SUSTAINABLE DISTRIBUTION SYSTEM IN FOOD RETAIL SECTOR- A SIMULATION MODELLING APPROACH

Sameh M. Saad [(a)], Ramin Bahadori [(b)], Jishnu Ravisankar [(c)]

[(a), (b), (c)] Department of Engineering and Mathematics,
Sheffield Hallam University, City campus Howard street Sheffield S1 1WB, UK

[(a)]S.Saad@shu.ac.uk, [(b)]b2047010@my.shu.ac.uk, [(c)] b6001595@my.shu.ac.uk

ABSTRACT
Nowadays, sustainability has become one of the most important topics in supply chain management which is received more global attention. Within food retail supply chain, downstream distribution system has a significant effect on environmental performance. The aim of this research is to model sustainable distribution system in food retail supply chain through two variables; Greenfield service constraints and fleet types which enables practitioners to make decision about the optimal number and location of distribution facilities and optimal types of fleet to minimise the CO_2 emission and transportation cost, maximise responsiveness and determine the optimal number of required transportation asset to meet customers demand. Through understanding the mathematical equations governing the problem of CO_2 emission, transportation cost and transportation time; multiple scenarios through a hypothetical two-stage food supply chain are created and validated using Supply Chain GURU Software. Experimental factorial design and statistical techniques are used to generate and analyse the results.

Keywords: modelling and simulation, sustainable distribution system, food retail supply chain

1. INTRODUCTION
Nowadays, sustainable supply chain is motivating many of the industrialists to meet customers, stakeholders and government's expectation through three dimensions of sustainable development including economic, environmental and social (Seuring and Müller 2008). Implementation of sustainable supply chain management is not voluntary, but it is a necessary requirement (Carter and Rogers 2008). While, there are different interpretations of sustainability there is a basic concept among all interpretations which is triple approach of sustainability; economic, environmental and social (Elkington 1997). In sustainable supply chain, environmental, social and ethical criterion should be considered by all supply chain members from upstream stage to downstream stage (Lerberg Jorgensen and Steen Knudsen 2006). Initiative to achieve sustainability in supply chain can be done by undertaking strategies, tactics and operational planning which are resulted in making sustainable decisions in network design, purchasing, freight transportation manufacturing and information technology (Allaoui et al. 2017).

Food industry is one such example for a dynamic type of environment where the expectation of customer's quality and availability of food is high. The awareness of retail firms in procuring green supply chain promotes high consciousness in delivering sustained food products to customers (Beske et al. 2014). The food supply chain can be distinguished from other kind of supply chains in terms of parties which are involved, features of process and product, and alternative redesign strategies (Van Der Vorst et al. 2009). Food supply chain includes vast variety of process centres like procurement and manufacturing companies, distributors, wholesale, retailers and food service firms deal with vegetable or animal-based products which each should acquire sustainability to develop long term relationship with the customers (Mattevi and Jones 2016). In terms of food products characteristics, seasonal production, quality constraints (e.g. degree and speed of decay), special condition requirements for transportation and storage, high demand frequency and etc. can be noted.

Within the field of food supply chains reducing the product waste which is caused by surplus food in each day, travelling distance of a product before it reaches to the target consumers and all greenhouse gas emissions related to the business processes in the supply chain network can make a green food supply chain (Van Der Vorst et al. 2009). In this research, the sustainability discussion focuses on the food distribution system design.

Distribution system consists of various activities which are differing according to the product and its market (Schary and Larsen 2001). Transportation is the basic link between each node in a supply chain and can be considered as the greatest pollution making factor in a logistics system. In a supply chain, distribution of product and the emission caused by transportation are the major environmental concern (Validi et al. 2014a). Matthews, Hendrickson, and Weber (2008) claimed that about 80% of CO_2 emission in a supply chain is the direct emission from transportation. Facility location, capacity of facility, the technologies used in the facilities and the transportation system provides a framework on creating a strategic approach to implement a sustainable distribution system in a supply chain (Salem and Haouari 2016). Food industry is the biggest user of transportation which constantly increases pollution by GHG and congestion. In the traditional methodologies, the food market distribution is handled by transportation and storage of perishable food products which is not sufficient to execute a sustainable environment on today's distribution system (Aghazadeh 2004). A traditional distribution system is controlled by a series of independent enterprises which are making their own decisions about inventory and products (Schary and Larsen 2001). These days, incorporating the environmental management principles into the operational decision-making process is the main challenge for the modern logistics system.

As part of global warming the green supply chain become a major trend for every organisation agenda and the government issues policies to fabricate supply chain sustainable. For the last couple of decades, there is research going on for location routing and fleet designing for reducing carbon foot-print from the network to implement sustainable supply chain (Lee et al. 2010). Location routing is done to optimise the product and vehicle movement based on the demand in the supply chain to deliver the product from primary stage to the end customers (Validi et al. 2014b). Optimum positioning the distribution centres will reduce the carbon foot-print throughout the system and also affect the financial and social aspect in a supply chain. There are different kinds of optimisation techniques adapted by the researchers to optimise the transportation system to achieve sustainable distribution system. For instance, Schwardt and Fischer (2009) developed a self-organised mapping technique to optimise vehicle routing problem. Marinakis et al. (2008) developed Honey Bees Mating algorithm to resolve location routing problem in distribution system. Bell and Mcmullen (2004) presented the Ant Colony Optimisation technique to analyse and optimise vehicle routing problems.

In the next section, sustainable distribution system through multiple scenarios is modelled for a hypothetical two stage supply chain involved in the distribution of food and beverage in the United Kingdom. To achieve the aim of this study, three methodologies are used; Greenfield analysis is used to identify the optimal number and location of facilities with different service constraints. Greenfield analysis can be useful for determining the location of a new facility in a regional configuration. In this method, the objective is to minimise the weighted total distance, where the demand of the customer is used as the weight. This method of analysis is quite frequently used in industries to determine the best location for a new and existing facility by which the location is indicated by latitude and longitude. This will be involved to optimise the travelling distance, travelling time, transportation routes etc. to consummate sustainability in food supply chain. Moreover, fleet route optimisation is used to minimising empty kilometres through outbound shipment consolidation to optimise the delivery routes. In addition, results are generated and analysed by using experimental factorial design and statistical techniques (MANOVA). Results obtained from these methodologies are shown in Section 3. Section 4 presents the optimisation of fleet type selection. The last part of this paper gives the overall conclusion of this study.

2. SUSTAINABLE DISTRIBUTION SYSTEM MODELLING THROUGH HYPOTHETICAL TWO-STAGE FOOD SUPPLY CHAIN

A large British food and beverage company wanted to determine the best number and location for DC facilities as well as optimal type and number of required fleet to meet customers demand for its national operations with multi objective approach; minimise the CO_2 emission and transportation cost and maximise responsiveness.

The company has 10% market share and serves 350 stores around the country (see Figure 1). In this case, the demand is considered to be 10% of the population of the city/town of stores location with respect to (Census, 2011).

There are two types of fleet available at the company; rigid 7.5 tonne and rigid 17 tonne with following attributes as shown in table 1.

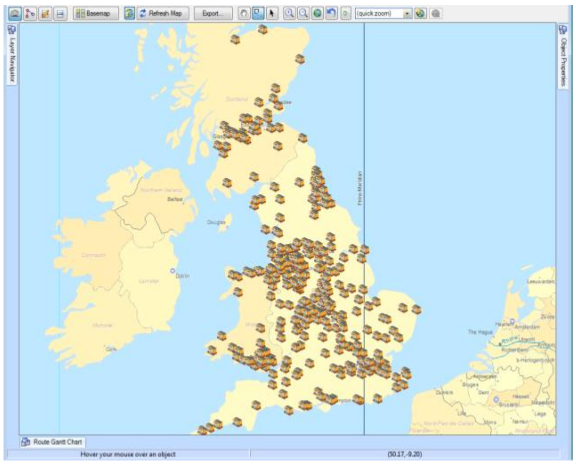

Figure 1: Supply Chain Guru Screen Shot of the Considered Stores

Table 1: Fleet Types Attributes

	Rigid 7.5 tonne	**Rigid 17 tonne**
CO_2 rate	0.0005442 kg per km	0.0007273 kg per km
Average transportation cost	£2.1 per km	£2 per km
Tare weight	3500 kg	9000 kg
weight fill level	1000 kg	3000 kg
weight capacity	3000 kg	8000 kg
Velocity	90 km/h (56 mile/h)	90 km/h (56 mile/h)

To achieve the company operational objectives, three scenarios through two variables; Greenfield Service Constraints and fleet types are created and validated using Supply Chain GURU Simulation Software. Greenfield analysis is used to identify the optimal number and location of DC facilities with different service constraints which is 100% of customer served within max sourcing distance of 113 km (first scenario), 161 km (second scenario) and 209 km (third scenario). Moreover, fleet route optimisation is applied on each scenario to minimising empty kilometres through outbound shipment consolidation to optimise the delivery routes. The output data is used to investigate performance measures impact of the different fleet designs.
The following equations are used to calculate the CO_2 emission, transportation cost and transportation time.

$$CO_{2e} = \left((F_W + SH_W) \times R_{CO_{2e}} \right) \times T_d \quad (1)$$

Where
CO_{2e}= Co_2 emission
F_W =Tare weight of fleet
SH_W= Weight of shipments on board
R_{CO2e}= CO_2 emission rate
Td= Travelled distance by fleet

$$T_C = T_d \times A_C \quad (2)$$

Where
T_C= Transportation cost
A_C= Average transportation cost per km

$$T_t = \frac{T_d}{F_V} \quad (3)$$

Where
T_t= Transportation time
F_V= Fleet velocity km/h

2.1. Experimental design

This section provides the design of experiments which allow us to find out the impact of the Greenfield service constraints and fleet type on the performance of distribution chain. Four performance measures (dependent factors) namely transportation cost, CO_2 emission, transportation time and number of required fleet are considered in this study.
After conducting pilot experiments, the two independent factors with their levels are identified and displayed in Table 2. Based on full factorial experimental design, a total of 46 experiments are required to gather enough data and to allow the authors to draw a valid conclusion from this study.

Table 2: Independent Factors with Their Levels

Factor	Level		
Greenfield Service Constraints	100% of Customer Served within 113 km	100% of Customer Served within 161 km	100% of Customer Served within 209 km
Fleet Type	Rigid 7.5 tonne	Rigid 17 tonne	

3. RESULTS ANALYSIS AND DISCUSSION

A full statistical factorial MANOVA technique was used to analyse the results obtained from GURU Simulation Software at 95% confidence interval. Table 3 displays these results and the following can be concluded:

- Greenfield Service Constraints has significant relationship with transportation cost, CO_2 emission, transportation time and number of required fleet.
- Fleet Type has significant relationship with transportation cost, CO_2 emission, transportation time and number of required fleet.
- Interaction between Greenfield Service Constraints and Fleet Type show that there is a significant relationship with transportation cost and transportation time; however, it is appeared that both CO_2 emission and number of required fleet are not significantly affected.

Table 3: Full Factorial MANOVA Results

Dependent variables	Independent variables	F	P
Greenfield Service Constraints	Transportation costs	20.124	.000<. 05
	CO_2 emission	23.507	.000< .05
	Transportation time	20.439	.000< .05
	Number of required fleet	7.129	.002< .05
Fleet Type	Transportation costs	21.955	.000< .05
	CO_2 emission	4.230	.046< .05
	Transportation time	20.320	.000< .05
	Number of required fleet	16.068	.000< .05
Greenfield Service Constraints * Fleet Type	Transportation costs	4.067	.025<.05
	CO_2 emission	.635	.535 > .05
	Transportation time	3.778	.031 < .05
	Number of required fleet	1.377	.264 > .05

3.1. Greenfield analysis and fleet route optimisation result

By applying Greenfield analysis, twelve, seven and four potential Greenfield DC facilities are determined within the best geographic locations which 100% of stores can be served within max sourcing distance of 113 km, 161 km and 209 km respectively.
GURU outputs which are obtained from fleet route optimisation through each scenario are presented as follows:

- *First Scenario*: The results proved that by using rigid 7.5 tonne fleet, 922 units of transportation asset are required to meet stores demand and total CO_2 emission, transportation cost and transportation time are 258,667 kg, £200,471 and 1,061 hours respectively. However, rigid 17 tonne fleet has better rate in terms of total transportation cost and transportation time with £ 81,978 and 455 hours respectively except total CO_2 emission which is 381,525 kg. Moreover, just 351 units of transportation asset of rigid 17 tonne fleet are required to meet all the stores demand.
- *Second Scenario*: The results showed in order to meet the stores demand in the case of rigid 7.5 tonne fleet t, 915 units of transportation asset are required resulting in the total CO_2 emission, transportation cost and transportation time are 411,825 kg, £318,994 and 1,688 hours respectively. Although, by using rigid 17 tonne fleet, 348 units of transportation asset are required to meet stores demand but this will result in total CO_2 emission, transportation cost and transportation time are 603,697 kg, £128,468 and 714 hours respectively.
- *Third Scenario*: In terms of service constraint which 100% of customer served within max sourcing distance of 209 km, 910 units of transportation asset of rigid 7.5 tonne fleet are required for meeting the stores demand and total CO_2 emission, transportation cost and transportation time are 483,163 kg, £373,868 and 1,978 hours respectively. But by using 17 tonne fleet, 352 units of transportation asset are required to meet stores demand and total CO_2 emission, transportation cost and transportation time are 677,256 kg, £143,455 and 797 hours respectively.

As illustrates in figures 2 and 3, CO_2 emission, transportation cost and transportation time for both fleets have rising trends from the first scenario to the third scenario with Greenfield service constraints which 100% of customer served within max sourcing distance of 113km, 161km and 209 km respectively, while, number of required transportation asset to meet stores demand has almost stable trends. Therefore, Greenfield service constraint which 100% of customer served within max sourcing distance of 113 km is identified as the optimum scenario to have the lowest CO_2 emission, transportation cost and transportation time.

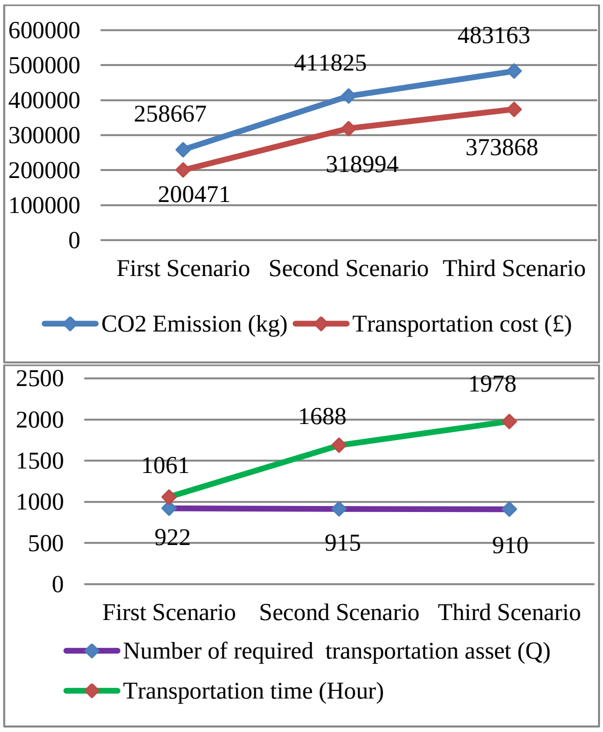

Figure 2: Performance Measures Trends from First Scenario to Second Scenario Based on Rigid 7.5 tonne Fleet

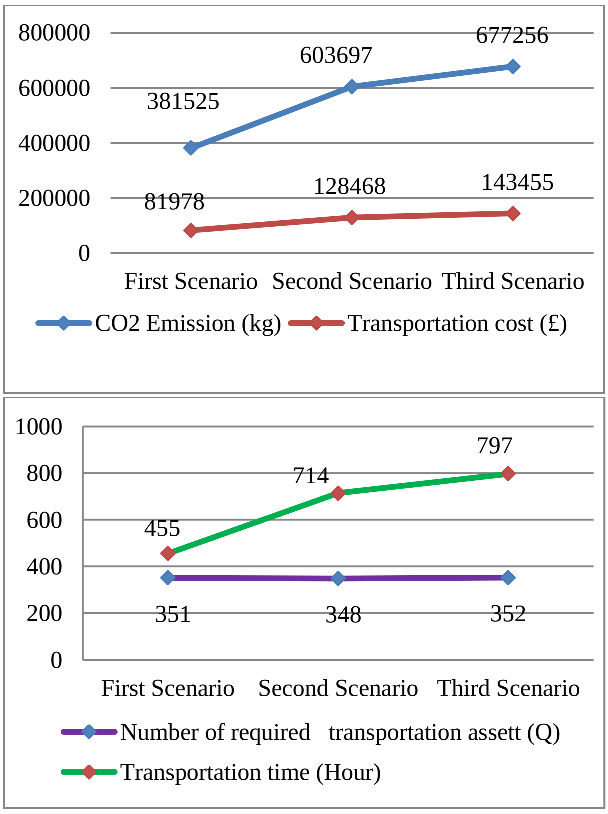

Figure 3: Performance Measures Trends from First Scenario to Second Scenario Based on Rigid 17 tonne Fleet

4. OPTIMISATION OF FLEET TYPE SELECTION

In accordance with obtained results in previous section, although, rigid 7.5 tonne fleet produced lower total CO_2 emission in comparison to rigid 17 tonne fleet, but it has more total transportation cost and transportation time. In this section, shuffling shipments among different fleet types are applied to determine the best balance among CO_2 emission, transportation cost and transportation time through Greenfield service constraint which 100% of customer served within max sourcing distance of 113 km which is identified as the optimum scenario. Thus, both fleet types are assigned among DC facilities, while, rigid 7.5 tonne fleet is specified as the first priority.

The results presented that 450 units of transportation asset of rigid 7.5 tonne fleet and 175 units of transportation asset of rigid 17 tonne fleet are required to meet stores demand and total CO_2 emission, transportation cost and transportation time are 330,109 kg, £146,715 and 789 hours respectively. Figure 4 displays the total CO_2 emission, transportation cost, transportation time and number of required transportation asset at different fleet designs; mix fleet design, rigid 7.5 tonne fleet and rigid 17 tonne fleet.

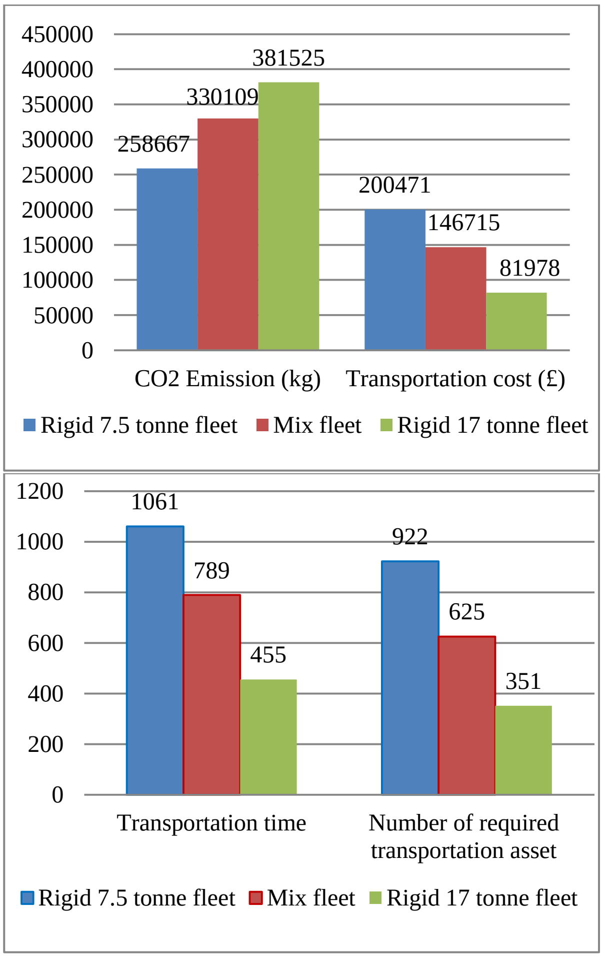

Figure 4: Total CO_2 Emission, Transportation Cost, Transportation Time and Number of Required Transportation Asset at Different Fleet Designs.

5. CONCLUSION

In this paper, sustainable distribution system in food retail supply chain is modelled to minimise the CO_2 emission and transportation cost, maximise the responsiveness and determine the optimal number of required transportation asset to meet customers demand through distribution chain.

Multiple scenarios through two variables; Greenfield service constraints and fleet types within a hypothetical two-stage food supply chain were developed and implemented and validated using Supply Chain GURU Software. Greenfield analysis was used to identify the optimal number and location of potential DC facilities with different service constraints. Moreover, fleet route optimisation was applied on each scenario to minimising empty kilometres through outbound shipment consolidation to optimise the delivery routes. The output data is used to investigate performance measures impact of the different fleet designs and results have been analysed and validated with a statistical techniques (MANOVA).

In order to have the best balance among the performance measures, shuffling shipments among different fleet types were applied through optimum scenario. Thus, both fleet types are assigned among DC facilities, while, rigid 7.5 tonne fleet is specified as first priority.

This work provides a systematic method through which practitioners should be able to decide upon the optimal number and location of distribution facilities as well as optimal types of fleet to minimise the CO_2 emission and transportation cost, maximise responsiveness and determine the optimal number of required transportation asset to meet customers demand through distribution chain.

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AUTHORS BIOGRAPHY

Professor Sameh M. Saad, BSc (Honours), MSc, PhD, PGCHE, CEng, MIET, MILT, FHEA, FCILT is the Professor of Enterprise Modelling and Management, Postgraduate Research Coordinator and MSc/MBA Course Leader, in the Department of Engineering, Faculty of Arts, Computing, Engineering and Sciences, Sheffield Hallam University, UK. His research interests and experience include fractal supply chain, modelling and simulation, design and analysis of manufacturing systems, production planning and control, reconfigurable manufacturing systems and next generation of manufacturing systems including fractal and biological manufacturing systems. He has published over 150 articles in various national and international academic journals and conferences, including keynote addresses and a book.

Ramin bahadori is a PhD candidate in the Department of Engineering, Sheffield Hallam University, UK. He received his BSc in Industrial Management from Persian Gulf University, IRAN and MSc degree in Logistics and Supply Chain Management from Sheffield Hallam University, UK in 2010 and 2014 receptively. His research interest is in the field of fractal supply chain, food supply chain sustainability, Co2 emission optimisation, modelling and simulation, logistics capabilities, inventory optimisation, logistics cost optimisation, information system, responsiveness optimisation, supply network integration, communication and collaboration within supply network, and multi-criteria decision-making fuzzy AHP.

Jishnu Ravisankar is an MSc studen in the Sheffield Hallam University, UK. He received his B-Tech in Mechanical engineering from University of Kerala, India in 2010. He worked as an engineer in Automobile dealer service engineering sectors for over 2 years from 2012 to 2015 in India. From bachelors he got experience in mechanical model designing software. His field of interest is in sustainability approach in supply chain, logistics carbon emission optimization, logistics cost optimization, designing, modelling and simulation, application of lean approach in supply chain, inventory management and optimization, procurement and strategic approaches etc. He is also a member of Chartered Institute of Procurement and supply (CIPS).