multi-criterion (non-monetary) (Thompson, 2014). Evaluation techniques also vary according to the scope of evaluation which is related to the definition of the system boundaries that need to be defined for designing surveys and models (Thompson, 2014). Danielis et al. (2015) summarize three approaches in the performance evaluation techniques for the city logistics with regards to the evaluation scope: (1) evaluations at firm level, (2) the firm within a supply chain and (3) the supply chain in a city context. In the specific case of UCC evaluations, Browne et al. (2005) highlight that the boundaries of the evaluation process should ideally be as far-ranging as possible, but observe that previous analyses of the impacts of UCCs have tended to focus only on the very specific changes in goods movements, while ignoring any wider changes. Finally, evaluation techniques can also vary according to the number of stakeholders included in the analysis. We will now summarize some common evaluation approached to the assessment of the UCCs in the literature.

Some articles focus on the firm level and discuss specifically the financial viability of the UCCs. In this category, Janjevic and Ndiaye (2016) investigate the financial viability of the UCCs by specifying the potential revenues and costs linked to its operation and Tsamboulas and Kapros (2003) develop a model for the financial evaluation of investments for a Freight village with public and private financing.

A common approach consists in evaluating the UCCs based on the logistical indicators (e.g. UCC throughput), the economic indicators (e.g. financial results of the UCC solution) and the environmental effects (e.g. reduction in the vehicle-km or reduction of the emissions). For example, ADEME (2004) performs an evaluation of the UCCs in La Rochelle and in Monaco and presents the operational, the financial and the environmental results. Morana and Gonzalez-Feliu (2010) provide an assessment of a UCC Cityporto in Padova (I) by discussing its profitability as well as the environmental and social effects. Van Rooijen and Quak (2010) examine the impacts of the Binnenstadservice UCC on the city of Nijmegen (NL) after one year of operation by focusing on logistical effects (e.g. number of truck-kilometres in city centre, total truck travel time) and the resulting effects on air quality, noise and hindrance. Browne et al. (2011) evaluate the use of an urban micro-consolidation centre in central London (UK) by explicating the environmental effects (distance travelled and greenhouse gas emissions, daytime road occupancy, kerbside occupancy while unloading) and the economic effects (impact of the trial distribution system on operating costs). LaMilo (2015) provides a comprehensive business case of a Camden Consolidation centre (UK) by detailing the commercial, operational, financial and environmental aspects.

In some cases, the effects of the UCC on the users (e.g. level of service or cost reduction) are included in this analysis. For example, Van Duin et al. (2008) performs a cost-benefit analysis in order to assess the effects of the introduction of the UCC on the city distribution centre (i.e. its profitability), on the public affairs (i.e. the societal value) and on the commercial stakeholders (i.e. costs and benefits for UCC users). van Duin et al. (2010) study the feasibility of a UCC in Hague (NL) and provides costs and benefits of several scenarios by focusing on three main elements: vehicle kilometre reduction, the net benefits of the UCC and the service level for the stakeholders. Quak and Tavasszy (2011) follow-up on the analysis by Van Rooijen and Quak (2010) for the Binnenstadservice UCC on the city of Nijmegen (NL) and detail elements relevant to the impacts on the users, such as savings by the carriers. Leonardi et al. (2015) performs an ex-ante assessment of a network of UCCs in Luxembourg, by estimating economic effects (e.g. cost per parcel for the users) and environmental effects (e.g. emissions per parcel and distance per parcel) of several scenarios.

Other articles focus specifically on the effect of the introduction of the UCC on its users, which can be monetary and non monetary. Janjevic and Ndiaye (2015) develop a model for assessing the effects of the introduction of a UCC on the cost of deliveries in Brussels-Capital Region (BE). Van den Berg (2015) analyses the potential value creation by the UCCs and differentiates it according to the direct last-mile value and additional network optimisation value. Blom and van Nunen (2009) identifies and quantifies the value of Binnestadservice UCC in Nijmengen (NL) for its customers. Roca-Riu and Estrada (2012) provide a model estimating the effects of UCCs on the operational costs and apply it to the case of a UCC in L'Hospitalet de Llobregat in Barcelona (ES).

A novel approach in the evaluation of the city logistics measures is the business model analysis. A business model analysis is an explanation of how an organization does business, describing the value that an organization offers to its customers, and the activities, resources and partners required for creating, marketing and delivering this value (Balm et al., 2014). STRAIGHTSOL project (see: (STRAIGHTSOL, 2014a)) applies the business model canvas to assessing the UCC in L'Hospitalet de Llobregat in Barcelona. Björklund and Abrahamsson (2015) analyses business models of three successful city consolidation initiatives in order to identify critical components, similarities and differences between the models applied.

Another approach for city logistics evaluation is the multi-criterion evaluation. Multi-criterion evaluation techniques allow both quantitative and qualitative multi-dimensional effects to be incorporated (Macharis et al., 2009). For example, Gonzalez-Feliu and Salanova (2012) propose a multi-criteria approach to assessing collaborative urban freight transportation systems to help the urban goods movement decision makers in their strategic choices (for both public and private stakeholders). The Multi-Actor Multi-Criteria Analysis or MAMCA (see : (Macharis, 2007; Macharis et al., 2009)) allow integrating multiple stakeholder views and has already been applied to a series of city logistics initiatives, including Urban Consolidation Centres. STRAIGHTSOL project (see: (STRAIGHTSOL, 2014b)) applies the Multi-Actor Multi-Criteria Analysis to assessing the UCC in L'Hospitalet de Llobregat in Barcelona (ES). Lebeau et al. (2015b) apply the Multi-Actor Multi-Criteria Analysis for assessing several scenarios of implementation of UCCs servicing the Brussels-Capital Region (BE).

Finally, another emerging evaluation technique for the UCC evaluations is the multi-agent based evaluation. Multi-agent system provides potential to meticulously replicate the urban freight movement by mapping complexity of domain, time and discipline simultaneously and describing the domain naturally and flexibly (Anand et al., 2010). Two papers apply agent-based modelling to assess the introduction of the UCCs. van Duin et al. (2012) develop an agent-based model in order to assess the dynamic behaviour between stakeholders linked to the introduction of a UCC. Wangapisit et al. (2014) apply a multi-agent model for studying the effect of city logistics measures consisting of the joint delivery systems, an urban distribution centre, and parking space restriction.

The literature review performed in this section shows that there are in fact numerous approaches to UCC evaluation. However, it is to be noted that despite the recommendations made by several authors, no supply-chain specific approach has been applied yet to the assessment of these city logistics initiatives.

Presentation of the SCOR model

The Supply Chain Operations Reference (SCOR) was developed by the Supply Chain Council in 1996 with the objective to conceive a framework to evaluate and compare supply chain activities and performance (Supply Chain Council, 2012) and is now widely used both in research and industrial sectors (Bolstorff, 2007). The basic purpose of this framework is to define a standard supply chain model for any industry, helping to structure the whole process and to highlight key aspects specific for each organisation. The SCOR process reference model contains four major elements (Supply Chain Council, 2012; Huan et al., 2004): (1) Processes (i.e. description of processes and framework of relationships between the processes); (2) Performance metrics (i.e. metrics to measure process performance); (3) Best practices (i.e. practices that produce best-in-class performance) and (4) People (i.e. training and skills requirements). In this article, we will focus on the two first elements of the SCOR model.

The description of processes in SCOR is made according to a four-level structure (see Figure 2). Process types are decomposed into process categories. They are decomposed into process elements and finally into industry specific activities (Huan et al., 2004). The last version of the SCOR model (11th version), published by Supply Chain Council describes the supply chain at the first level, with the following processes for each organisation: Plan, Source, Make, Deliver, Return and Enable (see Figure 1).

	Level #	Level Description	Examples	Comments
Within scope of SCOR	1	Process Types (Scope)	Plan, Source, Make, Deliver, Return and Enable	Level-1 defines scope and content of a supply chain. At level-1 the basis-of-competition performance targets for a supply chain are set.
Within scope of SCOR	2	Process Categories (Configuration)	Make-to-Stock, Make-to-Order, Engineer-to-Order Defective Products, MRO Products, Excess Products	Level-2 defines the operations strategy. At level-2 the process capabilities for a supply chain are set. (Make-to-Stock, Make-to-Order)
Within scope of SCOR	3	Process Elements (Steps)	• Schedule Deliveries • Receive Product • Verify Product • Transfer Product • Authorize Payment	Level-3 defines the configuration of individual processes. At level-3 the ability to execute is set. At level-3 the focus is on the right: • Processes • Inputs and Outputs • Process performance • Practices • Technology capabilities • Skills of staff
Not in scope	4	Activities (Implementation)	Industry-, company-, location- and/or technology specific steps	Level-4 describes the activities performed within the supply chain. Companies implement industry-, company-, and/or location-specific processes and practices to achieve required performance

Figure 1:SCOR as a hierarchical process model (Supply Chain Council, 2012)

SCOR also provides generic performance metrics. The Supply Chain Council supposes it is impossible to effectively manage the supply chain if every supply chain partner uses different metrics (Supply Chain Council, 2012). Alignment of the metrics throughout the organization and with the goal is mandatory for performance of the overall organization. Performance indicators/metrics proposed by the SCOR model are divided into 5 categories of performance attributes: (1) Reliability (i.e., the degree to which tasks are performed as expected), (2) Responsiveness (i.e. speed at which tasks are fulfilled), (3) Agility (i.e. an indication of the capability of a supply chain to answer to change and external influences), (4) Costs (i.e. how much is spend throughout the supply chain) and (5) Assets (i.e. how efficiently the organization is using its assets) (Supply Chain Council, 2012). A detailed overview of all SCOR metrics of the version 11.0 can be found in (Supply Chain Council, 2012). Finally, SCOR proposes proposing a set of strategic environmental metrics (referred to as "Green SCOR") that can be added to the SCOR Model to effectively allow the SCOR Model to be used as a framework for environmental accounting (Supply Chain Council, 2012).

Relevance of the SCOR model for assessing Urban Consolidation Centres projects

The different evaluation approaches described in the literature review in the section 0 correspond to specific views on the UCC implementation. We can see that most of the studies focus on the evaluation of the UCCs at a firm level (e.g. UCC financial viability) and the city level (e.g. environmental impact) or some combination of the two previous approaches. In fact, very few approached consider UCCs in a wider supply chain context.

Several authors already highlighted this issue. Browne et al. (2005) conclude that the wider supply chain implications are generally not explored in detail within the literature identified as no comprehensive investigation of wider supply chain impacts has been found in any of the literature and highlights the need for further investigation into the total supply chain costs and benefits associate with the use of UCCs. Marinov et al. (2008) indicate that freight transport and logistics operations in urban areas cannot be viewed and studied in isolation but rather in the context of the entirety of supply chains that typically cross the geographical boundaries of urban areas. Same authors mention the need to raise awareness of the UCC concept, especially of the benefits from cost reductions through the optimisation of other supply chain activities as a result of UCC usage.

It is to be noted that some current approaches do integrate some level of supply chain assessment. For example, the business model canvas analyses the firm activities with regards to its customers and suppliers. In this framework, SCOR model can be used to identify the supply chain impacts for the UCC users before studying how to convert these values into revenues for the UCC in business model canvas. Moreover, SCOR model brings an additional point of view compared to the business model canvas. In fact, the application of the aforementioned evaluation technique brings challenges with regards to the definition of the problem owner or the allocation of the costs and benefits Balm et al. (2014). SCOR model allows overcoming some of these challenges since it privileges the overall impact on the supply chain performance rather than local optimisation. For example, SCOR will to allow quantifying the cost variation for each supply chain actor, but will also allow aggregating this in an overall cost metric. Consequently, when considering a new city logistics scheme (e.g. a UCC), SCOR allows pinpointing the impact on the overall supply chain performance beyond its allocation between actors.

Another distinctive element of business model canvas for city logistics is the value proposition to society (Björklund and Abrahamsson, 2015) - in some cases, the value to society is taken into account as part of the value proposition (Balm et al., 2014). The SCOR allows taking into account explicitly the environmental performance of the supply chain through Green SCOR metrics.

Another evaluation approach that allows integrating supply chain metrics is the MAMCA approach. However, this assessment technique has a larger focus as it includes a comprehensive group of stakeholders who can be internal or external to the supply chain, providing valuable information about the acceptance of the city logistics initiatives. SCOR has a more specific focus on the supply chain performance and its metrics could therefore be used as input for defining indicators for a MAMCA analysis.

Finally, SCOR method presents some additional advantages. SCOR model resulted from the consensus between several industry leaders and is therefore adapted to the supply chain requirement of a broad variety of industries and applications (Supply Chain Council, 2012). It calls upon standard processes and performance indicators which provides the standards needs to communicate and enabling benchmarking (Di Martinelly et al., 2009). This permits to enhance comparability and put the evaluation of city logistics initiatives in a context of the evaluation of best practices across supply chains. Furthermore, the SCOR model is the only supply chain framework that links performance measures, best practices, and software requirements to a detailed business plan model (Klapper et al., 1999).

There are however two main limitations of this model. First, being a 'one size fits all' model, the framework can appear too idealistic. Sometimes reality needs to be fit into the model (Lauras, 2004). Second, (LEPORI, 2012) signals that not all activities can be assigned unequivocally to a process.

With this in mind, we argue that a supply-chain centred approach and the use of the SCOR method that is specifically designed for supply chain purposes cannot replace the existing evaluation techniques but can provide a complementary view and shed a new light on the role of these logistical platforms in a context of a sustainable city distribution.

Identification of UCC operating models

UCCs projects can vary across different dimensions. Allen et al. (2012) classify them based on the type of operation and geographical area served in the following three categories: (1) UCCs serving all or part of an urban area, (2) UCCs serving large sites with a single landlord and (3) Construction project UCCs. Construction project UCCs are very specific with regards to the type of goods handled and can be considered separately, but the first two categories of the UCCs can share some similarities as they can both handle retail goods for example. Moreover, in a case where the use of UCC is not compulsory and the UCC is situated at an off-site location, the site-specific UCCs are very similar to those serving all or part of an urban area. The UCCs within these two categories can however have significant differences in terms of proposed activities. For this reason, we will propose a classification of the UCCs within the first two categories based on the type of activities that they propose. In order to do this, we will perform a review of 10 UCC implementation cases, identify the activities performed in each UCC and then highlight the resulting operating models.

Selection of the case studies of Urban Consolidation Centres

In order to identify the new UCC operating models authors have analysed 10 recent case studies of Urban Consolidation Centres that were documented in the literature. **Error! Reference source not found.** presents the summary of the literature review and interviews that were performed.

Table 1: Overview of UCCs case studies

UCC Name	Documentation
Bristol-Bath consolidation centre (UK)	(Jones et al., 2008); (TRAILBLAZER, 2010a);(van Duin et al., 2010); (Moore, 2011); (Rees and Gahan, 2011); (Paddeu et al., 2013); (CIVITAS, 2013)
Meadowhall UCC, Sheffield (UK)	(Yorkshire and Humber Assembly, 2004); (Jones et al., 2008)
Heathrow retail consolidation centre (UK)	(OSMOSE, 2007); (Bastien, 2007); (Jones et al., 2008); (TRAILBLAZER, 2010b); (Transport for London, 2015a); (Rees and Gahan, 2011)
Lucca consolidation centre (IT)	(Björklund and Abrahamsson, 2015); (Di Bugno, 2010); (Layman, 2008); (TRAILBLAZER, 2010c); (Luccaport, 2015)
Cityporto Padova (IT)	(Morana and Gonzalez-Feliu, 2010); (BESTFACT, 2013); (Rossi and Giordani, 2011); (Vaghi, 2014); (Morana, 2014); (Interporto Padova SA, 2015); (Pandolfo, 2015)
ELCIDIS, La Rochelle (FR)	(ADEME, 2004); (Renaudin, 2014); (Proxiway, 2015)
Binnenstadtservice Nijmengen (NL)	(Van Rooijen and Quak, 2009; (Blom and van Nunen, 2009); (van Duin et al., 2010); (Björklund and Abrahamsson, 2015)
City Depot (BE)	(Schepers, 2013); (CityDepot, 2015); (Lovens, 2015)
Borlänge consolidation centre (SE)	(TRAILBLAZER, 2010d); (Björklund and Gustafsson, 2012)
Camden Consolidation Centre (UK)	(Churchill, 2014); (Transport for London, 2015b); (LaMilo, 2015); (Symonds, 2015)

Identification of the UCC activities

Based on the literature review and interviews, we have identified a series of activities that were performed at the analysed UCCs. In the following section, we will provide an overview of the different services and activities that can be offered by the UCCs. For each service, we will also provide a review of the potential benefits that were documented in the literature.

Consolidation and cross-docking

The consolidation is the basic service offered by the UCCs. It consists of consolidating multiple daily deliveries from a single or multiple suppliers into a single load to minimize empty-running, transport emissions and costs, while increasing productivity (Triantafyllou et al., 2014).

In theory, consolidation can lead to decreased costs of operations because of increased vehicle utilisation. For example, (Transport for London, 2015a) mentions a 90% use of vehicle load capacity for the Heathrow airport UCC leading to a 75%

reduction in the number of vehicles delivering to the airport. However, consolidation with transhipment does not always lead to desired economies of scale because of the costs involved with the construction and the operation of the transhipments as well as negative effects linked to the necessity of using a single transhipment point (Button and Pearman, 1981; Van Duin et al., 2008). The impact on the transport distance is not clear from the literature. For example, (Transport for London, 2015b) mentions procurement savings from reducedsupply distances for the The London Boroughs Consolidation Centre: and (Transport for London, 2015a) mentions a saving of up to £5,000 in fuelbills per supplier per annum for the Heathrow UCC whereas (Blom and van Nunen, 2009) mentions that distance savings are not substantial for the Binnenstadservice in Nijmengen.

However, the impact on the driving time seems to be positive. In fact, the cross-docking performed at the UCC allows for deliveries to be made to a UCC at a time to suit suppliers leading to potential reductions in transport costs (Triantafyllou et al., 2014). Therefore, delivery companies experience an increased flexibility over delivery time (with added possibility of overnight deliveries for the next morning), avoiding traffic rush hours, and the option of scheduling vehicles and drivers at times which are traditionally quieter for deliveries (Jones et al., 2008). For example, in Bristol-Bath, the 24 hours operations of the centre has allowed deliveries to be taken at any time of day or night (Jones et al., 2008)(OSMOSE, 2007). In the case of Borlänge UCC set-up by a Swedish municipality (see (Björklund and Gustafsson, 2012)), it was also possible to deliver in early mornings when the traffic is less intense. This increased flexibility of the deliveries for transporters can also to lower cost of transport for shippers/transporters and consequently for receivers, knowing that some delivery companies were charging a premium in order to guarantee deliveries during some specific time periods (Jones et al., 2008).

The cross-docking performed at the UCC also allows for deliveries to be made at a time to suit receivers, leading to potential reductions staff costs (Triantafyllou et al., 2014). For the case of Binnenstadservice, due to the time-window regulations shopkeepers have high personnel cost since a part of the delivery is outside opening hours (Van Duin et al., 2008). In this case, the control over delivery time is found to be as a major benefit for the retailers (Blom and van Nunen, 2009). Another example is one retailer in Meadowhall UCC who was forced to accept 6am deliveries despite not opening the store until 10am – the UCC allowed to receiver the early morning deliveries, store then until 10am an deliver directly into store (Yorkshire and Humber Assembly, 2004).

The consolidation service also has a direct impact on the reliability of the delivery. (TRAILBLAZER, 2010a) and (Moore, 2011) report 100% on time delivery for UCC in Bristol. Similar conclusions are made by (Paddeu et al., 2013) who mentions the punctuality of deliveries as one of the advantages for retailers. For example, (Transport for London, 2015a) mentions a 99% delivery success rate, overall project plan reliability increased by 4% and the on time delivery performance to the retail outlets of 95% for Heathrow UCC.

(Morana and Gonzalez-Feliu, 2010) mentions that a UCC in Padova has allowed to reduce of the number of failed deliveries since improves the management of the undelivered commands by reserving a special area of the platform for this purpose and quickly informing the customer and finding a solution to deliver.

The consolidation service also impacts the delivery time for both for the transporter/supplier and the receiver, linked to two factors: the decrease of the number of stops and the decrease of the delivery time. For example, UCC in Bristol achieved 76% reduction in delivery trips for retailers (Moore, 2011) and in the the retailer satisfaction surveys conducted in relation to the UCC, more than half of retailers surveyed are saving over 20 minutes per delivery tasks (TRAILBLAZER, 2010a)(Moore, 2011). (OSMOSE, 2007) mentions more frequent and scheduled deliveries to the Heathrow Airport terminal buildings, enabling retailers to know more accurately when goods will arrive, within agreed delivery periods, helping a retailer to receive merchandise in a shorter time, something that is greatly appreciated, leading to improved staff planning and productivity (Bastien, 2007)(Transport for London, 2015a). Several authors (for example (Paddeu et al., 2013), (OSMOSE, 2007), (Bastien, 2007), (Blom and van Nunen, 2009)) mention time savings for suppliers linked to more efficient delivery operations. For example, Borlänge UCC has allowed to decrease the number of stops by 50 – 75%(TRAILBLAZER, 2010d). The reduction of the number of drops and the will also result in less uncertainty with planning for transport operators (Blom and van Nunen, 2009).

With regards to the duration of deliveries, (Churchill, 2014) reports a turnaround time of 5 to 20 minutes for suppliers' vehicles in the London Boroughs Consolidation Centre. This figure is in line with classic delivery duration (see: (Routhier et al., 2001)), however, it is to be noted that this duration corresponds to deliveries to several receivers and that the overall time spent on deliveries is therefore reduced. For Heathrow airport, (Transport for London, 2015a) mentions time savings calculated to be 234 hours per week for Heathrow UCC.

Stockholding and replenishment

UCCs also present an opportunity for stockholding, inventory monitoring (i.e. information collection and analysis linked to in-store inventory systems (Triantafyllou et al., 2014)) and replenishment (i.e. splitting big and unmanageable deliveries into smaller regular deliveries throughout the day, also called stock buffering (Triantafyllou et al., 2014)). These services are commonly proposed by the recent UCCs. In Binnenstadservice, retailers can purchase extra storage so they can use their shop to store goods or rent storage space elsewhere (Van Rooijen and Quak, 2009). CEDM Lucca allows for third-party remote warehousing services, providing space rental, remote stocking services and related electronic services (e.g. stock state information, replenishment order submission, etc.) for interested shops and other service operators (Ambrosino et al., 2007)(Di Bugno, 2010). Heathrow Consolidation Centre offers remote storage and stock room management for inventory at point of use at the terminals (TRAILBLAZER, 2010b). Meadowhall UCC proposes storage facilities with management and collection of surplus stock, single item visibility and ordering on intranet and multiple daily deliveries (Yorkshire and Humber Assembly, 2004).

These services can yield significant benefits for the participating retailers. Stockholding and short-time storage and the application of the JIT-principle and the transhipment facility at the distribution centre allows shopkeepers to reduce their stocks in the shops and increase the sales surface (Van Duin et al., 2008)(Jones et al., 2008). (Jones et al., 2008) demonstrates that in the Meadowhall Centre UCC in Sheffield, UK, clothes retailers have reduced from the typical 30% of back of house space to roughly 1%. Bristol, more frequent deliveries lead to less space is required in-store to stock products back of house, allowing retailers to maximise profitable selling space (TRAILBLAZER, 2010a). However, the effect will vary strongly between shops since the adjustment of the physical space is not always possible (Van Duin et al., 2008). The service can also be relevant for some exceptional storage needs: in Meadowhall UCC, one retailer undergoing a refit of their store shortened the refurbishment period by two days by removing all shop stock to The UCC to allow more efficient working (Yorkshire and Humber Assembly, 2004).

The additional floor space can also allow increasing the product offer and availability, with many additional items available on the shop floor at any one time (Jones et al., 2008)(Triantafyllou et al., 2014) and an increased security of stock (Bastien, 2007). For example, (Bastien, 2007) reports better product availability through increased delivery frequency and offsite storage at the Heathrow airport. On one hand, this can be relevant for products difficult to store: for example, in Meadowhall, one store did not have enough space to store products and needed daily deliveries to ensure constant availability - the use of the UCC allowed to drop from 7 to one delivery per week with 100% stock availability and an increase of 5% on the sales of the product in question (Yorkshire and Humber Assembly, 2004). On the other hand, this can be relevant for the seasonal or peak storage (Triantafyllou et al., 2014): in fact, (Van Duin et al., 2008) shows that it is difficult to stock small volumes for short and long term, preventing shopkeepers to anticipate with an extra buffer for their peak-season demands.

Replenishment allows to decrease the lead times (Rees and Gahan, 2011), increase response to customer needs and therefore eliminate lost sales (Triantafyllou et al., 2014). For example, retailers at Meadowhall have reported instances in which certain items have not been available within a store, but have been able to retrieve from the UCC in response to customer requests within the time that customers stay at the centre (Jones et al., 2008). (TRAILBLAZER, 2010b) reports support service of emergency or ad-hoc deliveries to the Heatrow airport at short notice.

Finally, Inventory Monitoring can also allow to increase the visibility of the supply chain and lead to better availability and service levels (Triantafyllou et al., 2014). The use of the UCC allows more reliable and accurate inventory management (Rees and Gahan, 2011). Moreover, a number of participating retailers are reporting decreases in shrinkage rates when using UCC schemes (Jones et al., 2008). For example, (Yorkshire and Humber Assembly, 2004) reports that the Meadowhall UCC helped reduced stock shrinkage by 70% since it offers clear product visibility so that employees know the products are being closely monitored and acts as a strong dissuader for theft. (Moore, 2011) reports no losses and damaged for the Bristol UCC and the security of the deliveries in terms of damages and shortages is also reported as a benefit by (Paddeu et al., 2013).

Gate-keeping operations and pre-retailing

Gate-keeping Operations consist of screening of delivered and returned products at a UCC and can help alleviate some of the problems associated with the quality of product returns and reduce unnecessary transport (Triantafyllou et al., 2014). In Meadowhall, the UCC proposes the receipt and inspection of product any time (Yorkshire and Humber Assembly, 2004). At the Heathrow airport, the UCC is a central point for receipt of all incoming deliveries and all processing including security scanning (Jones et al., 2008). Moreover, the UCC performs performance monitoring and ensuring compliance for all the suppliers (Bastien, 2007), leading to improved security (TRAILBLAZER, 2010b). If the security question is particularly relevant for airports, we can note that other UCCs such as Meadowhall UCC can offer additional security measures over and above the warehouse security (e.g. sealed cages) (Jones et al., 2008).

UCC schemes can offer a variety of pre-retail options (or pre-merchandizing activities), such as quality/quantity checks, unpacking, sorting, products preparation for display and price labelling, allowing to streamline the process from the UCC to the shop floor (Triantafyllou et al., 2014)(Jones et al., 2008). Pre-retail activities are carried out for example at Meadowhall Shopping Centre UCC in Sheffield (Lewis et al., 2007), and at Bristol Broadmead UCC (Jones et al., 2008). For example, in Meadowhall, the clothing garments for one retailers are prepared for display by steaming and hanging prior to delivery in store (Yorkshire and Humber Assembly, 2004). In addition to freeing space previously used for these activities within the shop, this process offers major savings in both staff time and cost and staff morale, allowing retail staff to concentrate on their core sales duties while reducing time-consuming pre-retail work (Jones et al., 2008). For example, in Bristol, retail staff are able to spend more of their time on core tasks e.g. selling or helping customers and not on logistics or delivery-related tasks (TRAILBLAZER, 2010a). A retailer satisfaction survey reported 45% indicating that staff are less stressed and have improved morale, and 38% saying that staff can now spend more time with customers (Jones et al., 2008).

Business-to Customer (B2C) Services

UCCs can offer a range Business-to Customer (B2C) Services, such home delivery or customer collection of products purchased in town or by mail and online orders (Triantafyllou et al., 2014).

For example, Binnenstadservice offers home-deliveries (for example for large goods, such as fridges and computers) (Van Rooijen and Quak, 2009). ELCIDIS in La Rochelle offers home deliveries for large retailers such as Monoprix, Super U and Carrefour (Renaudin, 2014). CEDM is Lucca also offers home delivery services, for generic users (i.e. citizens living in the service area) or specific user categories (e.g. elderly people, etc.) (Ambrosino et al., 2007), but also deliveries to specific locations such as hotels, park&buy areas, pick-up points or e-lockers (Layman, 2008)(Di

Bugno, 2010). The CEDM can also operate as a pick-up point for any goods purchased in the historical centre and bound for outside destinations - the purchase process may be originated in the ordinary way (i.e. directly at the selling point) or by any distant selling means (e.g phone order placement, e-commerce purchase, etc.) while the transport service between the selling location and the CEDM is provided by the CEDM fleet of electrical vehicles (TRAILBLAZER, 2010c). This can allow transitioning towards “hands-free shopping” systems (i.e. shoppers do not need to carry their purchases with them, and they can easily combine shopping activities with others such as visiting theatres or restaurants, see: (Stratec and others, 2005)). Customer collect by car points, particularly for retailers of haeavier and bulkier goods can lead to an increased customer dwell time within the shopping area and an increased average spend to the benefit of retailers (Jones et al., 2008). UCCs can also offer kitting for just-in time delivery services. For example, Colizen (Paris, France) works with Nespresso – the UCC holds a local stock of Nespresso capsules and receives customer orders online. The capsules are kitted and delivered by appointment on the same day. The operator also offers additional services such as descaling of coffee machines at customers’ homes (Guillaume, 2010).

Supplier management and collaborative sourcing

UCCs also present opportunities for supplier management and collaborative sourcing. For example, (Bastien, 2007) reports that Heathrow airport consolidation centre performs supplier management for the retailers by agreeing time windows for each retailer, monitoring and reporting the supplier performance to the retailers and ensuring compliance of the suppliers. In other cases, the UCC is served as a basis for both supplier management and collaborative sourcing. On one hand, this can lead to an improved management of the supplier portfolio. For example, in the case of Borlänge UCC set-up by a Swedish municipality (see (Björklund and Gustafsson, 2012) and (TRAILBLAZER, 2010d)), the supplier management and collaborative sourcing has allowed to increase the competition between suppliers (i.e. several small suppliers did not have sufficient logistics services to be included in the tender) and the number of suppliers increased from eight in 1999 to fifteen in 2001 with more than 20% of the food comes from regional food producers. It is to be noted however that in the following two years, the number of minor suppliers has drastically reduced during the last years, and no clear explanation behind this has been identified (Björklund and Gustafsson, 2012)). On the other hand, collaborative sourcing can lead to supplier discounts. For example, the Camden Consolidation Centre (see: (LaMilo, 2015)) has implemented a collaborative sourcing procedure and has reports supplier discounts of 5 to 7% (Symonds, 2015) which partially a result of a reduction in a number of suppliers (Transport for London, 2015a). In the Borlänge case however, no supplier discount was observed, despite that the number of delivery points were drastically reduced (Björklund and Gustafsson, 2012)). It is to be noted that so far, there are few documented cases of collaborative sourcing and that most of them relate to public institutions (for example: Värnamo case, Katrineholm case documented in (Björklund and Gustafsson, 2012, p. 201) or Southampton case in the Citylab project, see (CityLab, 2015)), but that CityDepot in Belgium (see: (CityDepot, 2015)) also proposes this service to its private customers.

Return logistics

UCCs can also serve as hubs for return logistics. In fact, packaging, waste collection and recycling at the UCC consists of using the platform as a storage, trans-shipment and/or treatment facility of waste and recyclables produced by participant retailers (Triantafyllou et al., 2014). Returns Management allows suppliers to use UCCs to consolidate returns into a central stream ideally using the available backload capacity of delivery vehicles (Triantafyllou et al., 2014). All of the analysed UCCs propose this type of sercice. In Broadmead, Bristol, retailers have cardboard and plastic materials collected and recycled (Jones et al., 2008). Heathrow airport UCC also receives outgoing waste and recyclable material from stores (Jones et al., 2008). Binnenstadservice offers collection of the clean waste as a service (Van Rooijen and Quak, 2009).

Other services

Specific UCCs also offer some other services. CityDepot in Belgium and Lucca UCC also propose transport brokerage services for their customers (CityDepot, 2015; Luccaport, 2015). For example, Lucca UCC proposes national and international deliveries in collaboration with the major carriers and transport operators (Luccaport, 2015). Finally, some UCCs also propose a series of niche services. For example, Lucca UCC proposes transport and storage services for buyers and retailers of Lucca antique market (Luccaport, 2015). La Rochelle UCC propose the pick-up and the deliveries of the laundry (ADEME, 2004).

Summary of different UCC operating models

Based on the analysis of the case studies, we have been able to identify main activities performed at each UCC (see Table 2). Although differences exist within each category with regards to the scope or the intensity of the performed activities, we can see that there are roughly three major operating models for the UCC experiences:

(1) UCCs based on retail-activities (Bristol-Bath consolidation centre (UK), Meadowhall UCC (UK) Heathrow retail consolidation centre (UK)): these UCCs are relevant to clearly defined retail areas or retail sites and focus on activities such as temporary storage or pre-retailing, providing a clear added value for participating retailers. The main target are the participating retailers and there is little evidence of proposed B2C services.

(2) Generalist UCCs (Lucca consolidation centre (IT), Cityporto Padova (IT), ELCIDIS, La Rochelle (FR), Binnenstadtservice Nijmengen (NL), City Depot (BE)): these UCCs diversify their activities and propose consolidation, value-added services as well as B2C services, targeting a range of actors such as shippers, carriers, retailers and private customers.

(3) Public stakeholders UCC (Borlänge consolidation centre (SE), Camden Consolidation Centre (UK)): these UCCs focus on cross docking activities with some evidence of short-term storage and propose collaborative sourcing activities for the participating parties.

Table 2: Overview of UCCs case studies and activities from the literature review

UCC Name	Consolidation and cross-docking	Stockholding, inventory monitoring and replenishment	Gate-keeping operations and pre-retailing	Business-to Customer (B2C) Services	Supplier management and collaborative sourcing	Return logistics
Bristol-Bath consolidation centre (UK)	++	++	++	-	-	++
Meadowhall UCC, Sheffield (UK)	++	++	++	-		++
Heathrow retail consolidation centre (UK)	++	++	++	-	-	++
Lucca consolidation centre (IT)	++	++	-	++		++
Cityporto Padova (IT)	++	+	-	+		++
ELCIDIS, La Rochelle (FR)	++	++	-	++		_
Binnenstadtservi	++	++	-	++		++

ce Nijmengen (NL)						
City Depot (BE)	++	++	-	++	+	++
Borlänge consolidation centre (SE)	++	+	-	-	++	++
Camden Consolidation Centre (UK)	++	+	-	-	++	++

Application of SCOR model to different UCC operating models

The application of the SCOR model to different operating models of UCCs is done in two steps: (1) modelling with SCOR the supply chain processes without the UCC and with the UCCs in order to highlight those that are affected by the introduction of this new service; (2) identification of the performance metrics relevant to the identified processes and aggregation of the metrics according to their category.

In order to model the supply chain operations, we have first identified all the supply chain actors. Other than the UCC, actors will depend on the considered operating models and can be put in two major categories: transporters (who can be a third party transporters or shippers for all types of operating models) and receivers (who can be retailers for retail-based or generalist UCCs, private customers for generalist UCCs performing B2C services or actors such as a municipalities for public UCCs). The next step is the identification of the relevant processes and sub-processes (in the case of UCC operations, the sub-processes will always be part of the plan, source, deliver, return and enable processes). The modelling of the processes allows highlighting which activities are performed by each actor and how these activities change with the introduction of the UCC. An example of the modelling of the SCOR processes for the retail-based UCC can be seen on the following pages. Figure 3 shows the processes without the UCC and Figure 4 shows the processes with the UCC. We can see that the introduction of the UCC results in the shifting of certain activities from the retailer towards the UCC (e.g. the verification of the products and the management of the returns), allowing the retailer to focus more on the core activities. We can also see the appearance of some new activities such as sE3 Manage Data and Information. However, the graphical representation of the processes at Figure 3 and Figure 4does not allow to fully appreciate certain elements such as the reduction of the lead time for restocking orders by the retailers. These elements will be accounted for in the second phase of the application of the SCOR model, the identification of performance metrics.

The generalists UCCs will have a similar process description for the retail deliveries as well as a parallel branch for the B2C services such as the home deliveries. The public UCCs will not include the pre-retail activities but will have a much higher focus on the supplier management and sourcing.

Once that the SCOR processes have been modelled it is possible to identify the performance metrics relevant to all sub-processes. The Table 3 shows the performance metrics according to different categories for the three operating models as well as for a simple transhipment centre where only cross-docking and consolidation activities are performed. For each of the performance metrics, the relevant stakeholders are identified. We can draw several conclusions. First of all, UCCs can in fact yield significant supply chain benefits and positively influence its performance beyond elements that are traditionally considered in their evaluations such as the capacity utilisation (Asset Utilisation) and the environmental impact (Green SCOR). In fact, UCCs can significantly improve the supply chain performance with regards to its reliability, responsiveness and agility. These impacts (e.g. delivery reliability, reduction of the lead time, stock availability) have been documents in the literature review of the 10 UCC case studies performed in the previous section and the application of the SCOR model has allowed to identify the related performance metrics which can be measured (e.g. for the delivery reliability: RL.3.32 Customer Commit Date Achievement Time Customer Receiving, RL.3.33 Delivery Item Accuracy, RL.3.34 Delivery Location Accuracy and RL.3.35 Delivery Quantity Accuracy). Secondly, we can see that the new operating UCC models described in this paper have indeed a much higher impact on the overall supply chain performance than a simple transhipment centre, confirming the conclusion that the value-added services performed at the UCC can indeed increase their attractiveness. Finally, we can see some differences in terms of impact between the different operating models: for example, the metrics RL.3.36 Fill Rate will only be relevant to B2C services for generalists UCCs whereas the metrics RS.3.3 Assess Supplier Performance Cycle Time will only be relevant for retail and public UCCs

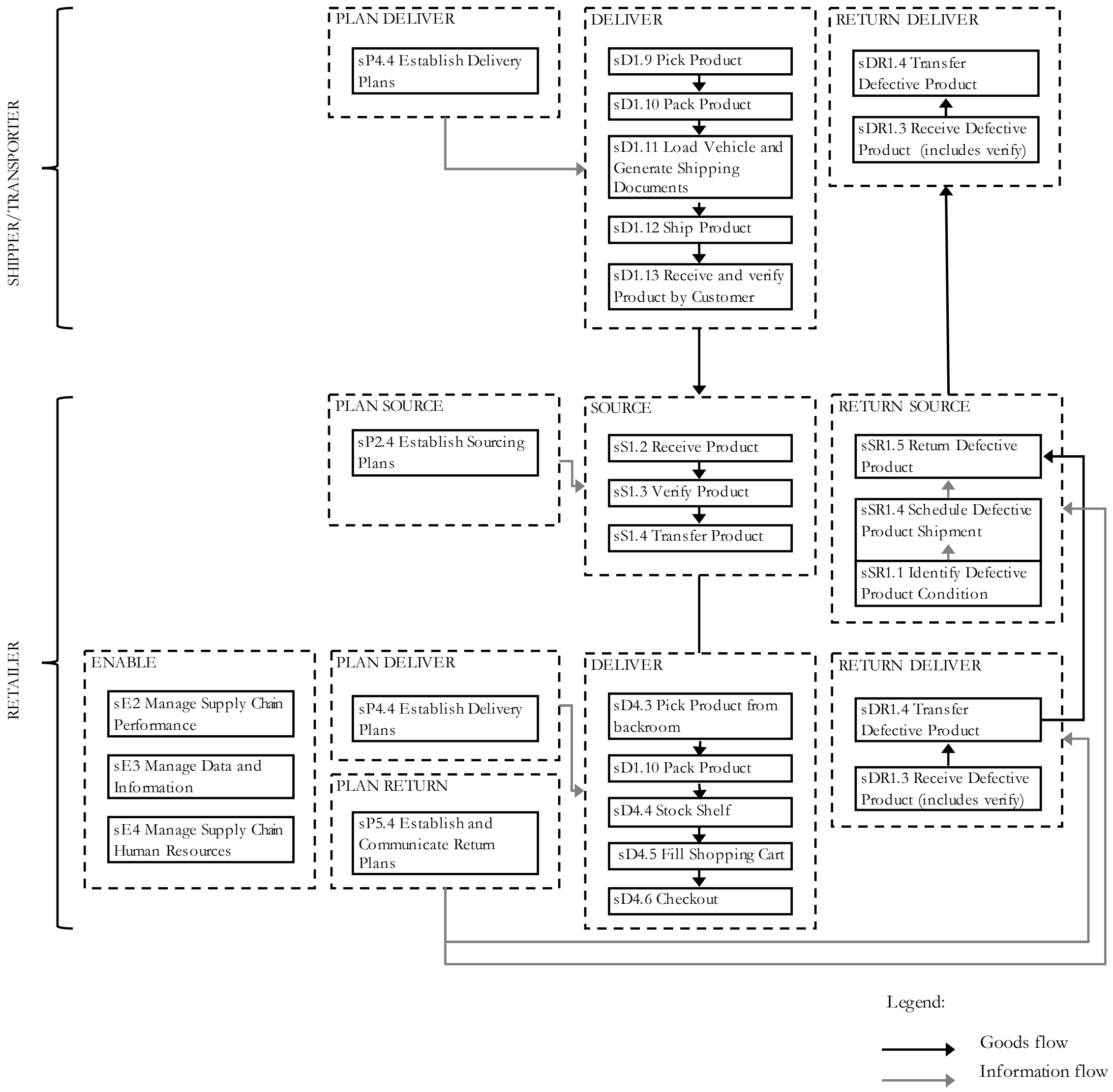

Figure 2: Modelling of the SCOR processes without the Urban Consolidation Centre for Retail-Based UCC

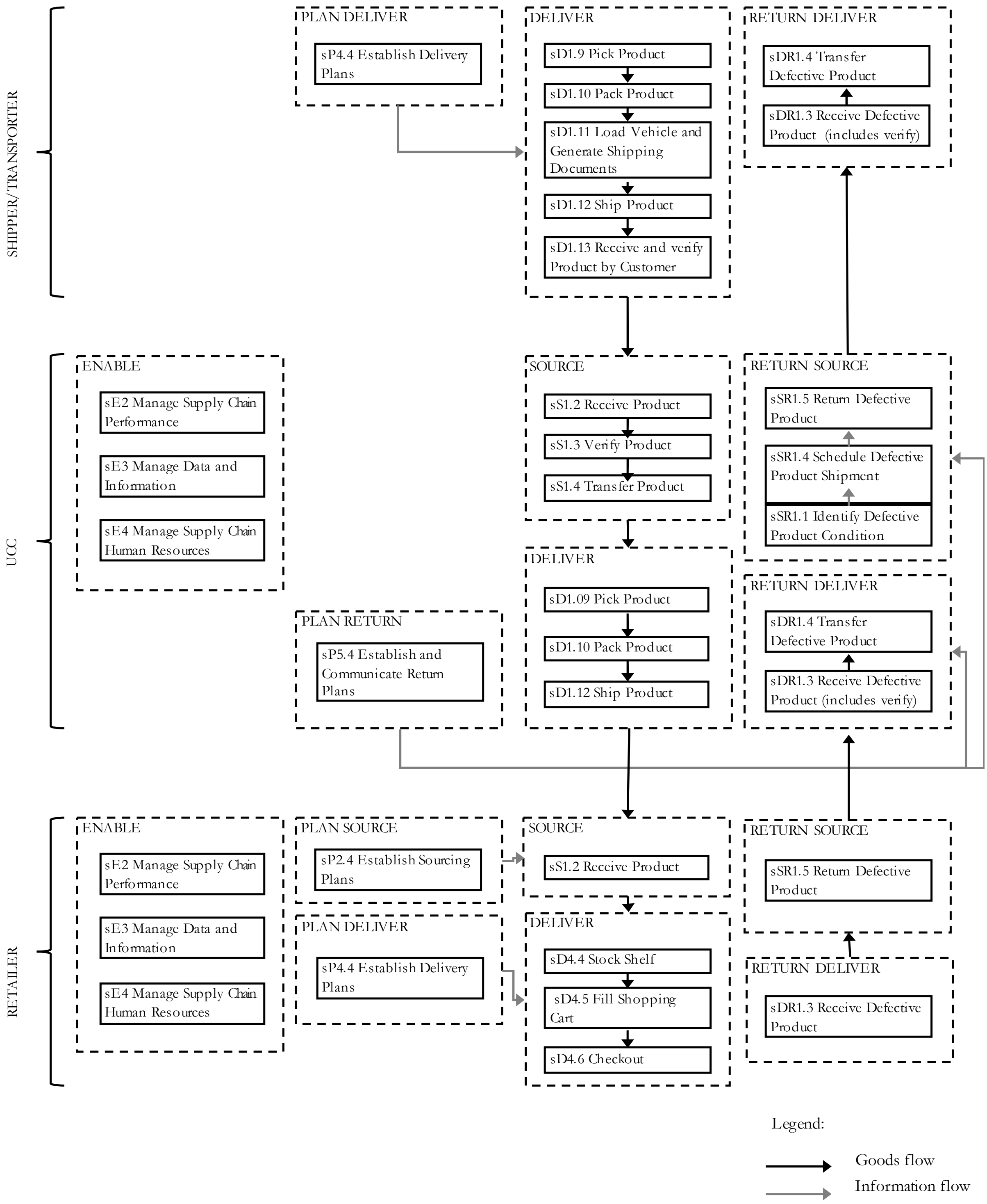

Figure 3: Modelling of the SCOR processes with the Urban Consolidation Centre for Retail-based UCC

Table 3: Performance metrics for various operating models (R=receiver, T=transporter/shipper, C= private customer, (++)=major impact, (+)=minor impact)

Indicator	Transhipment	Retail UCC	Generalist UCC	Public UCC
Reliability				
RL.3.5 % Error-free Returns Shipped		R(++)	R(+)	R(++)
RL.3.31 Compliance Documentation Accuracy		T(++)	T(++)	T(++)
RL.3.32 Customer Commit Date Achievement Time	T(++)	T(++)	T(++)	T(++)
Customer Receiving	T(++)	T(++)	T(++)	T(++)
RL.3.33 Delivery Item Accuracy	T(++)	T(++)	T(++)	T(++)
RL.3.34 Delivery Location Accuracy	T(++)	T(++)	T(++)	T(++)
RL.3.35 Delivery Quantity Accuracy		T(++), R(++)	T(++), R(++)	T(++), R(++)
RL.3.37 Forecast Accuracy	T(++)			
RL.3.41 Orders Delivered Damage Free	T(++)	T(++)	T(++)	T(++)
Conformance		T(++)	T(++)	T(++)
RL.3.50 Shipping Documentation Accuracy				
Responsiveness		T(++),		T(++),
RS.3.2 Assess Delivery Performance Cycle Time		R(++)	R(+)	R(++)
RS.3.3 Assess Supplier Performance Cycle Time		R(++)	R(++)	R(++)
RS.3.22 Current Supplier Return Order Cycle Time		R(++)	T(++),	R(++)
RS.3.26 Establish and communicate returns plan		T(++), R(++)	R(++)	T(++),
cycle time		T(++), R(++)	T(++),	R(++)
RS.3.27 Establish Delivery Plan cycle time		R(++)	R(++)	T(++),
RS.3.34 Generate Stocking Schedule cycle time		R(++)		R(++)
RS.3.47 In stock %		T(++)	R(++)	
RS.3.94 Order Fulfilment Dwell Time		R(++)	T(++)	
RS.3.95 Pack Product Cycle Time		R(++)	R(+)	T(++)
RS.3.96 Pick Product Cycle Time		R(++)	R(+)	
RS.3.97 Pick Product from Backroom Cycle Time	R(++)	T(++)	R(+)	
RS.3.102 Receive and Verify by Customer Cycle	R(++)	R(++)	T(++)	
Time	R(++)	R(++)	R(+)	T(++)
RS.3.103 Receive and Verify Product Cycle Time		T(++)	R(++)	R(+)
RS.3.107 Receive Product Cycle Time		T(++)	T(++)	R(++)
RS.3.117 Route Shipments Cycle Time		R(+)	T(++)	T(++)
RS.3.122 Schedule Product Deliveries Cycle Time		T(++)	R(+)	T(++)
RS.3.125 Select Supplier and Negotiate Cycle Time		R(++)	T(++)	R(++)
RS.3.126 Ship Product Cycle Time		R(++)	R(++)	T(++)
RS.3.127 Source Deliver Cycle Time		R(++)	R(++)	R(++)
RS.3.136 Transfer Defective Product Cycle Time			R(++)	R(++)
RS.3.138 Transfer MRO Product Cycle Time		R(++)		R(++)
Agility		R(++)	R(++)	
AG.3.1 % of labor used in logistics, not used in		R(++)	R(++)	R(++)
direct activity		R(++)	R(++), C(++)	R(++)
AG.3.9 Additional Source Volume		R(++)	R(++)	R(++)
AG.3.40 Current Purchase Order Cycle Times			R(++), C(++)	R(++)
AG.3.41 Current Source Return Volume		T(++), R(++)		R(++)
AG.3.42 Current Source Volume		R(++)	T(++), R(++)	
Cost		R(++)	R(+)	T(++), R(++)
C0.3.001 Planning Labor Costs		R(++)	R(+)	R(+)
C0.3.005 Sourcing Labor Costs	T(+)	T(++)	R(+)	R(+)
C0.3.007 Sourcing Property, Plant and Equipment	T(++)		T(++)	R(+)
Costs	T(++)	T(+)	T(+)	T(++)
C0.3.008 Sourcing GRC and Overhead Costs	T(++)	T(++)	T(++)	T(++)
C0.3.018 Order Management Labor Costs	T(++)	T(++)	T(++)	T(++)
C0.3.022 Transportation Costs		T(++)	T(++)	T(++)
C0.3.023 Fulfilment Customs, Duties, Taxes and		T(++)	T(++)	T(++)
Tariffs Costs		R(++)	R(++)	T(++)
		R(++)		

C0.3.024 Fulfilment Labour Costs			R(++)	R(++)
C0.3.026 Fulfilment Property, Plant and Equipment	T(+)	R(++)		R(++)
Costs	T(+)	T(+)	R(+)	
C0.3.027 Fulfilment GRC and Overhead Costs		T(+)	T(+)	R(+)
C0.3.029 Disposition Costs		T(++)	T(+)	T(++)
C0.3.030 Returns GRC and Overhead Costs		R(++)	T(++)	T(++)
Assets		R(+)	R(+)	T(++)
AM.3.8 Average age of Excess Inventory		R(+)	R(+)	R(+)
AM.3.9 Capacity Utilization		R(+)	R(+)	R(+)
AM.3.11 Deliver Fixed Asset Value	R(++)		R(+)	R(+)
AM.3.24 Return Fixed Asset Value	T(++)	R(++)		R(+)
AM.3.37 Percentage Excess Inventory		T(++)	R(++)	
AM.3.22 Recyclable waste as % of total waste	R(++)	T(++)	T(++)	R(++)
AM.3.26 Return Rate	T(++)	R(++)	T(++)	T(++)
AM.3.28 Percentage Defective Inventory		T(++)	R(++)	T(++)
Green SCOR		R(++)	T(++)	R(++)
GS.3.007 Material Acquisition Management Carbon		R(+)	R(++)	T(++)
Emissions		T(+)	R(+)	R(++)
GS.3.010 Sales Order Management Carbon		R(+)	T(+)	R(+)
Emissions			R(+)	T(+)
GS.3.013 Deliver Return Carbon Emissions				R(+)
GS.3.015 Source Air Emissions				
GS.3.017 Deliver Air Emissions				
GS.3.018 Return Air Emissions				
GS.3.030 Source % Recycled				
GS.3.032 Deliver % Recycled				
GS.3.033 Return % Recycled				

Conclusion

The present paper proposes the application of the SCOR model in order to investigate the impact on the supply chain performance of several UCC operating models. This allows highlighting that the overall impact on the supply chain performance tends to increase with the number of value-added activities performed at the UCC. In particular, SCOR model allows emphasizing the impact of the UCCs on the reliability, responsiveness and agility of the supply chains. This brings an innovative aspect to the UCC projects evaluation. In fact, many current evaluation methods focus only on cost, environmental or asset utilisation related metrics.

The present approach does however have some limitations. SCOR does not include all activities performed by the supply chain actors. An example of such unaccounted for activity is sales: the UCC impacts on these activities are missing although evidence from literature does tend to suggest that the introduction of the UCCs can in fact increase sales. SCOR model does however allow pinpointing one of the root causes of the sales increase, which is the increased product availability, but does not account for other elements such as the increase in product range resulting from the decreased inventory requirements. In fact, an increase in product range falls within strategic company decisions with regards to its commercial approach. SCOR model does not allow modelling these decisions but does however provide as assessment of the supply chain that aims in evaluating the operational feasibility of the aforementioned decisions.

The next step is to apply this model in practice and to quantify these metrics. The SCOR model presents the advantage of proposing a set of measurable metrics for investigating the supply chain performance and linking them to the operational processes. However, in order to highlight the overall impact of the different UCC operating models on the supply chain performance, it is necessary to provide a weighting and an aggregation of these metrics. This analysis can serve to demonstrate the role of UCCs in sustainable city distribution but also in sustainable supply chain management.

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SORTATION IN ECOMMERCE LOGISTICS IN INDIA: DESIGN PRINCIPLES FOR SCALABILITY & FLEXIBILITY

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Abstract: The choice of sorting automation needs to be based on trade-offs on cost economics, reliability and operational challenges. A greater degree of warehouse maturity is required to handle increasing throughputs. While generally the per-unit-cost of operation will reduce as warehouse move towards greater degree of mechanization and automation, costs are also dependent on local factors. At the same time, awareness of the tipping point is essential to maintain low cost of operations with the promised level od service. This becomes even more essential for low-margin sectors like ecommerce logistics and low-wages countries like India.

Given this, key questions that we need to answer on Sortation are:

1. **Network design related:**
   1. What is the right sort philosophy – sort at source vs. sort at destination vs. hybrid?
   2. What factors will govern the choice of sorting centre locations?
2. **Asset strategy related:**
   a. What is the asset cost-structure and accordingly the right technology for future sort requirements?
   b. How can we modularize the investment to handle peaks & scalability while factoring in practical constraints like land availability in urban areas?

The answer to above questions might change from industry to industry. As we scale beyond low-throughput sorters at Flipkart, we have analysed and answered some of these questions to build applicable strategies and business cases

Keywords: Sorting, Network, Technology

Introduction

A typical supply chain network comprises of warehousing, First Mile, MotherHub, Delivery Hub. Mother hub or the sortation centre is a critical node in supply chain given that all the shipments have to flow through sortation centres and has to orchestrate for SLAs and variations upstream and downstream. A critical portion of world-class supply chain design is network, process and automation design of sortation centres….. Lets look at the network design portion of the puzzle first

Network Design: The major portions of network design are sort philosophy andtailoring for various types of services.

Sort Philosophy: The choice of sorting philosophy is based on trade-offs on cost economics and need for flexibility. Table 1 analyses the pros & cons of both the philosophies.

1. Sort at Source
   - Sort for the final destinations at source
   - Involves lower touches and eases downstream operations
2. Sort at Destination
   - Sort for the next node in the system
   - Manages very high throughput and sort locations

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Table 1. Sort Philosophies

Parameter	Sort at source	Sort at destination
Packaging Cost*(material and manpower for bagging)*	Lower due to bagging at one location	Higher due to duplication at both the nodes
Sorting Time	Will be longer with higher complexity of sorts and increased odds of choking at hubs	Dual packaging and handling will add to the sorting time but hub choking is minimized
Flexibility –Direct DH	Can deliver directly to high demand DHs	Rigid structure –Cannot deliver to high demand MHs
Error Rates	Higher due to very high complexity at one stage	Lower due to moderate range of sorts at both stages

Postal networks do sort at destination; Courier & express players adopt a mix of sort at destination and source as tabled below.

Table 2. Postal & CEP

	Shipments per day	Delivery Hubs	Sorting Centres	Sort Philosophy
Postal				
USPS	500m+docs and non-docs in the US	30,000+post offices (~150-250 post office per sorting centre)	200+ sorting centres	Sortingat 2 nodes Sort at source sorting centrefor 150-200 destination sorting centre Sort at destination sorting centrefor 150-250 post offices
India Post	16m+docs and non docs in India	1,50,000+ post offices	75-80 sorting centres	Sortingat 2 nodes Sort at source sorting centrefor 75-80 destination sorting centres Sort at destination sorting centrefor 1500-2000 post offices
CEP: Courier, express, Parcel				
UPS/FedEx	15m+ docsand non docs in the US	20,000+ delivery branches	Not disclosed	They adopt a dynamic sorting approach – sort next node in their network as well as a few key high demand lanes (“Jackpot lanes”) to balance their high throughput and sort requirements
DTDC	1 lakh non docs in India	300 delivery branches	15-30sorting centres	They sort at the source sorting centrefor the next sorting centre

Sort at destination becomes cheaper when the sort threshold for a particular technology or manual setup is reached. The same is highlighted in the following table. SAS favourable for retail….high volume, less destinations…

NDD, SDD → SAS gives speed

Table 3. Sort Destinations

No. of Destinations	80K per day BAU- (Designed for 1.5x, 1 Shift Operation for an inbound skew of 1.3 hourly lean:peak)	
	Sort @ Source CPS	Sort @ Destination CPS
250	5.7-6.2	6.8-7.3
500	5.7-6.2	6.9-7.3
750	6.5-7.1	7.8-8.5
1000	16.0-16.5	13.0-13.5

Learnings

Build flexibility in sorting solution to sort for optimal number of destinations at each mother-hub based on through-put requirement.

Maximize number of sorts at hub through dynamic bin allocation and managing in-bound waves.→ based on the load pattern of destinations

Sort Centre Tailoring for various types of services

Sorting requirements should be clubbed for scale benefits as well reducing the inbound skew of the FA and non FA shipments. But in scenarios where clubbing is not possible due to practical considerations like land availability etc., the following options are available.

Table 4. Sort Tailoring

Options	Pros	Cons	Model
Local and Non Local	Reduction in number of sort destinations Enables faster local to local marketplace shipments	Process change required at the FC –segregating at the time of picking to avoid merge of local/non local orders	Segregation at Pickup Hubs and sent to the resp. MHs The FC MH will send unsorted shipments directly to the local MH enabled by local wave picking or dedicated local pickers
FA and NonFA	Enables faster local to local marketplace shipments	Loss of flexibility to reduce the skew of inbound No reduction in sort destinations	FC MH caters to FAload & sends unsorted shipments directly to the local MH MP MH caters to non FA load. Segregation at Pickup Hubs and sent to the resp. MHs

Learnings

Local vs. Non local tailoring is recommended if clubbing of requirements is not possible.→ geographical demand pattern

FA vs Non FA tailoring is governed solely by business needs & supply chain construct.

Facility Design Strategy

Sorting Technologies

A variety of sorting technologies are available to support different sort complexity and through-put requirement. Emerging market players have been late technology adopters –and are considering automation only now. This paper talks about the various factors and trade-offs in selecting sorting technologies. There is a wide range of options in sorting technologies. Some of the typical ones are:

Manual – manual segregation of shipments by scanning the shipment IDs using scanners/hand held devices.

Linear Sorter - pneumatic arm based lowthrough put primary sorting equipment used to sort items using dynamic sorting logic. As the name suggests, the destinations are arranged linearly, in a straight line.

Tilt tray Sorter - tray-based medium throughput system arranged as an endlessloop. Mostly used as baggage or shipping sorter.

Cross Belt Sorter - casket-based high throughput system arranged as an endlessloop. The system is well-suited for operations in areas with limited space or challenging layouts and high number of end-destination sorts.

Table 5 Compares the above technologies and their applicability.

Table 5. Sorting Technologies

Type	Manual	Linear Sorter	Tilt-Tray Sorter	Cross-Belt Sorter
Capex (mio INR)	~2	10	100	180
Throughput per hour	2K	3K	10K	15K
Optimum Sorts	10 per person	20	100	200
Area required (sq feet)	6 per bin (w/o aisle space)	4k	15k	25k
Products Handled	Cansupport multiple dimensions and product types	Mostly boxes, does not work too well with non-flat surfaces like poly bags	Wide range incl. apparel, small items in poly bags, CD’s and small to large corrugated boxes	

Criteria to determine level of Automation

Cost Economics **-** Operations and staging area costs. Factors that impact cost economics:

- Inbound window –Duration of inbound
- Inbound skew –Peak to average ratio of skew
- Number of sort destination
- Sortation SLA

Flexibility & Reliability **-**

- Ability to handle differing volumetric profile of products
- Accuracy
- Reliability (up-time)

Operational aspects **-** Other operational considerations

- Challenges of managing a large work-force
- Space constraints, especially in large cities

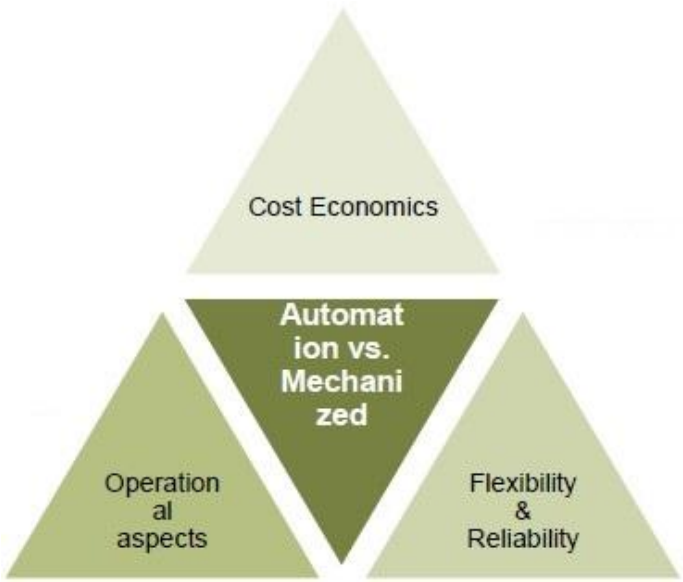

Figure 1. Sorting Technology Criteria

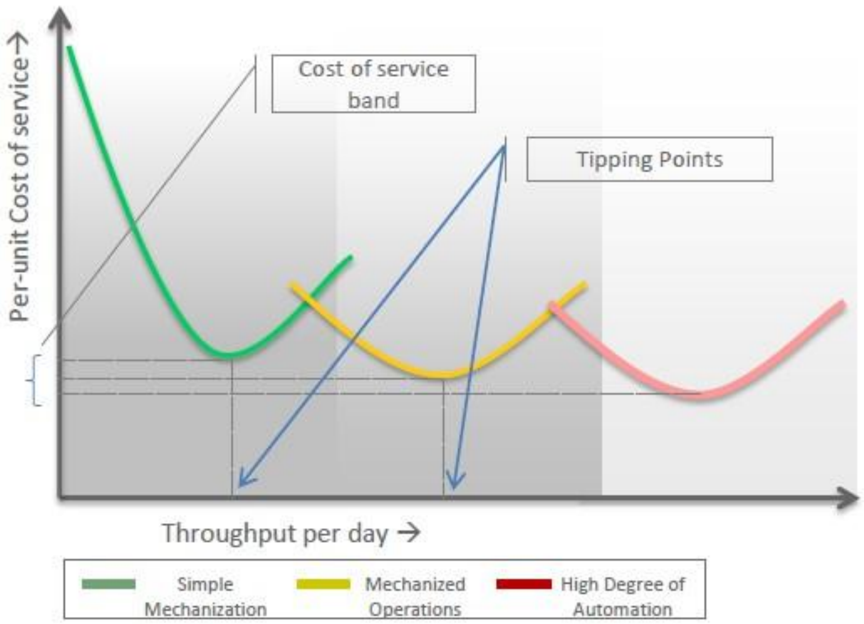

Figure 2. Sorting Technology Curve

The above graph demonstrates the CPS trend with increase in daily demands. While generally the per-unit cost of operation will reduce as warehouses move towards greater degree of mechanization and automation, costs are also dependent on local factors. At the same time, awareness of the tipping point is essential to maintain low cost of operation with the promised level of service.

Learnings

Overlaying other factors linear sorters becomes attractive from 50K daily through put onwards

Tilt tray sorters at 100K-250K have a range bound cost per shipment under different scenarios

In the 200K-400k throughput range Cross Belt sorters are better

Significant manpower reduction and higher reliability makes automation more attractive

The final mix for sorting technologies would be derived from the final network model

All of the above are for a 2 shift scenario.

Approaches for Peak Design Capacity

Sortation Centres need to handle the following 3 types of peaks and there are permanent & temporary capacity levers to address them

- Intra-day Peak
- Daily Average peak
- Sale month peak

Levers for Capacity Management

Permanent Capacity Management – Design for highest vs Design for intermediate peak

Temporary Capacity Management –

SLA Management **-**

- Set a higher delivery time promise during the peak season
- Take pre-bookings/ expand from single day to multiple day promotions

Manpower Planning **-**

- 3rd shift / Night shift operations using additional temporary staff
- Re-designing resourcing –overstaff for faster operations

Leveraging 3PL Sorting Centres –

- Enter into partnerships with 3PLs to utilize their spare capacity
- Typically difficult given matching of peaks during the period

Learnings

Designing for highest peak is 2-2.5 times more expensive than the designing for the second peak

Capacity planning for peak months (Sale) can leverage better SLAs, manpower planning and outsourcing

Solution Map

Data Basis

- Taken at network design throughput of ~100,000 shipments per day for a manual setup for 2 shifts (16 hrs)
- Labour cost linked with throughput (~90-95% variable)
- Security and rentals driven only by space (~100% fixed)
- Capital Expenditure driven only by installed capacity (~100% fixed)
- 2nd Peak taken to be 1.5-2 times average daily peak and highest peak 4-4.5 times the average daily peak

Sort Philosophy	Sort at destination becomes cheaper when the sort threshold for a particular technology or manual setup is reached Build flexibility in sorting solution to sort for optimal number of destinations at each mother-hub based on through-put requirement. Maximize number of sorts at hub through dynamic bin allocation and managing in-bound waves.→ based on the load pattern of destinations
Sort Tailoring	Local vs. Non local tailoring is recommended if clubbing of requirements is not possible.→ geographical demand pattern FA vs Non FA tailoring is governed solely by business needs & supply chain construct.
Sorting Technologies	Overlaying other factors linear sorters becomes attractive from 50K daily through put onwards Tilt tray sorters at 100K-250K have a range bound cost per shipment under different scenarios In the 200K-400k throughput range Cross Belt sorters are better
Peak Design Capacity	Designing for highest peak is 2-2.5 times more expensive than the designing for the second peak Capacity planning for peak months (Sale) can leverage better SLAs, manpower planning and outsourcing

Conclusion

For a huge, diverse& growing country like India most of the decisions are based on optimization of resources. The answers the questions raised might change from industry to industry.

Network

Build flexibility to sort for optimal number of destinations at each mother-hub based on through-put requirement.

Maximize number of sorts at hub through dynamic bin allocation and managing in-bound waves.

Asset

The final mix for sorting technologies would be derived from the throughput requirement &final network model

Capacity planning for peak months (Sale) can leverage better SLAs, manpower planning and outsourcing

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SUPPLY RISK MITIGATION OF SMES THROUGH LEVERAGING SOCIAL CAPITAL: DEVELOPMENT AND VALIDATION OF A MEASUREMENT INSTRUMENT

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Abstract: Literature on supply risk management has consistently promoted the use of network capital to mitigate supply risk of small and medium-sizedenterprises (SMEs). Many scholars in supply chain management have suggested that structural, relational and cognitive dimensions of social capital in both the buyer–supplier network and the network of peers within a cluster can play an influential role in mitigating the supply risk of SMEs. Although research interest in supply risk management through a social capital approach is growing, so far no study has been directed towards the development of an instrument to measure network capital in the context of SMEs. To supplement such inadequacy, this study conceptualizes, develops and validates four constructs of network resources/practices, namely, buyer–supplier social capital, cluster social capital, buyer–supplier integration and cluster cooperation, and supply risk construct. In developing the instrument, a rigorous process employing literature review, focus groups discussion, opinions of academics and experts, and agreement survey has been followed. Using the survey data collected from the apparel SMEs of Bangladesh for validation, the findings of the study suggest that the proposed instrument is a set of reliable and valid measures of the above-mentioned constructs. Therefore, it can be subsequently applied in other studies through a contextual modification as a means to examine various theoretical and conceptual models.

Keywords: Measurement, Social capital, Supply risk, Small and medium-sized enterprises

Introduction

In today's global business environment, supply chains have become more complex in structure and challenging in management (Ambulkar et al. 2015; Cheng et al. 2012). Consequently, firms are exposed to higher supply risks in recent years (Christopher et al. 2011). Supply risks can be defined as the probable deviations in the inbound supply from the initial overall objectives that may result in incomplete or unfinished orders(Kumar et al. 2010). Supply risks incur significant financial and non-financial losses for organizations who fail to protect themselves against the risks (Kim & Vonortas 2014; Wiengarten et al. 2013). In general, the impact of supply risks on firm performance is more severe for small and medium-sized enterprises (SMEs) than large corporations (Ellegaard 2008; Hendricks & Singhal 2005; Hendricks & Singhal 2003). For instance, through a comparative study, Hendricks andSinghal (2005) reported that similar supply risk reduces operating income of SMEs by 75.77% more than that of large enterprises.

Although SMEs are more vulnerable to supply risks than large enterprise, focus of previous studies on supply risks or supply risk management has been placed mainly on large corporations(Kim & Vonortas 2014; Ellegaard 2008). Moreover, the majority of these studies primarily recommended holding buffer stock, developing supplier, and ensuring formal process for mitigating supply risks. Each of these measures needs either considerable resources or strong position power to influence suppliers. These measures are usually beyond the capabilities of SMEs due to their limited resources and managerial skills (Chowdhury 2012; Prasad et al. 2012). As an alternative avenue, many authors proposed leveraging social capital to mitigate supply risks of SMEs (Prasad et al. 2012; Jansen et al. 2011; Villa & Antonelli 2009). The authors argued that social capital, which exists within the horizontal and vertical network of an organization, can help develop SMEs' ability in mitigating supply risks. However, social capital requires less financial investment (Uphoff 2000) which overcomes the barrier of resource deficiency of

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SMEs. While different studies suggested the use of different types of social capital to mitigate supply risk, Chowdhury et al. (2016) mentioned, through an extensive literature review, that two types of social capital are particularly relevant to SMEs. They include buyer–supplier social capital – resources gained via the network of sourcing SMEs and their suppliers – and cluster social capital – resources leveraged through the network of similar SMEs within the same geographical cluster. The authors also contended that buyer–supplier integration and cluster cooperation mediate the relationship between (a) buyer–supplier social capital and supply risk, and (b) cluster social capital and supply risk respectively, as depicted in Figure 1. To validate the relationships between the constructs, they called for future research to investing ate these associations. While leveraging social capital to mitigate supply risks of SMEs is suggested in the literature, no research so far has been directed towards the development of a survey instrument to measure the above-mentioned network resources and supply risk in the context of SMEs. Given that operational measures of a construct depend on the size and context of the firm (Venkatraman 1989), it is important to develop an instrument to measure the above-mentioned constructs in the context of SMEs before testing the relationships.

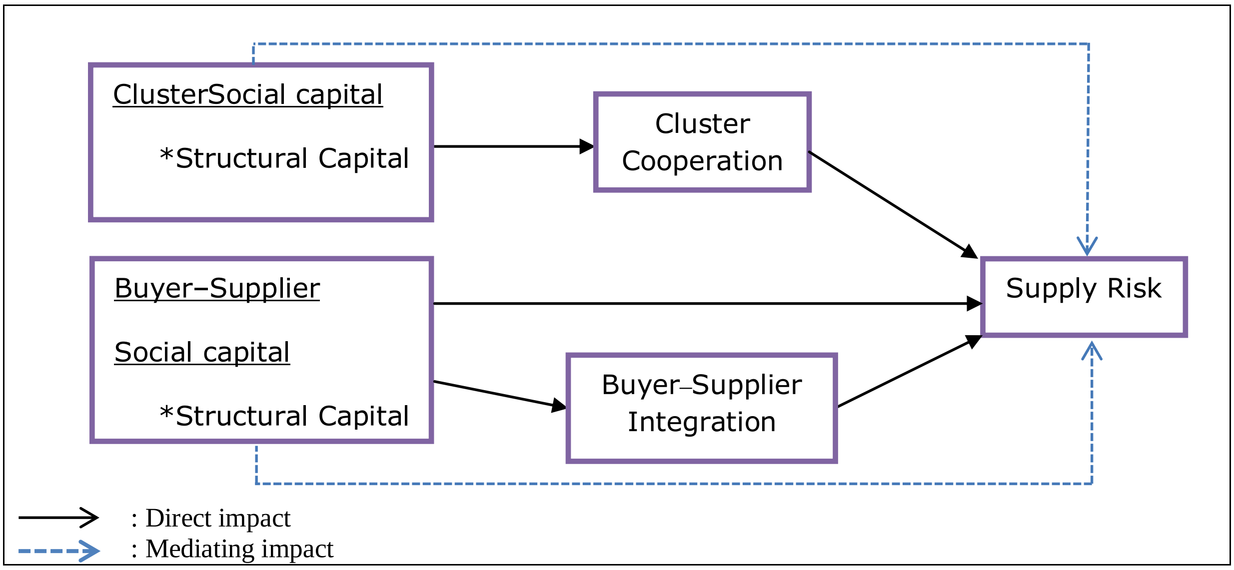

Figure 1: A conceptual framework of network resources and supply risk (Source: Chowdhury et al. (2016, p. 40)

The primary purpose of this study, therefore, is to develop an instrument to measure five constructs, namely, buyer–supplier social capital, cluster social capital, buyer–supplier integration, cluster cooperation and supply risk in the context of SMEs. Many authors in the field of supply chain management have highlighted the importance of clearly defining constructs and measurement items under various contexts to enhance stringency of the research (Li et al. 2005; Chen & Paulraj 2004). Given that development of a measurement instrument for the constructs is at the core of theory building (Venkatraman 1989), we intend to contribute to the development of supply risk and network resources constructs with a set of operational measurements. Towards this end, we have followed a very rigorous step-by-step process to minimize the errors of the measurements. Therefore, the findings of this study provide a set of valid measures that can be subsequently applied in other context to extend or refine the conceptualization as well as operational measures. Such an effort reflects a cumulative theory-building perspective where advancement is made by successively examining the efficacy of the measures in varying theoretical networks (Cronbach 1971). Moreover, this study will allow researchers to examine various theoretical and conceptual models with any of the five constructs, developed in this research, in the contexts of SMEs.

The rest of the paper is organized as follows. In section 2, we define the domain and dimensions of all the constructs. Section 3 describes the data collection procedures of this research, followed by a section on the measurement development process.

Finally, section 5 discusses the implications and the limitations of this research.

Domain and Dimensions of the Constructs

Domain of a construct is usually a brief yet reasonable and acceptable representation of the concept of interest (Lewis et al. 2005). In this research we specified the domain and the dimensions of all the constructs from the extant literature because reviewing the literature to identify the domain and the dimensions of a construct is considered as a more appropriate technique (Lewis et al. 2005).

Social Capital

Social capital, which is available through social network, has been considered as a valuable resource (Granovetter 1992). Although a number of definitions of social capital exist in the literature (Inkpen & Tsang 2005), we define social capital as "the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit"(Nahapiet & Ghoshal 1998, p. 243). We adopt this definition because it accommodates both individual and organizational social capital (Inkpen & Tsang 2005) and provides a wider view of the subject (Carey et al. 2011). This view of social capital comprises three dimensions: structural, relational and cognitive social capital (Nahapiet & Ghoshal 1998; Tsai & Ghoshal 1998).

Structural capital refers to the frequency of the social interaction between the network members (Carey et al. 2011). It emphases the benefits of multiple social ties across different levels and functions among the firms within the network (Prasad et al. 2012). Relational capital is the extent of kind of personal relationship between the members (Nahapiet & Ghoshal 1998; Tsai & Ghoshal 1998). Relational capital includes trust, commitment, reciprocity, friendship and mutual respect that network members have developed with one another (Villena et al. 2011). Finally, cognitive capital is the level of common perspectives, such as shared values, philosophies, languages and understanding, between the members of the network (Coleman 1988).

This research focuses on two types of social capital – buyer–supplier social capital and cluster social capital – because both of these social capitals assist SMEs in mitigating their supply risks (Chowdhury et al. 2016). While buyer–supplier social capital refers to the network resources leveraged from the network of sourcing SMEs and their key suppliers (Carey et al. 2011), cluster social capital refers to the network resources derived from the network of similar SMEs operating within a particular geographical cluster (Inkpen & Tsang 2005). This study provides the measures of all three dimensions of social capital for both buyer–supplier social capital and cluster social capital.

Buyer–supplier Integration

Effective supply management needs integration of key strategies within the process (Lambert & Cooper 2000). Following the definition of Chen et al. (2004) and Das et al. (2006), this research defines buyer–supplier integration as the synchronisation of information, resources and activities of suppliers and buyer in an essence of cooperation to gain mutual benefits. Multidimensional measures, such as (1) information sharing, (2) resource sharing, and (3) supplier collaboration between the buying firms and its key suppliers, represent the buyer–supplier integration.

***Cluster Cooperation*:**

Cluster cooperation can be defined as the situation whereby homogeneous firms within the cluster share timely and quality information, share resources, and take remedy actions jointly (Oprime et al. 2011). Cluster cooperation is especially important for SMEs as they do not have sufficient physical resources and knowledge to individually deal with all the uncertainties.

Supply Risk

In the classical decision theory, risk is conceptualized as "variation in the distribution of possible outcomes"(March & Shapira 1987, p. 1404). Following the variation-based view, this study conceptualizes supply risk as deviations in inbound supply from the initial overall objectives (Chen et al. 2013; Kumar et al. 2010). These deviations can occur in the time of delivery, quality of products, quantity of products or overall requirements.

Data Collection

In this research, required data has been collected from the manufacturing SMEs in the apparel industry of Bangladesh, one of the major developing countries in terms of growth in Gross Domestic Product (GDP) (World Bank 2015). Bangladesh is chosen as a study country for a number of reasons. First, literature on operations research, particularly on supply risk mitigation, of developing countries is still relatively limited (Sodhi & Tang 2014). Second, selecting a country from the developing world seems more appropriate for this research because SMEs in the developing countries are more inclined to rely on social capital to manage risks (Gao et al. 2011). Finally, SMEs play a very significant role in the economy of Bangladesh (Rahman et al. 2015; Chowdhury et al. 2013). SMEs in the apparel industry are chosen as the subjects because this industry has been contributing significantly – around 80% of the total export for the past few years – to the economy of Bangladesh (Ahmed et al. 2014). Considering the context, firms having a maximum of 250 employees are considered as SMEs (Industrial Policy, Government of Bangladesh,2010)

Measurement Development Procedures

In designing the instrument, we followed a rigorous step-by-step process adapted from Straub et al. (2004), Vogt et al. (2004) and Haynes et al. (1995) to minimize errors. Initially, measurement items of all the constructs were developed by reviewing the facets of similar constructs from previous studies(Straub et al. 2004). Then, three focus group meetings with some members of the survey populations were conducted to validate the developed instrument and to reveal any new constructs or facets that are specific to the target population of the study (Vogt et al. 2004; O'Brien 1993). After the focus group meetings, the instrument was modified and new items were added. The instrument was then shown to academics and members of the target population to establish its appropriateness, adequacy and clarity(Lewis et al. 2005). Following the suggestions of the reviewers, the instrument was revised again. Finally, an inter rater agreement survey was carried out to determine the relevancy of the items to the constructs (Lindell 2001).The process is depicted in Figure 2.

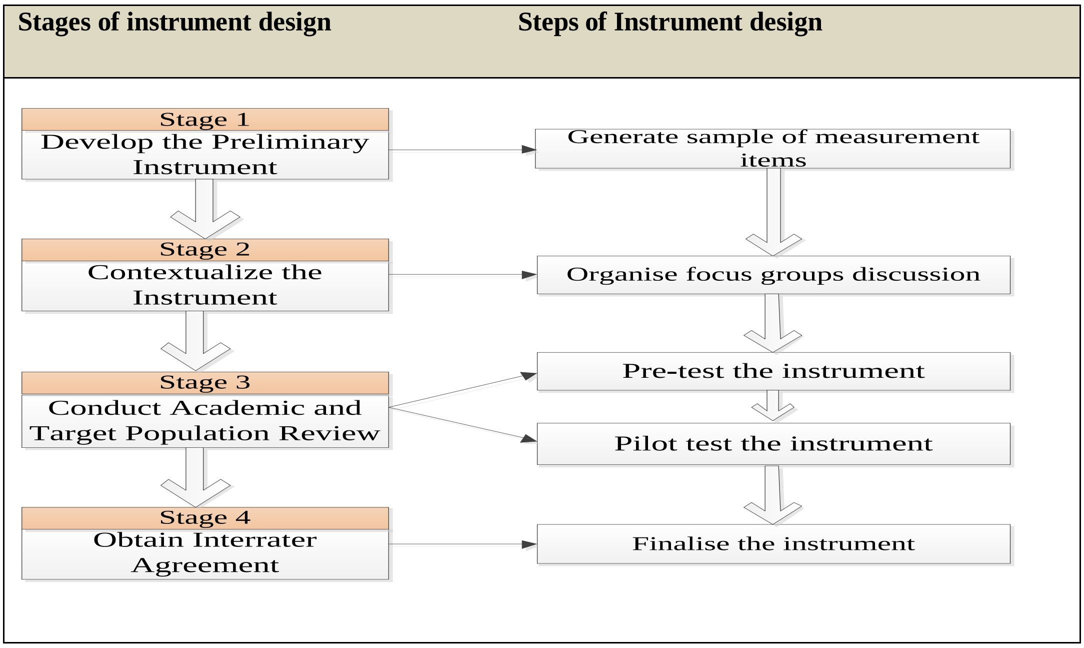

Figure2:Stages and steps of the survey instrument development process

Development of Preliminary Instrument:

Preliminary Measurement Items for Social Capital

This study investigates two forms of social capital – buyer–supplier social capital and cluster social capital. Research that investigates two or more types of network capital generally uses the same items for different networks (Mesquita & Lazzarini 2008; Schmitz 1999). Thus, same items were initially selected to measure both forms of social capital. However, they were referred in separate questions. Upon reviewing the extant literature, six items were selected to measure the structural social capital. These items are mainly concerned with the frequency of interactions and the multiple connections across diverse functions between the personnel of member organizations of the network. These interactions between network members include interactions in social events, joint workshop, co-location, team building exercises, interactions across different functions (Carey et al. 2011), and intensive interactions between the personnel (Villena et al. 2011). In order to measure the relational social capital six items were selected that examine the extent to which the relationship between the network members is characterized by trust, mutual respect, friendship, reciprocity, interpersonal communication and commitment (Carey et al. 2011; Krause et al. 2007; Kale et al. 2000). Finally, we selected five initial items to measure the cognitive social capital. These items examine the extent to which network members are congruent in organizational cultures, business philosophies, goals, ambition and vision, and codes and language(Johnson et al. 2013; Villena et al. 2011).

Preliminary measurement Items for Buyer–supplier Integration

Thirteen initial items measuring three dimensions – information sharing, resource sharing and supplier collaboration – of buyer–supplier integration were initially selected to operationalize the construct. We selected four items from Prajogo & Olhager (2012),Chen & Paulraj (2004) and Chen et al. (2004) to measure the information sharing. These items measure the extent to which the buying SMEs and their key suppliers: (1) share sensitive information, (2) share any information that might help other party, (3) exchange information timely, accurately and/or completely, and (4) keep each other informed about events or changes that may affect other party. In order to operationalize the resource sharing, we selected four initial items from Yim & Leem (2013) that examines the extent to which the buying SMEs and their key suppliers share: (1) business experiences, (2) technical supports, (3) tangible resources when necessary, and (4) financial resources. Finally, we selected five measurement items from Li et al. (2005) to examine the supplier collaboration. These items examine the extent to which SMEs (1) solve problem jointly with key suppliers, (2) help key suppliers to improve quality, (3) include key suppliers in improvement program, (4) include key suppliers in planning, and (5) involve key suppliers in product development.

Preliminary Measurement Items for Cluster Cooperation

Eight items were initially selected to measure the cluster cooperation that examine the extent to which SMEs within the cluster share information and resources, and take joint action to gain mutual benefits (Li & Geng 2012; Schmitz 2000). These items are reflected in the cooperation with other SMEs within the cluster to: (1) exchange information, (2) share business experience, (3) exchange resources, (4) follow up the activities of each other, (5) take joint action to improve product quality, (6) organize labour training jointly, (7) use cooperative sourcing, and (8) solve common problem jointly.

Preliminary Measurement items for Supply Risk

This study uses the variance-based view in defining supply risk. We initially select six items to measures variation in inbound supply demonstrated through (1) quality, (2) quantity, (3) lead time, (4) overall requirements, (5) maintaining promise, and (6) capacity(Chen et al. 2013).

In summary, 61 items are initially selected from the extant literature to operationalize the constructs of this study.

Contextualization of the Instrument

Next, three focus group meetings with some members of the target populations – operation managers of apparel SMEs of Bangladesh – were organized to validate and modify measurements of constructs to enable a better fit in the context of the research (Vogt et al. 2004). In this research, the size of each focus group was five, which allowed the participants to involve more in the discussion as recommended in other studies (Neumark-Sztainer et al. 1999; Kitzinger 1995). The three group discussions lasted for 55 minutes, 69 minutes and 71 minutes respectively. As the same issues and topics identified in the first and the second meetings also emerged in the third meeting and there was no new finding, the point of saturation was reached and the focus group discussions were considered completed (Morgan 1997). All the sessions were audio recorded with the permission of the participants to facilitate the coding and the analysis of the data (Owen et al. 2016; Kidd & Parshall 2000). From the analysis of the focus group data, thirteen new items were added under four constructs – buyer–supplier social capital, cluster social capital, buyer–supplier integration and supply risk. Respondents endorsed the measurement items of cluster cooperation construct but they did not provide any new item.

Buyer–supplier Social Capital

Two new items were identified under the construct of buyer–supplier structural capital. These are: (1) SMEs interacts with their suppliers face-to-face, and (2) SMEs interacts with the suppliers via multiple channels. Respondents of all three focus group meetings mentioned about these two items. For example, one of the participants of the first group meeting mentioned that "w*e physically go to the suppliers' house to buy the material, although we know they will deliver it to us if we order through mobile*". Another respondent of the first group meeting said that "*in addition to face-to-face interaction, we communicate with the key suppliers in different ways: sometimes we call them, sometimes we use social media to communicate with them, and sometimes we use email to interact with them".*

One additional item was added in this stage to buyer–supplierrelational capital. One of the respondents in the second group meeting mentioned that "*we always value the best interest of the relationship; we try to avoid any behaviour that may harm the other party*". Thus, one item that relates to the togetherness in the relationship between SMEs and their key suppliers was added to the buyer–supplier relational capital. One item was also added to the buyer–supplier cognitive capital. Respondents in the first group meeting mentioned that "Most of *our supplying firms are also small firms like us; hence we understand each other substantially".* Similar discussion also emerged from the second group meeting; hence the measurement item – buying SMEs and their key suppliers share the similar resources/capabilities – was added to the buyer–supplier cognitive capital.

Buyer–supplier Integration

Three initial dimensions – information sharing, resource sharing and supplier collaboration – of buyer–supplier integration were supported as the dimensions of buyer–supplier integration by the respondents of the groups meeting. One more dimension – flexible sourcing – was identified at this stage as respondents of all three groups discussion mentioned about fulfilling sudden needs and modifying the orders. For instance, one of the respondents of the second group meeting mentioned that "*if we need something urgently, we just make a call to our key suppliers and they take all necessary actions to deliver the materials to our factory*". Based on the findings of all three group meetings, four items were identified to operationalize the flexible souring. They include: (1) firms can make quick orders, (2) firms can modify the order specification, (3) firms can modify the delivery time, and (4) suppliers take necessary actions to fulfil sudden needs.

Cluster Social Capital

Discussions with the respondents in all three group meetings revealed that firms within a cluster interact quite frequently in different ways with other firms to build personal relationships. For instance, one of the respondents of the second group meeting mentioned that "*as we are doing business in the same area, we frequently take lunch or go to the mosque together for the prayers; this kind of social interaction improves the bonding between us".* Consequently, one item – firms within a cluster interact in the various daily activities – was added to the measurement of structural cluster capital. One measurement item was also added to the cluster relational capital that relates to togetherness, as the respondents of the second and the third focus groups clearly mentioned that they valued the collective benefit of the cluster, and together with other firms they were trying to develop the whole cluster. For instance, one of the respondents of the third focus group mentioned that *"despite all of us (the firms) in this apparel cluster are doing the same business, we work hard together to develop the image of this cluster. We believe if we can work together, we can improve the reputation of the cluster and can attract more buyers."* Two items were also added to the cluster cognitive capital to measure the extent to which: (1) firms within a cluster use the same terms and jargons, and (2) employees of the firms within a cluster have similar professional and trade skills. Respondents of the second and the third group meetings mentioned the first item while respondents of all three groups mentioned the second item. For instance, in the second group meeting, one of the respondents mentioned that *"as we all are based in the same area, we always use the same terms and jargons*". One of the respondents in the first group meeting mentioned that *"employees of all the firms in this area have similar skills because we are doing the same business and producing identical products"*.

Supply Risk

In addition to the measurement items identified from the literature review, respondents of the group meetings mentioned about the deviation in price in sourcing. For instance, one of the respondents of the first group meeting mentioned that "*sometimes we face problem due to the frequent price increases by the suppliers. For example, I bought some materials from a supplier last week and when I returned a couple of days later to buy some additional materials the price had increased*". Therefore, it was added as a measurement item for supply risk.

In summary, through the focus group discussions, thirteen new items were added to the instrument, giving a total of 74 items to operationalize the constructs of this research.

Academic and Target Population Review

Pre-testing the Instrument

The instrument of this study was pretested by the academics to examine whether the instrument accomplishes the study objectives (Forza 2002). The instrument was pre-tested in two phases. First, the English version of the questionnaire was presented to three academics to ensure that the instrument measures all the constructs appropriately and adequately. Some modifications were made with the scaling and anchoring of the questions in the questionnaire. The questionnaire was then translated into Bangla, the mother language of Bangladesh, by a professional interpreter. At the second phase, the translated questionnaire was presented to five local academics to comment on the questions in the instrument in terms of their relevancy, adequacy and clarity. Some minor modifications were also made with the wording of the questions.

Pilot Testing the Instrument

At this stage, the researchers physically visited five samples of the target population, and questionnaire was presented to them face-to-face(Schwarz et al. 1991). Respondents were asked to review whether (1) definitions of constructs are clear, (2) wording and meaning of the questions are clear, and (3) there is any likely problem in answering the questions. Based on the comments of the respondents, some minor revisions were made to ensure that the questions and instructions are clear and user friendly.

Interrater Agreement Survey

Finally, an interrater agreement survey was carried out to determine the relevancy of the items to the constructs and ensure the further content validity(Haynes et al. 1995).A five-point Likert scale ranging from 'not relevant' to 'absolutely relevant' for all 74 items of the instruments is used in this study (Banerjee 1999). Using 10 or more raters is suggested for the interrater agreement survey (Lindell et al. 1999). In this study 20 interrater survey questionnaires were distributed and collected from the respondents to ensure more consistent results (Lindell 2001).From the responses of the judges, a mean score was computed to represent the extent to which a particular item is relevant to a construct (Polit & Beck 2006). If the mean value of an item is less than half of the maximum scale point (i.e. 2.5 in this case), that item is considered irrelevant to the construct (Shoukri 2010; Davis 1992), and should be deleted from the instrument (Lindell 2001). Mean score of all the items of the instrument of this study is more than 2.5 (appendix 1), thus all of them are retained for further analysis.

If an item receives more than half of the maximum possible mean score, then it should be further analyzedthrough investigating the power and the p-value of the items to examine the consensus of the agreement among the raters (Preston & Colman 2000; Lindell & Brandt 1997). In the situation when judges rate multiple items of a single target, Lindell (2001) have developed the mathematical equation to calculate the index of interrater agreement$\left(r *_{wg}\right)$.The recommended equation for calculating the interrater agreement is as following;

$$r *_{wg\ (J)} = 1 - \left(\frac{s_n^{-2}}{s_{EU}^2}\right)$$

where

J is the number of items

s_n^{-2} is the variance of the ratings of judges

s_{EU}^2 is the variance of the uniform distribution

Based on the index of interrater agreement, p-value and power of each of the items were calculated. An item, which sustains through the evaluation of the mean value, is dropped from the instrument if the p-value of the item is more than 0.05 and/or the power is less than 0.8 (Sud-on et al. 2013). Summarizing the discussion above, the decision regarding dropping the items was taken based on the following criteria-

1) Drop item when its mean value is less than the midpoint.
2) Drop items left from 1) when p > .05.
3) Drop items left from 2) when power < 0.8.

The results of the interrater agreement analysis (appendix 1) demonstrate that altogether 10 items of this study received p-value more than 0.05 and/or power less than 0.8. These 10 items were dropped from the instrument. The final instrument, therefore, contains 64 items used to measure the four constructs of network resources and supply risk constructs. Appendix 1 includes all the items to operationalize these five constructs.

Discussion and Conclusion

This study presented the development of the operational measures for four network resources constructs and supply risk construct in the context of SMEs. During the construct validation process, thirteen new items and one sub-construct were added with the preliminary instrument which was developed based on literature review. However, during the purification process, 10 items were deleted for improving the content validity of the constructs. Deletion of these 10 items does not affect the underlying theoretical construct. Their deletion only reflects that these items are not important in the context of SMEs.

The major contribution of the present study is the provision of a rigorously validated instrument for of a set of constructs related to network resources and supply risk in the context of SMEs. We believe the measures developed in this research are valid and can be used for further studies on network resources and their relationship with other outcome constructs, such as operational performance, knowledge creation and knowledge sharing. Although, many scholars suggested that social capital can play a very significant role in mitigating the risks of SMEs, there is alack in the understanding of what constitutes a comprehensive set of network capital constructs. The measures of four network resources constructs – buyer–supplier social capital, cluster social capital, buyer–supplier integration and cluster cooperation – provided in this paper can be useful to SME practitioners in evaluating their state of network capitals. These measures can help them formulate proper strategies to leverage various types and dimensions of network capitals.

In the present work, data was only collected from SMEs in Bangladesh. Future studies can broaden their scope by collecting data from various developing and developed countries. This is because measures developed in this study may not be appropriate for the SMEs in developed countries as they are relatively IT savvy and provided with formal training opportunities (Tang et al. 2015; Kartiwi & MacGregor 2007). Since the concept of social capital can be studied in the context of various networks (Inkpen & Tsang 2005), a single study may not be able to cover the domain of various networks. In this study, we only focused on two networks – network between sourcing SMEs and their key suppliers, and network of peers operating within a geographical cluster. Future studies can develop measures of social capital for other networks, such as manufactures with their customers, subsidiaries working under a unified business identity, and manufacturers with different logistics service providers. Another direction for further study is that dimensionality, convergent and discriminant validity of the constructs can be checked through quantitative analyses, such as exploratory factor analysis or confirmatory factor analysis. A large-scale survey can be conducted to test the dimensionality, convergent and discriminant validity of the developed constructs.

Appendix: 1

Measurement of Constructs with the results of interrater agreement analysis

Constructs	Items	Mean	p-value	Power	Decision
Buyer–supplierStructural Capital**	Intensive interaction between the personnel	4.40	0.000	1.00	√
	Interaction between the personnel across different functions	3.35	0.024	0.56	Dropped
	Interaction in the organized social and family events	3.75	0.001	0.95	√
	Interaction in the joint workshop	2.80	0.209	0.12	Dropped
	Interaction in the co-location	4.10	0.004	0.86	√
	Interaction in the team building exercises	3.40	0.071	0.32	Dropped
	Face to face interaction *	4.25	0.000	0.99	√
	Interaction via multiple channels *	4.35	0.001	0.98	√
Buyer–supplierRelational Capital**	Trust between the partners	4.50	0.000	1.00	√
	Mutual respect between the partners	4.05	0.001	0.97	√
	Personal friendship between the partners	3.90	0.004	0.86	√
	Reciprocity (feelings of fairness to work mutually) between the partners	4.40	0.006	0.81	√
	Personal interaction between the partners	3.65	0.005	0.82	√
	Commitment for working in the foreseeable future	4.40	0.000	1.00	√
	Togetherness between the partners*	4.00	0.004	0.85	√
Buyer–supplierCognitive Capital**	Similar corporate values	4.45	0.000	1.00	√
	Similar philosophies/ approaches to business dealings and management styles	4.20	0.000	1.00	√
	Similar business goals	3.70	0.021	0.58	Dropped
	Similar ambition and vision	3.40	0.071	0.32	Dropped
	Similar business codes and language	3.65	0.001	0.98	√
	Similar resources/capabilities of the business	3.25	0.004	0.87	√
Information Sharing**	Buying firm and its key suppliers share sensitive information	3.85	0.001	0.98	√
	Buying firm and its key suppliers share with each other any information that might help other party	4.35	0.000	1.00	√
	Buying firm and its key suppliers exchange information timely, accurately and/or completely	4.65	0.000	1.00	√
	Buying firm and its key suppliers keep each other informed about events that may affect the other party	4.10	0.000	1.00	√
Resource Sharing**	Buying firm and its key suppliers share business experiences	4.45	0.000	1.00	√
	Buying firm and its key suppliers share technical supports	4.00	0.000	1.00	√
	Buying firm and its key suppliers share equipment when necessary	3.40	0.013	0.67	Dropped
	Buying firm and its key suppliers share financial resources	3.85	0.002	0.92	√
Supplier Collaboration**	Buying firm regularly solve problems jointly with its key suppliers	4.40	0.000	1.00	√
	Buying firm have helped its key suppliers to improve their product quality	4.00	0.004	0.85	√
	Buying firm have continuous improvement programs that include its key suppliers	3.35	0.012	0.69	Dropped
	Buying firm include its key suppliers in planning and goal-setting activities	3.95	0.001	0.97	√
	Buying firm actively involve its key suppliers in new product development processes	4.05	0.002	0.91	√
Flexible Sourcing**	Key suppliers allow the buying firm to make quick order when necessary*	4.10	0.001	0.95	√
	Key suppliers allow the buying firm to modify the order specifications when necessary*	4.55	0.000	1.00	√
	Key suppliers allow the buying firm to modify the delivery time when necessary*	3.90	0.004	0.86	√

	Key suppliers take necessary actions to fulfil the sudden needs of buying firm*	4.55	0.000	1.00	√
Cluster Structural Capital***	Intensive interaction between the personnel	4.25	0.001	0.95	√
	Interaction in the organized social and family events	4.10	0.000	0.99	√
	Interaction in the joint workshop/training	3.80	0.000	1.00	√
	Interaction between the personnel across different function	3.65	0.005	0.82	√
	Interaction in the co-location	4.00	0.001	0.94	√
	Interaction in the cluster development meeting and conferences	4.45	0.000	1.00	√
	Interaction in the daily activities *	3.35	0.002	0.92	√
Cluster Relational Capital***	Trust between the members	4.45	0.000	1.00	√
	Mutual respect between the members	4.05	0.002	0.91	√
	Personal friendship between the members	4.05	0.000	1.00	√
	Reciprocity(feelings of fairness to work mutually) between the members	4.10	0.001	0.95	√
	Personal interaction between the members	3.95	0.002	0.91	√
	Commitment for helping in the foreseeable future	4.05	0.001	0.97	√
	Togetherness between the members*	3.85	0.002	0.92	√
Cluster Cognitive Capital***	Similar culture and values	4.45	0.000	1.00	√
	Similar philosophies/ approaches to business dealings and management styles	4.50	0.000	1.00	√
	Similar business goals	3.75	0.004	0.87	√
	Similar ambition and vision	3.25	0.171	0.15	Dropped
	Similar codes and language	4.10	0.000	0.99	√
	Common terms or jargons*	3.90	0.000	0.99	√
	Similar professional or trade skills of employees*	3.95	0.001	0.97	√
Cluster Cooperation***	Similar firms of the local area exchange information (e.g. information about suppliers)	4.50	0.000	1.00	√
	Similar firms of the local area exchange experiences	4.55	0.000	1.00	√
	Similar firms of the local area share resources	3.95	0.001	0.97	√
	Similar firms of the local area can follow up the innovations of each other	3.40	0.025	0.54	Dropped
	Similar firms of the local area take joint effort to improve the quality of products	3.50	0.014	0.66	Dropped
	Similar firms of the local area jointly organize labour training program to improve the employees' skills	3.90	0.000	1.00	√
	Similar firms of the local area use cooperative sourcing of material and/or parts	4.10	0.001	0.95	√
	Similar firms of the local area take joint actions to solve the problems	4.10	0.000	0.99	√
Supply Risk	Deviation of quality specified by buyer	4.65	0.000	1.00	√
	Deviation of delivery lead times specified by buyer	4.60	0.000	1.00	√
	Deviation of volume/quantity specified by buyer	4.65	0.000	1.00	√
	Deviation of overall requirements specified by buyers	4.15	0.002	0.92	√
	Break of promise by key suppliers in delivering material	3.95	0.001	0.97	√
	Fluctuation of the capacity of key suppliers	3.95	0.001	0.97	√
	Inconsistent price of the material*	3.75	0.001	0.95	√

*Items marked by an asterisk were added from the focus groups discussion.

**Constructs marked by two asterisks measured network resources in the network of sourcing SMEs and their key suppliers.

***Constructs marked by three asterisks measured network resources in the network of similar SMEs operating within a geographical cluster.

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EVOLUTION OF UNITIZATION IN E-COMMERCE SUPPLY CHAIN

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Abstract: Unitization as a way of moving bulk shipments is known to save on multiple fronts like time, space, costs, manpower and damages in any supply chain. This study talks about the need for evolution of unitization in e-commerce supply chains in emerging markets like India. We also highlight the challenges faced while designing a standardized unit for a wide range of shipments, with non-standard packaging being transported across various facilities and in non-standard vehicles. Secondary level unitization is identified as a key focus area for addressing the challenges and three variations of using roll containers as units are proposed for different scenarios of a versatile end-to-end e-commerce supply chain. A detailed view is given on interaction of unitization with various activities in the supply chain and the subsequent benefits derived in key performance metrics of the supply chain. To quantify this impact, estimated improvements are provided based on a theoretical study was conducted in a leading Indian e-commerce supply chain. As suggested earlier, roll containers bring improvements in areas like process throughput, manpower requirement, space efficiency, handling ergonomics and reduction of damages.

Keywords: Unitization; Material Handling; E-Commerce

Introduction

While sustainable competitive advantage in the e-commerce industry comes from an efficient supply chain design, the idea is to do more with less, and scrutinize every aspect of operations for efficiency and savings. An end-of-the-line function, like unitizing, is at the very core of creating the perfect load for handling, shipping and storing product. Truck utilization and turn-around time, staging area utilization, shipping damages, material handling manpower, operational productivity, transport center dock management, packaging costs, etc. are some of the key metrics that are directly affected by the unit used to transport goods.

Unitization is the process of consolidation of several smaller units into a single unit. It allows the combination of boxes, cartons, packages, etc., into one load (such as a pallet) for ease of handling, identification, and transportation. Factors like the types, materials and sizes of items, and transportation are key while designing the most suitable material handling unit. The finer design elements depend on the functional area, be it handling, transporting or storing the products. The process gets more complex when we try to unify these areas into a single unit design.

Most traditional industries have their own best suited methods for unitization which are integrated across the supply chain. Typically, large items are secured directly to a pallet while smaller boxes and other containers are secured to a pallet using shrink-wrap or steel strapping.[1] Industries involving products like bicycles or furniture, that are larger than an average pallet, tend to design customized units based on their requirement. Goods that are fragile, perishable or very expensive require added layers of protection. Nonetheless, each of these industries are fairly matured in terms of material handling standardization. On the contrary, e-commerce, in the emerging markets, is still in its initial phases of development.

The peculiar attributes of an e-commerce supply chain are

- Owning the end-to-end supply chain process
- High variability and range in shipment sizes and packaging design

- Loose shipment handling at source and destination
- Extremely short Service Level Agreements (SLA) time frames
- Managing high rate of returns due to damages

Some of these attributes are common to the Package Delivery and the Retail industries considering their shipment level treatment, varied range of products and extremely short SLA time frames. Hence, while designing the most appropriate form of unitization, the supply chains of global giants in these industries were studied, and learnings from these helped the base design take shape. The air cargo industry has designed large standardized secondary units or the ULD (Unit Load Device), which in turn carry primary units like bulk bags or large loose shipments.[2] The ULD forms the base of unitization for global leaders in the package delivery industry for their bulk transportation. Their counterparts in the emerging markets are less dependent on air cargo routes and thus, don't have any use for the secondary units. Retail industry, on the other hand, is largely local, and depends on surface transport, where apart from pallets, roll containers are used as secondary units.[3] In this study, roll containers are taken up as a starting point for the next step of evolution from bags as primary units.

E-Commerce in India

In a typical Indian e-commerce logistics, a shipment travels through the basic supply chain route i.e.

- Originating from a warehouse (Inventory Model) or a seller location (Marketplace Model)
- Sortation at source Consolidation Centers
- Transportation through Line Haul to the next / destination Consolidation Centers
- Transportation to the Delivery Centers from destination Consolidation Centers
- Customer level sortation at Delivery Centers
- Doorstep delivery to customer

Figure 1 shows the flow of shipment through a typical e-commerce supply chain.

In this supply chain, bulk bags are being used as a unit for bulk handling of shipments. Based to ergonomic considerations, typically such a filled bag, is restricted to weigh between 10-12 kg. These bags have been used for long enough to become the foundation around which all the systems, processes and metrics of the supply chain are defined.

Following are the observable benefits of using bags:

Flexibility

Being flexible in size and shape is one of the biggest benefits of a bag. While loading in trucks, bags allow utilization of the entire truck irrespective of the body dimensions. Additionally, a semi-filled bag takes no additional volume than what the aggregate of its shipments requires. This is a boon from space utilization point of view.

Easy Handling

The size of each bag is kept limited to allow an operator to lift, move and load a bag into the trucks. This eliminates the need for special equipment of infrastructure to handle the bags. Thus, every facility including the much smaller Last Mile and First Mile hubs can easily manage operations.

Cost-effective

The plastic bulk bags are inexpensive as compared to any rigid units made of plastic, wood or metal. Their durability is something which will be discussed further into the study.

Each of these benefits come with a flipside which could become limiting factors for a sustainable and scalable growth of the supply chain. Across the organization, people see the need to move towards a superior and more standardized unit.

Need for Evolution

This section briefly touches upon the existing pain points of the e-commerce supply chains in emerging markets which are looking for newer and superior methods of material handling as they head from a phase of rapid growth to maturity. Primary units like bulk bags carrying multiple shipments face multiple challenges as detailed below:

- **High variability and In-accurate Planning**

Owing to the non-standard and highly variable dimensions of a filled bag, making it un-stackable, it

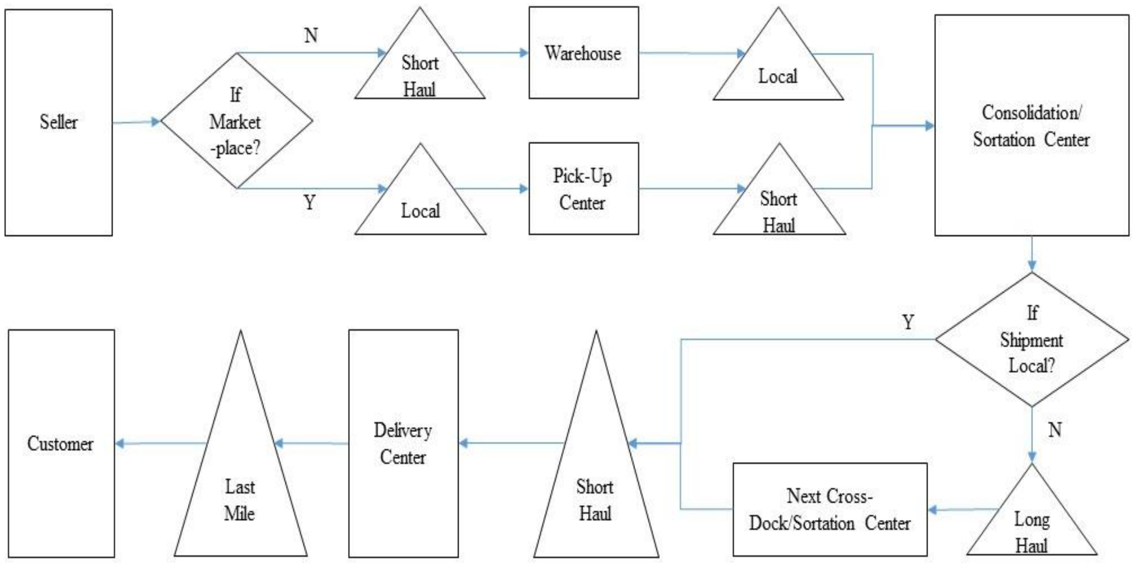

Figure 1: Forward Shipment flow through an E-Commerce Supply Chain

is difficult to compute the space and time required for the given number of shipments. The problem inflates When transportation through trucks is considered, since it prevents us from planning for the number of shipments that can be loaded onto the truck. This can lead to maintaining a buffer in the truck capacity, hence, underutilization of trucks. In monetary terms, a full truck must be rented even if only part of it is being utilized, which is often the case.

- **Time Consuming**

A typical long haul truck can be loaded with close to a thousand of these bags and can take up to four hours before it is completely filled. Even within the facilities, bags are generally moved around using trolleys. Each movement from one point to another involves loading, unloading, stacking and unstacking on and off trolleys respectively. These additional steps may seem insignificant, but they consume a good chunk of time and manpower at the facilities and lead to choking of the docks for long hours.

- **Space Consuming**

Storage and Sorting facilities dedicate up to 40% of their built-up area for staging the inbound as well as the outbound load before it moves to the next stage. Since bags don't allow for any special equipment for stacking, these are just piled up on each other in a pyramidal structure which is manually feasible. Space requirements increase with growing operations, shifting the focus on designing solutions involving secondary units which enable vertical staging.

- **Handling Ergonomics**

As mentioned earlier, bag operations are laborious with a typical bag going up to 12 kg. in weight and 6-8 cu. ft. in volume. Each bag must be handled twice while going on a trolley, being staged or being loaded into a truck. A single operator does this for more than 100 bags in a day. While loading trucks, these need to be lifted to a height of 7 feet. This slows down the process and requires additional manpower to handle the same no. of bags. Secondary units designed with respect to the truck dimensions can make these processes more ergonomic and efficient.

- **Scope for Damage**

Bulk bags are flexible which exposes the shipments to external forces when being stacked or loaded in trucks. Also, manual handling of bags increases the chances of lifting and dropping the bags on hard ground or inside trucks. This leads to measures taken on designing durable shipment packaging, to reduce the damage percentages, thus increasing packaging expenditure. Hence a need is seen in making rigid units to reduce damages, packaging costs and rate of returns.

- **Recurring costs of Consumables**

Plastic bulk bags also tend to get damaged with improper handling and multiple handshakes. Typical lifecycle of a bag is around 6 trips which leads to a consumption of lakhs of bags every month. This means that an average bag can cater to a little more than 100 shipments in its lifetime. Considering the recurring expenses on consumables and the larger impact on environment caused by these bags, a clear need is seen to move towards more durable units.

Existing Logistical Challenges in Emerging Markets

1. Non-Standard Trucks

For an e-commerce entity in its growth phase, one of the most fundamental challenges while running operations in a country like India, is dealing with a large number of vehicle service providers. There exists an 'unholy equilibrium' in the trucking sector in India wherein the regulations, financing, competition and corruption did not incentivise a trucking company to own a large fleet of trucks.[4] Roughly 75% of the fleet is with those who own up to 5 trucks. Only about 10% of the fleet is with those who own more than 20 trucks. At this scale, having a few standard players across all the regions is difficult. One must deal with more than 100 trucking companies at a Pan-India level just to run its Line Haul operations.

Another concern is the nature of the market. OEM's sell their trucks with just the cowl or a cabin. This comes with various benefits. Mainly they don't need to worry about the regulations around the body type and dimensions which are different for every state. Customers also prefer to get the bodies fabricated from external sources. Apart from getting the body made to suit the application, it also allows them to cheat the regulations and resort to bribes where necessary.

This leads to a condition where trucks provided differ with manufacturer, region and service provider. Designing secondary units which will be transported through a wide range of trucks becomes a challenge.

a) ***Truck Floors:*** Most trucks in India have corrugated metal flooring. This design allows extra rigidity and strength with thin metal sheets, and avoids contact of the load with any residual rain water if any. Any kind of unitization, be it based on wheeled containers or pallets moved using MHEs, require a standard flat flooring to allow movement within the truck. This poses a challenge from scalability point of view since only limited trucks have flat flooring and any additional installation in them like chequered plates to flatten the surface adds to a cost of around INR 20000 - 30000 per truck, and it is also a hassle with a high churn in existing fleets.

b) ***Truck Dimensions*:** As mentioned earlier, the truck bodies are fabricated by external sources and thus the dimensions (length, breadth and height) of the truck vary substantially. Although, largely the big trucks are categorised based on their length in feet (17', 20', 22' and so on), their actual length can vary quite a bit from their claimed length. Their width also varies from 6' to 8' while their height varies from 7' to 10'. Truck utilization being a key performance indicator for the line haul operations, only flexible units like bags can ensure full utilization of trucks with such variations in dimensions. With secondary units, a single size that fits all is to be designed.

c) ***Truck Bed Height*:** The dock height in facilities across India is kept at a standard 4'. Although majority of the trucks do match the dock height, the smaller length trucks and those which are modified by external fabricators do pose a problem. Since trucks with tail lifts is a rare sight in places like India, a dock leveller is a must while moving towards standard units. New installations at almost every facility across the supply chain accounts for a significant expenditure while moving towards secondary unitization.

One obvious solution to the above problems faced by an e-commerce supply chain could be to have its own fleet of trucks. However, there are plenty of hassles that come along with owning and administering a fleet, making it a mammoth management task, and most players choose to leave this to the experienced vehicle service providers.

The logistics sector in India is on the brink of a major transformation. The pace of introduction of new reforms is changing now with added efforts from the Ministry of Road Transport and Highways (MoRTH) on infrastructure, regulations and telematics to boost the logistics sector for fuelling economic growth. Standardization is the need of the hour. Unitization is one of the many ways by which growing entities can embrace the forthcoming revolution in the logistics landscape.

2. *Wide Range of Shipments*

The second most fundamental challenge is the wide range of shipments to be dealt with using standard units. To simplify the processes, levels of separation based on shipment size are created within the supply chain, which is divided into Large and Non-Large segments. White goods, furniture, and other similar categories with a high weight or volume constitute the Large segment and require a different handling and storing procedure. Rest of the categories fall under the Non-Large segment which still has a huge variation in size, shape and weight. Following are the complexities that come along with designing a standard unit for a wide range of shipments.

a) Shipment Sizes: The same supply chain caters to shipments ranging anywhere between a pen drive to a teddy bear or a bean bag. This eliminates the use of standard cartons, boxes or pallets for unitization and narrows down the options to large collapsible boxes or roll containers as seen in the retail or package delivery industries.

b) Packaging Types: The secondary packaging also varies based on size and categories and mainly constitutes cardboard boxes, polybags or bubble wrap. Standardization exists on the box sizes and polybag types used for the inventoried shipments, but it is difficult to exercise a tight control on the packaging used by the innumerable sellers in the marketplace model.

c) Loading Efficiency: Like most cases in a supply chain, here too, there exists a trade-off between productivity and utilization. While proper stacking of the shipments in a unit ensures maximum space utilization, it comes a cost of productivity. Bags, being flexible, allow a good space utilization, even if stacking is not followed. So, time required per shipment to be filled in the bag is relatively low. Rigid units require proper stacking of shipments to ensure good space utilization and this comes with a compromise on filling throughput. This needs to be weighed against the time and manpower saved in closing, staging and moving these units.

3. *Non-Standard Facilities*

Every E-commerce supply chain consists of dedicated warehouses and sortation centers spread across the country with capacities to manage their usual load. In preparation for peak sale events of the year, additional facilities are rented and developed on a temporary basis, based on the specific needs arising out of the operations conducted at each facility.

a) ***Flooring:*** Warehouses with G+5 storage required specialized MHEs and with it comes the commercial grade heavy duty flooring. Sorting hubs which don’t require any MHEs and can do with simple trolleys for bag movement have basic concrete flooring. Often even in the same facility, the type of flooring changes from docks to internal storage areas.

b) ***Docks***: The loading and unloading of bags at the docks requires a lot of time and manpower, but it does not require dock levellers. Operators are positioned at the docks and inside the trucks as the bags are handed over from one to another, one by one. Owing to this, very few facilities have dock levellers and even those are left un-utilized.

As new methods towards standardization are introduced, a need to define the norms across all facilities will arise.

4. *Truck Space Utilisation*

The limitations arising due to non-standard trucks, wide range of shipments and the compromise on loading efficiency with productivity lead to under-utilization of the trucks. Bags being smaller and flexible can use up every available space within the truck. When moving to rigid units of defined size, productivity is improved at the cost of truck utilization. Assuming roughly 40% of the trucks going completely full on any given day, truck space utilization becomes one of the crucial metrics in the overall economics of the supply chain. An average reduction of 8-10% in truck utilization comes by just moving from flexible to rigid units of the same volume. Additional under-utilization can creep in as the size of the primary unit goes on decreasing.

5. *Size for Sorting*

A typical life-cycle of a shipment involves multiple stages of sorting before it reaches the final leg of its journey. Units filled at the end of one stage of sorting go to the next stage based on the assigned destination (zone, city or postal code). Also with every successive stage of sorting, the no. of sorting stations rises and the no. of homogenous shipments per sorting station falls. At each sorting station, we need to ensure that the size of the unit is small enough to keep a healthy ratio of filled units to under-utilized ones. The initial stage where the no. of shipments per sorting station are high, they can be filled directly into the secondary units, while as they move to the next stage, primary units start coming into picture. Assuming every last unit per station is under-utilized, the effective under-utilization of assets (units, trucks and facilities) will be lesser in case of a well designed primary unit.

Design Study

The focus of the study is to propose units which can cater to most of the needs mentioned above. As a starting point, the designers started solving for making dock operations easier to save on damages, human effort and truck turnaround time by making loading and unloading of trucks faster and easier. The units have to allow a single person to swiftly move them into and out of the trucks. As the design thinking progressed, the remaining use cases were added like reducing the staging area requirement by using more vertical space, and improving the throughput at sorting stations by where sealing activity was a bottleneck.

Roll Containers

Roll containers are one of the widely used modes of material handling on shop floor and warehouses due to the ease of movement and protection of items stored inside. They also facilitate fast and smooth loading and unloading processes at the docks. Variations in no. of walls, wall dimensions, material and accessories are seen depending on the industry and the type of products associated with the roll containers. But the elegance of the solution lies in functionality and the multitude of use cases a simple design can solve for. Most importantly, the roll containers are collapsible and nestable to allow for space efficiency and easy movement when not in use. A critical factor in designing the right dimensions of the secondary units is truck utilization. An optimal design should minimize space wastage in trucks with a wide range of length and width. Underutilized truck width accentuates the space inefficiency as it spreads throughout the truck length. Taking learnings from the pallet design, units were designed with a rectangular cross section instead of square. Each unit is designed with length and breadth of 3 feet and 4 feet respectively. They can be arranged in a way to give a combined width of 6 feet, 7 feet or 8 feet, thus accommodating for the truck width variability. Considering majority of the trucks in use have a storage body height of more than 8 feet, the roll containers were designed with a height of 8 feet including wheels. Increasing the width of the roll container wheels will allow to overcome the corrugations of the truck bed. The design also needs to take care of locking the roll containers once inside the truck. Additional accessories like parking locks, detachable shelves, harnessing belts can be a part of the finer design of the roll containers. The main advantage, though, comes from the fact that, once these roll containers are filled and sealed after sorting, they are opened directly at the next destination for finer level of sorting. This reduces the number of handshakes or direct handling of shipments or primary units which means reduced time, manpower and damages and consumable costs. Roll containers are versatile, as they can be designed to accommodate shipments as well as primary units like bags or totes. This is a useful property as depending on the stage of sorting, they can serve as primary or secondary units.

Figure 2 shows the interaction of roll containers with various activities and the key metrics which are improved in each of these activities. As mentioned earlier, truck space utilization is the only area which takes a hit while moving from bags to rigid units, although with standardization, this impact can be minimized. While playing role of secondary units in most logistics processes, roll containers bring improvements in areas like process throughput, manpower requirement, space efficiency, handling ergonomics and reduction of damages. Proposed below are three variations showing different ways in which roll containers can be used for unitization.

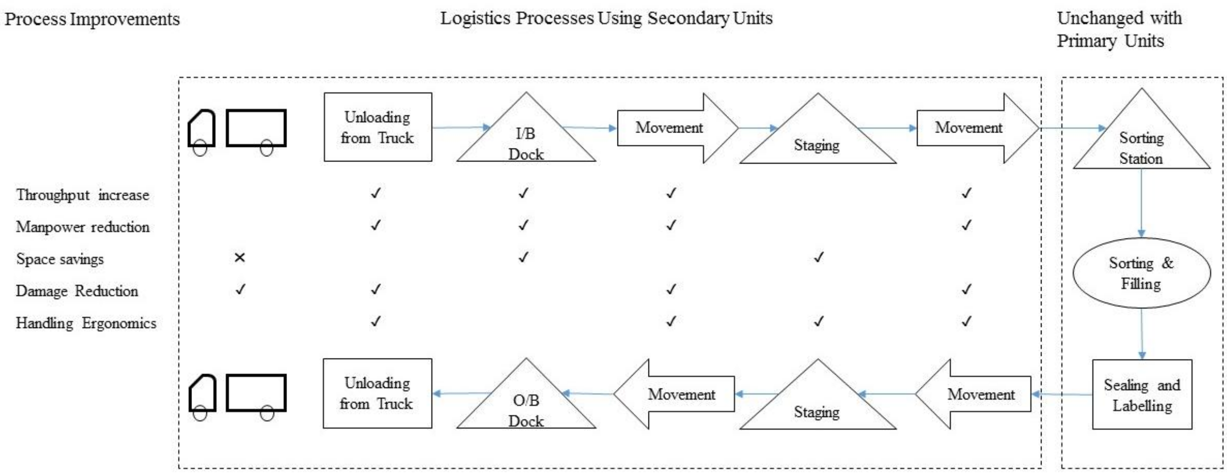

Figure 2: Secondary Unit interaction with Logistics Process at the Sortation Center

Figure 3. Nestable Roll Container with Split Door

Elaboration of Several Design Alternatives:

As part of the study, three variations of roll containers were designed based on requirements of different legs of the supply chain at Flipkart, a leading E-commerce player in India. The supply chain network and processes resembled that of a standard e-commerce entity. A benchmarking study was conducted at selected warehouse and sortation centers and metrics like throughput, manpower, space requirement etc. were extracted from the value stream mapping data and layout design in the existing condition. Further, theoretical studies conducted at these facilities with each of the above-mentioned proposals gave us reasonable estimates of the revised metrics. Specifically, Proposal A is a roll container used as a Primary load unit, best suited for use between the primary and the secondary stage of sorting. Post fine level of sorting, roll containers prove beneficial as secondary load units as seen in Proposals B and C. Given below are the details on the designs and their potential benefits as estimated in the theoretical study.

Proposal A: Roll Containers as Primary Units

Initial legs of the e-commerce supply chain, like inventory transfers and primary sorting involve a high quantity of shipments per sort. A large primary unit works best in such situations where a larger bulk of shipments are to be dealt with. Factors like manual handling capability and efficient truck space utilization put an upper limit on the size of primary units. In the Figure 3 we can see one variation of roll container designed as a primary unit. At the manual sorting stations, shipments can be directly put into these roll containers. A split door allows filling in contents with a higher throughput without spillage. Detachable shelves allow separation within the container, if necessary. Considering their size equivalent to 20 times that of a bulk bag, no additional manpower is required for sealing them once they are full. This leads to a reduction of 33% in manpower requirement at sorting stations as compared to the traditional bagging process. At the staging area, a 12 sq. ft. floor space, which can typically accommodate 8 bags stacked in two layers, can now accommodate a unit equivalent of 20 bags, thus saving 60% of staging space. Moreover, movement to staging area and the docks and into the trucks requires significantly lesser manpower owing to the larger unit size. 5 operators can now achieve the same throughput which otherwise requires 14 operators. The same holds for operations at the destination facility where the trucks are bound. An effective manpower reduction of 52% can be achieved in the facility by introducing larger primary units. Furthermore, the loading activity at the docks is 3.5 times faster, thus increasing the productivity of the docks and improving the truck turnaround time. Approximately 30% of the shipment packaging damages in transit are attributed to erratic handling of the bags while getting them on and off the trolleys or in and out of the trucks. Roll containers, being rigid, should eliminate the occurrence of these damages. While considering the cost of consumables, the cost of replenishing damaged bags can be compared with the maintenance and repair costs of a roll container. It is often the wheels of the roll container which need to be replaced after frequent intervals while the rest of the body suffers little damage. Considering estimates on average life span of a bag and a wheel of a roll container, and using the 20:1 leverage, significant savings of 94% can be achieved by getting rid of bags and moving to roll containers as primary units. Truck space utilization is one area which takes hit while moving from bags to rigid walled units. A typical truck used in the initial legs of the supply chain has a storage body measuring 20 feet, 8 feet and 8 feet in length, width and height respectively. This volume, which usually accommodates 300 bags on average, can now accommodate 12 roll containers or an equivalent of 240 bags, thus reducing truck space utilization by 20%. Although this drawback can be weighed against the other benefits to understand the overall impact on the supply chain costs and improvements in other key metrics.

Proposal B: Roll Containers as Secondary Units containing Bags

Bulk level sorting builds large unit loads of shipments which then proceed to the sorting facilities where they are put through secondary sortation for finer level of sorting with a relatively low shipment count per sort. From here on, movement down the supply chain requires smaller primary unit loads. In the current scenario, this constraint is met by using bags which carry around 20 shipments each. This proposal aims to retain bags as a primary unit due to a multitude of benefits that bags bring to the table as mentioned in this study. There are also a lot of limitations which come along with the use of bags as primary units. To solve for these issues, secondary units like roll containers are introduced into the system. The bags created at a sortation station can be directly stored in roll containers. Roll containers serve as a trolley as well, collecting bags from multiple stations serving the same route. The same unit can be further used in transportation.

Figure 4. Roll Containers for large and varied range of products. (Source: http://furnibox.com/index.html)

To improve stackability and space efficiency while using bulk bags as primary units, a larger roll container with twice the width and capacity of the standard roll container can also be explored. This unit, as shown in Figure 4, is 6 feet wide and 4 feet deep with a height of 7 to 8 feet. It normally caters to shipments in the large category and is a common sight in furniture or white goods warehouses. The main aim is to achieve space efficiency while dealing with primary units having a wide range of shapes and sizes. Since, in this proposal, 40 bags can be stored and moved together as compared to 20 bags in Proposal A, savings in manpower and time are slightly more pronounced.

Processes till the bag creation are retained as before, but once a bag is created it gets loaded into a roll container assigned to it based on the desired destination. Once these destination specific roll containers are filled, they can be moved to the staging area and the docks and into the trucks as in Proposal A. Although manpower required for sorting remains the same, the manpower for movement in the outbound area is reduced from 14 to 3 as compared to handling bags. Overall manpower reduction per facility is estimated to be 54%. The savings on floor space required for staging are the same as those in Proposal A since the dimensions and capacity of this unit are simply doubled in Proposal B. The loading activity at the docks is 5.6 times faster, thus increasing the productivity of the docks and improving the truck turnaround time. Since bags aren't eliminated in this proposal, shipment damages due to bag handling will still exist, although a lot lesser due to reduced handling. We estimate a 20% reduction in damages. While considering the cost of consumables, we must consider a fundamental assumption that a life of a bag is inversely proportional to the number of touches in a typical usage cycle from a sealed bag to the next time it is opened. A touch corresponds to each time a filled bag is lifted and dropped. The traditional bag handling process involves 26 touches per bag per cycle, whereas Proposal B reduces that number to 11. This implies a 2.3 times improvement in life of a bag which corresponds to savings of 57% on consumable costs. On adding a factor of unit maintenance and repair to the equation, the overall savings comes down to 45%. As seen in Proposal A, truck space utilization is reduced while moving to rigid secondary units carrying bags. A typical truck used at the sorting facilities of the supply chain has a storage body measuring 32 feet, 8 feet and 8 feet in length, width and height respectively. This volume, which usually accommodates 500 bags on average, can now accommodate 10 roll containers or an equivalent of 400 bags, thus reducing truck space utilization by

20%. Since the distances traveled by trucks in this leg are at a zonal and national level, under-utilization of truck-space could turn out to be very expensive as compared to initial legs of the supply chain. Trucks costs are measured in terms of capacity measured in tonne-kilometer (TKM) and every under-utilized TKM adds to wastage in the Line Haul of the supply chain. This metric has to be carefully weighed against the benefits achieved from introducing secondary units.

Proposal C: Roll Containers as Secondary Units containing Totes

Figure 5. Totes in Roll Container

A typical roll container as seen in Proposal A, but with only two walls can also be used for carrying totes instead of bags as primary units. Totes are preferred over bags in cases where the shipments are small-sized, are fragile or have a standard size allowing stackability within the totes. Typical areas of application are specific supply chains involving mobile phones, apparels, shoes, grocery, etc. Since space efficiency is not a challenge while stacking totes, a normal size roll container as that used in Proposal A serves the purpose of an ergonomic and convenient secondary unit. It stacks up 10 totes in a 2X5 matrix as shown in Figure 5. Since, primary units are retained, manpower requirement in sorting remains unchanged, while manpower savings in movement are like that seen in Proposal A. This allows an overall reduction in manpower of 44% as compared to traditional bagging process. Savings in consumable costs are negligible while moving from totes to bags since a 10-15 times improvement in life per unit is compensated by a 10 times increase in cost per unit along repair and maintenance of the primary units. To allow optimal use of volume, the dimensions of the totes should allow compact stacking of the shipments and the totes in-turn should be compactly stacked in the roll container. This will minimize truck space wastage and may even bring it lower than that seen in Proposals A and B. Although this number is heavily dependent on the type of shipment in consideration.

Comparison of alternatives

Table 1 quantifies the improvements in various metrics of a typical e-commerce supply chain for each of the proposals as compared with the existing processes. The huge difference in performance of each alternative highlights that each of them have a unique set of merits and demerits. Process design professionals can match these attributes with their specific supply chains depending upon the type of shipments and network design to choose the most suitable alternative for achieving maximum benefits.

Metrics	**Proposal A**	**Proposal B**	**Proposal C**
Sortation Productivity Improvement	43%	-	-
Manpower Reduction	52%	54%	44%
Staging Space Reduction	60%	60%	60%
Transport Capacity Utilization	-20%	-20%	-20%
Docking Time Reduction	71%	82%	71%
Damage Reduction	30%	20%	30%
Consumable Cost Reduction	94%	45%	-

Table 1 Estimated Improvements based on Theoretical Study

Managing Logistics of Units

As methods of secondary unitization are introduced, roll containers are no more kept captive within a single facility. They move vertically across the network from pick-up points and warehouses to delivery centers and back. This calls for attention to managing the logistics of these units ensuring replenishment of units at each facility as needed. Additionally, the procurement, maintenance, repair and lifecycle of the roll containers also needs to be considered. Depending on the load going through a single facility, it requires a couple of hundred of units at any point. The entire network, then, would require thousands of units, empty or filled, to be circulated between its facilities every day. Logistics at this scale also needs technology backed management by dedicated teams of professionals positioned centrally and at each of the sites. The movement of the units in and out of the facilities can be tracked using RFID solutions and a central logistics management portal, which can be integrated with the central ERP system of the organization for end-to-end mapping and visibility. Internal teams for managing the supply chain of roll containers and dealing with suppliers for fresh batches as and when required. Assuming most routes of the network have a two-way traffic with balanced load, transporting empty units to a facility for replenishment will be rare. Nonetheless, the roll containers, being nestable, minimize the additional costs of transporting for replenishment. Alternatively, organisations can outsource the management of the unit logistics to external partners with expertise in the field and provide solutions at lucrative costs. Similar models exist in the pallet industry where players like CHEP® cater to a range of clients with pallet pooling solutions. A caveat for unit pooling is that pallets are standard across industries while roll containers aren't as popular and standardized. But large e-commerce players have the onus of taking the initial steps before their practices become an industry standard and are widely adopted.

Conclusion

Unitization is a fundamental function deeply woven into the fabric of the supply chain and its influence spans vertically across all teams, processes and facilities. Hence there is a lot of inertia attached to it and bringing about a change in unitization requires bringing together various internal functions and external partners. This study provides a bird's-eye view of the interactions, benefits, challenges and possible solutions associated with evolving to roll containers for secondary unitization. Multiple benefits can be seen in terms of reduction in costs, time, space, manpower and damages which form the key metrics for any supply chain. These benefits will only be enhanced with standardisation across various functions like transportation, facilities and logistics processes. As the emerging markets throw one challenge after another at the e-commerce entities, their supply chains struggle to strike a balance between growth and profitability. It is important for them to recognize the importance of solving fundamental problems like unitization to step into the next phase of sustainable growth. E-commerce entities in emerging markets have roughly 80% of their shipments are transported by surface. With terms like Same Day Delivery and Next Day Delivery becoming more common, it becomes necessary to remove inefficiencies and buffers built into the system and make way for just-in-time processes. This also calls for more automation and lesser handshakes to build predictability into the system. Robust material handling and movement is the foundation for building a highly sophisticated supply chain.

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THE DIMENSIONS OF GREEN SUPPLY CHAIN MANAGEMENT PRACTICES

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Abstract: Green Supply Chain Management (GSCM) has become known as a key approach to enhance the environmental sustainability. GSCM has also been receiving the spotlight in many studies. In this era, preserving the natural environmental has become very challenging so that business organizations have started to feel the pressure of increased awareness level of environmental protection by the society.

This paper therefore is intended to provide a critical evaluation of literature review on Green Supply Chain Management Practices. A rigorous literature review was carried out in order to critically evaluate the definitions and different Green supply chain management practices discussed by many authors. Both conceptual and empirical papers published in past years in the reputed journals were chosen for the review. Then a content analysis was carried out comparing and contrasting the theories presented and discussed in the chosen articles published on Green management practices. Green Procurement, Green Design and Manufacturing, Green Distribution, Reverse Logistics were the identified dimensions of Green Supply Chain Management.

Keywords: Green Supply Chain Management Practices, Green Procurement, Green Design and Manufacturing, Green Distribution, Reverse Logistics

Introduction

Supply Chain Management (SCM) is the integration and coordination of business processes and strategy throughout a supply chain procedure finally for the satisfaction of end consumer. In the past, manufacturing industries were not much concerned nor persecuted on their environmental hazardous practices. Nowadays however, most manufacturing companies have been changing to eco-friendly activities to avoid environmental pollution and also to meet the customer demand for more environment friendly products. In present, organizations are shrinking in the red ocean to find new businesses. They have to find new strategies to retain the existing business due to competitiveness in the market. As a result, most organizations adopt the Green Supply Chain Management (GSCM) practices to retain the current businesses whilst trying to find methods to increase their organizational sustainability. Green Supply Chain Management follow the practices of free air pollution and methods of environment friendly waste disposals. Currently, there have been noticeable increase of continuing practices and implementing new rules and regulations to enhance the green environment in the society. The speedy global industrialization has contributed towards the damaging of the ozone layer and rapid melting of Antarctic icebergs- both of which could lead to cataclysmic consequences. The substantial increase of such issues has created the human demand to force the manufacturers to adhere to more eco-friendly practices. The effect of more pressure urges the firms to give prominence to run today's businesses on a more customer-pull mode than the customer-push status they enjoyed earlier. Today, organizations are shrinking their profit margins, implementing environment friendly practices, reducing the carbon air pollution throughout the supply chain while offering competitive prices. The concept of Green Supply Chain Management creates a new empirical approach to win the competitive advantage in the business world. Most organizations adopt the Green Supply chain management practices thus helping to enhance the quality of human living standards and increasing the expectations of reduced health hazards whilst winning the consumer's mind in the process.

Aim of the paper

This paper is based on the evaluation of literature review of Green Supply Chain Management Practices analysed and highlighted in many authors in different research papers. It's undeniable that new technological changes, innovations and global economic developments will change the organizational performance substantially as we proceed into the future. The future of organizational sustainability is balancing on the green material and the environmental friendly production in their supply chains. Today manufacturing companies are effectively changing to the green supply chain because the changing of business environment demand it. It has posed the companies to balance cost reduction and the profit growth. With the ever rising competition coupled with the imposing new environmental rules in the business world, manufacturing companies are struggling to maintain their market share. Nowadays, the green environment has become a popular topic and most organizations consider it to be paramount to be aware of economic and ecological impact on their businesses. The aim of this paper therefore is to evaluate the concept of Green Supply Chain Management to identify the different dimensions of it.

Design & Methodology

The literature written on Green Supply Chain Management was carefully selected to review for the purpose of this study. The articles written on Green Supply Chain Management during last five years only on the reputed journals such as Emerald International Journal (Emerald), International Journal of Managing Value and Supply Chains (IJMVSC), International Institute for Science, Technology and Education (IISTE), International Journal of Economics, Finance and Management Science (SciencePG), International Journal of Environmental Monitoring and Protection (Open Science), Journal Sustainability (MDPI), International Journal of Management & business studies were selected. The key words of Green Supply Chain and sustainable supply chains were used to filter the articles. The selected papers were read many times to identify the different dimensions of Green Supply Chain Management. More than 35 papers were downloaded and read by the authors. When one theme was identified and highlighted by a few articles, the rest of the articles were then reviewed to see whether same theme can be evident or any other can be evident. In the same way as new themes were identified the rest of the articles were again reviewed to ensure whether the evident for the identified dimensions were found out.

Green Supply Chain Management Practices

Today, environmental issues are increasing due to high demand of eco-friendly products from worldwide consumers. Organizations are forced to introduce Green management practices in their operations to obtain an economic growth. Due to rapid changes in the global manufacturing industry, environmental issues become more prominent to continue the business.

Shultz and Holbrook (1999), stated that the facing of regulatory and community pressures with competitiveness, the importance of organizations to be balance the economic and environmental performance. Lewis and Gretsakis, (2001); Sarkis, 1995, (2001) highlighted that organizations has to introduce strategies to overcome the environmental impact on their products due the increased pressure on environmental sustainability. Introduction of environmental friendly practices may create new opportunities for competitiveness and add value to the core businesses (Hansmann and Claudia, 2001).

The approaches of cleaner production, eco efficiency and environmental management systems have implemented the Green Management Practice. Risk management, regulatory compliance, and business efficiency are the identified factors by Confederation of British Industries (CBI) in 1994 for driving the competitive advantage through the environmental performance. Environmental impacts occur at all stages of a product's life cycle. GSCM has shown the new model for organizations achieve profits and market share objectives by reducing their environmental risks and raising their performance (Van Hock and Erasumas 2000).

The appropriate development of the GSCM concepts and practices may indeed aid the country by showing the environmental burden of both manufacture and disposal of products while even potentially improving the economic positioning.

Srivastava (2007) stated that Green Supply Chain Management is a root of both environmental management and supply chain management. The contribution of green component enhances the relationship among the supply chain management practices and natural environment.

Hevani et al., (2005) describe that supply chain management is a complex network including coordination and management activities involving in to deliver a finished product to the end customer. It involves various business activities such as sourcing raw materials, manufacturing and assembling parts, storing, distributing and final delivery to the customer. The Globalization, customer expectation, information technology, government regulation, competition and the environment are the influence factors in successful supply chain management. And also further explained about the corporate performance measurement and its applications giving the example that when companies measuring the performance consider the existing financial measures such as return on investment, profitability and revenue with market share.

Hevani et al., (2005) defined the GSCM as adding the "Green" component to the supply chain management influence the relationship of supply chain management to the natural environment and construct the following formula of GSCM.

Green Supply Chain Management (GSCM) =Green Purchasing+Green Manufacturing/ Material Management +Green Distribution/Marketing + Reverse Logistics.

The literature review explained the major elements in GSCM and organizational internal responsibilities with regard to the environmental performance. Several techniques such as life cycle assessment, product stewardship and design for environment principals help managers to map the environmental impact on supply chain. Also explained is that life cycle assessment is a structural approach to define and evaluate the total environmental service incorporate with development of an inventory of data, impact of materials, product and processes and improvement of analysis aspects.

Hevani et al., (2005) identified the Green supply chain management tools and major boundaries such as external pressure and internal pressure associated with managing the Green Supply chain management and performance measurement system. Outcome of the results are discussed. Another popular tool identified in the corporate performance management literature is the "Balanced Scorecard". It is suggested that organizational performance should be viewed from four perspectives such as the learning and growth perspective, the business process perspective, the customer perspective and financial perspective.

The final outcome of the paper is Strategic level support is needed when providing financial support to overcome internal pressure. They discussed external communications, internal improvements and regulatory compliance being the measuring factors of Green supply chain management practices on organizational performance management.

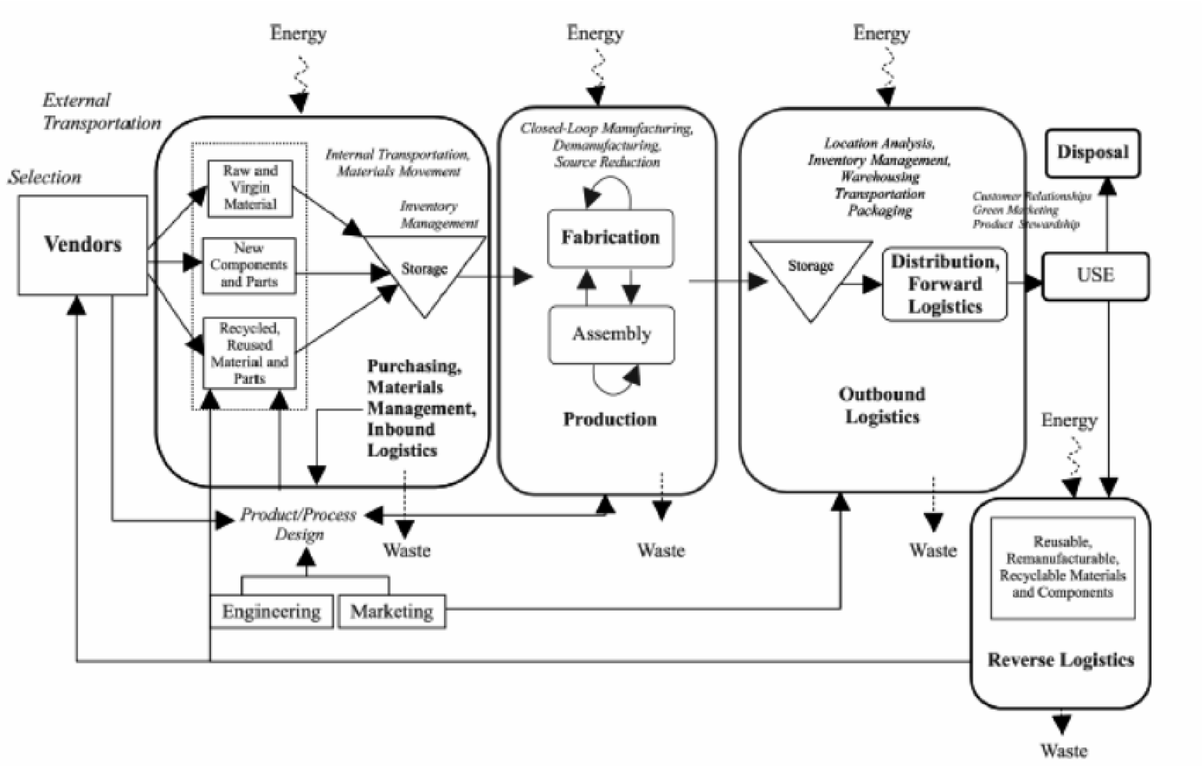

Figure 1. Graph of the GSCM (Hervani et al., 2005

Components of the Green Supply Chain Management

Figure 1 highlights the a few components of Green Supply Chain Management; Green Procurement, Green Design and Manufacturing and Green Distribution and Reverse Logistics.

Green Procurement

Green Procurement can be defined as a set of practices followed by an organization to select suppliers who are practicing the eco-friendly methods when manufacturing goods. Manufacturing organizations are compelled to select suppliers who are having environmental competence, technical and eco design capability, environmental performance, ability to develop environmentally friendly goods and ability to support focal organizations eco- friendly objectives. The 3 R uses in green procurement are Reuse, Recycle and Reduce in the process of green procurement in terms of placing orders through e-mail, use eco labelling of products, ensure suppliers' environmental compliance certification and conducting audits on suppliers' internal environmental management are also studied by (Chin et., al 2015)

Green Design and Manufacturing

Srivastava (2007) stated that the life cycle assessment/analysis and environmentally conscious design of the product explain in the literature. A hierarchic framework for environmentally conscious designs are presented by Madu et al., (2002). Green manufacturing is a very important area in green supply chain operation. Three related fields of study to reduce the use of virgin materials are pinch analysis (Linhoff 1993), and energy and lifecycle analysis (Lee et al., 1995).

Green Distribution and Reverse Logistics

Reverse logistics practices are different from traditional logistics practices. Green distribution consist of Green packaging and green logistics. Packaging characteristics gives an impact on distribution. Better packages help to rearrange the loading patterns can reduce the material usage and increase the warehouse space and reduce the double handling (Carter and Ellram, 1998).

Sarkis (2011), provide a framework to understand and help advance the field of Green Supply Chain Management and its relationship in various research streams. These frameworks explain the issues faced by green supply chains when using the boundaries and the flows of the system. In general overview, supply chain is described with upstream, downstream and internal organizational activities. Explain the relationship of purchasing and procurement functions and flows of *upstream activities* including the topics of outsourcing, vendor auditing, management and selection, supplier collaboration and supplier development. The Traditional purchasing discipline is enhanced by the upstream activities of supply chain management which can be expanded to have greening components. Traditional production and operations management are related with Internal *organizational supply chain activities* in the organizations. The activities such as research and design, quality, inventory material and technology management influence the environmental behaviours in the organizations. Outbound logistics and transportation, marketing, distribution, packaging and warehousing are called as *downstream flows and relationships* utilised by individual consumers or commercial customers. The reverse supply chain explain the activities of recycling, remanufacturing, reclamation and reverse logistics which are related to the *closing of the supply chain loop*.

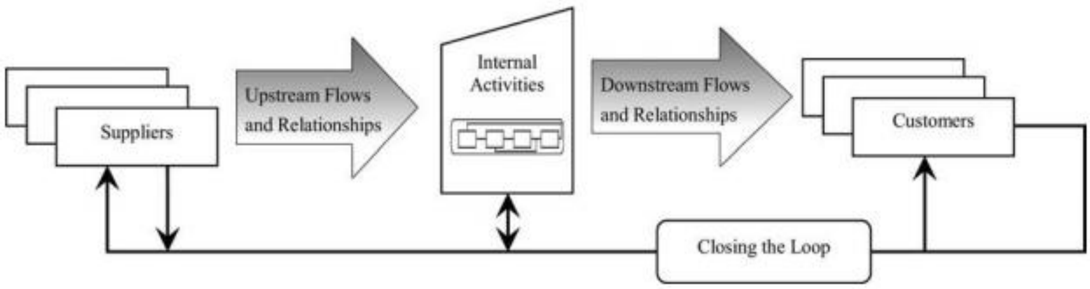

Figure 2. A green Supply Chain diagram with Stages and relationship (Sarkis, 2011)

Table 1 shows the Definitions of the Theoretical Model constructed by Kenneth et al., (2012),Internal Environment Management & Green Information System are moderated by Green Purchasing, Corporation with customers, Eco-design and Investment Recovery with mediating effect of Environmental Performance, Operational Performance and economic performance leading to measuring the organizational performance.

Table 1. Construct Definitions (Kenneth W. Green Fr et al, 2012)

Construct	Definition
Internal Environmental Management	Internal environmental management is the practice of developing green supply chain management as a strategic organizational imperative through commitment and support of the imperative from senior and mid-level managers (Zhu et al., 2008a)
Green Information systems	Green Information systems are information systems that have been modified and are used to monitor environmental practices and outcomes (Esty and Winston, 2006)
Green Purchasing	Green purchasing focuses on cooperating with suppliers for the purpose of developing products that are environmentally sustainable (Zhu et al., 2008a;carter and

	carter, 1998)
Cooperation with customers	Cooperation with customers requires working with customers to design cleaner production processes that produce environmentally sustainable products with green packaging (Zhu et al.,2008a)
Eco Design	Eco-design requires that manufacturers design products that minimize consumption of materials and energy that facilitate the reuse, recycle and recovery of component material and parts and that avoid or reduce the use of hazardous products within the manufacturing process (Zhu et al., 2008a)
Investment recovery	Investment recovery requires the sale of excess inventories, scrap and used materials and excess capital equipment (Zhu et al., 2008a)
Environmental Performance	Environmental performance relates the ability of manufacturing plants to reduce air emissions, effluent waste and solid wastes and the ability to decrease consumption of hazardous and toxic materials (Zhu et al., 2008a)
Economic performance	Economic performance relates to the manufacturing plant's ability to reduce costs associated with purchased materials, energy consumption, waste treatment, waste discharge and fines for environmental accidents (Zhu et al., 2008a)
Operational Performance	Operational performance relates to the manufacturing plant's capabilities to more efficiently produce and deliver products to customers (Zhu et al., 2008a)
Organizational Performance	Financial and marketing of the organization as compared to the industry average (Green and Inman, 2005)

Their findings make a logical sense of the relationship among the performance constructs seem to be leverage of environmental performance and economic performance has improved operational performance which leads to improve the organizational performance.

Bjorklundet. al., (2012) identified the five dimensions in the framework developed by Caplice and Sheffi (1995) and developed further as shown in table 2 for the review of their paper. They are mentioned in table 2 and explained later;

Table 2: Framework Dimensions

Caplice and Sheffi (1995)	Bjorklund et. al., (2012)
Comprehensive	Stakeholder perspective
Causally Oriented	The Purpose of measuring
Vertically integrated	Managerial levels of measuring
Horizontally integrated	Measuring across the supply chain
Internally comparable	Combination of measurements

Stakeholder perspective

Environment performances are influenced by stake holders such as governance, customers and suppliers. Caplice and Sheffi (1995) explain the importance of well-designed logistics performance measurement system and how it is aligned with relevant processes. Both Lu et al., (2007) and Zhu et al., (2008) highlight that companies become more environmentally due to the community pressure and the consumer pressure. Bjorklund et. al., (2012) stated that the influence from stakeholder is an important aspect to measure the potential environment impact through environmental measurements.

The Purpose of Measuring

The fundamental issues in GSCM on PM are economic rent, managing the business better and understanding the business better and continuous improvement (Hevani et al., 2005).The practitioners can use various methods of scales to measure green supply chain management for continuous improvement and implementation of green supply chain management for the measuring purposes (Zhu et al., 2008). The purpose of measuring in the study clear and provide support for future design of the supply chain (Bjorklund et. al., 2012)

Managerial level of measuring

Vanteddu et al., (2006) Gunasekeran et al., (2004) explained about the three managerial levels of strategic, managerial and operational. Vertical integration of management decision ant strategic level and tactical decision of planning at middle level management and operational decision made my lower level management. (Bjorklund et. al., 2012) highlight the necessity of the strategic management level involvement to the reverse supply chain.

Measuring across supply chain management

The importance of horizontally integrated management system includes all activities, functions and processes related to the entire supply chain operation (Caplice and Sheffi (1995).

Combination of measurement

Gunasekeran et al., (2004) and Caplice and Sheffi (1995) explain the importance of financial and non-financial performance measures which most companies failed to apply. Both environmental aspects and economical aspects are simultaneously proving the win-win situation in the measurement system (Bjorklund et. al., 2012).

Lee et al., (2012), study is to explore green supply chain management practices and their relationship with organizational performance of small and medium enterprises who servers to large customer firms in the Electronic Industry. The findings shows that there was a direct link between GSCM implementation and business performance.

Shi & Koh (2012) publish a paper to conceptualise a structural model of natural resource based green supply chain management and its relationship with an indication of cause and effect to relevant performance measures and drivers. They identified that causal relationship have been formulated through both existing empirical findings and by identifying theoretical propositions.

Seman et al., (2012) their study is based on an overview of the development of GSCM literature in a developed countries and developing countries. They conclude that some studies in the literature discuss the GSCM implementation, GSCM drivers, practices and performance all over the world but less research about the GSCM implementation and adoption in Malaysia.

Lakshmimeera & Palanisamy (2013) consolidated a paper on a Conceptual Framework on Green Supply Chain Management practices for Indian Manufacturing industry. They conclude that Green Supply Chain management Practices can improve competitiveness and environmental performance leading to sustainability.

Chien (2014), explain the influences of green supply chain management practices

on organizational sustainable performance and found that Green Supply Chain Management practiced by Taiwan Electrical and Electronic manufacturers and will positively affect the economic, environmental, and social performances.

Diab et al., (2014) tested the impact of Green Supply Chain Management Practices on Organizational performance and their study based on Jordanian Nutrition Industries and selected six companies specialised in food industry. Results of the study shown that there was an impact on green supply chain management practices on organizational performance which are environmental performance, financial performance and operational performance.

Muma et al., (2014) investigate the effect of Green Supply Chain Management on environmental Performance among tea processing firms in Kericho County. Based on the

Findings, study confirm that there is a positive relationship between Green supply chain management practices, green purchasing, green manufacturing, Green distribution, Green marketing and reverse logistics and environmental performance.

Al Khattb et al., (2015) tested the impact of the green supply chain management on environmental-based marketing performance. Their selected five Jordan companies and distributed 125 questionnaires. It has proven that Green Supply chain management such as Internal environmental management, Green Purchasing, Green Information systems, Cooperation with customers, Eco-design and packaging, and investment recovery practices affected the environmental marketing performance.

Cosimato. & Trosi. (2015) investigated how logistics organisations try to face the recent ecological challenges and the role of emerging green technologies play in making them green and competitive. Their findings in DHL case study evidence that logistics innovation is based on emerging technologies which are more related to the development of sustainable and environment-friendly approach.

Chiu. & Hsieh (2015) tested the green supply chain practices in Taiwan Resturant and firm performances. GSCM practices and firm performances are mediating with green capability and their research concluded that Green Practices in restaurants in Taiwan have an indirect effect on firm performance through green capability and highlighted that if it is a higher degree it will contribute to the organisational performance.

Chin et al., (2015) discussed a conceptual model which are related to Relational View Theory originated by Dyer and Singh (1998) linking with GSCM practices, Environmental Collaboration and sustainability performance. The GSCM practices are conceptualized with Green procurement, Green manufacturing, green distribution and green logistics. The sustainability performance is measured through Economic, Environmental and Social performance with the moderating effect of Environmental Collaboration including trust, loyalty, fairness in negotiation, commitment.

Tomar &Oza (2015) study relationship of Green supply chain management practices and organizational performance and selected ISO certified companies in Gujarat Region. The study shows that all green practices are not followed by the companies the available resources and capabilities are vary towards that GSCM implementation.

Conclusion

Through this study the concept of Green Supply Chain Management was critically reviewed to identify the different dimensions of it. Although it is a relatively new aspect of supply chain management, the green supply chain management is an emerging trend to ensure the sustainability of the organisational supply chains. However, the mostly prominent dimensions of green supply chain management through the reviewed literature were Green Procurement, Green Design and Manufacturing, Green Distribution, Reverse Logistics were the identified dimensions of Green Supply Chain Management.

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