ISSN 1816-6075 (Print), 1818-0523 (Online)
Journal of System and Management Sciences
Vol. 3 (2013) No. 2, pp. 1-9

A study of eco-performance of logistics services in food supply chains

Dong Li[1] ,Zurina Hanafi[1]
[1]Management School, University of Liverpool, Liverpool, UK
Dongli@liv.ac.uk, zurina@liverpool.ac.uk

Abstract: Transportation is one of the main contributors of greenhouse gases which give direct negatives impact on environment. Management of logistics services plays an important role in maintaining business competitiveness and sustainability as well as social responsibility. Optimizing logistics service with integrated economic and ecological objectives can help to reduce negative impact on the environment by reducing the amount of carbon emissions and improving operations efficiency. This study focuses on multimodal transportation planning and optimal strategies with a UK food supply chain case under carbon emissions control policies. Carbon emissions policy is a driving factor for multimodal transportation planning in eco-logistics management. With differences in the level of carbon emissions control, the different characteristics of the cost structure and carbon emission in different logistics processes will lead to different business performance. The research investigates and identifies impact of the policies on logistics performance.

Keywords: Multimodal Transportation Planning, Carbon Emission Control Policy, Fresh Produce, Optimization

1. Introduction

Since last decade, over 50% of the fresh produce supplies in the UK market are imported(EFFP,2010). The large volume of import has significant impact on transportation costs and carbon footprint in such global fresh produce supply chains which cross several sectors from farms, logistics to manufacturing and retailing. How to manage the supply chain sustainably to achieve both economic and ecological objectives in such a complex multi-sector, multimodal transportation and international context has been a great challenge. With the negative impacts from the prevalent road-based freight transport in congestion, energy consumption and carbon emission and with a trend of speeding up application of carbon emissions policies (carbon tax and carbon trading scheme, etc) to the industry, multimodal transportation has been attracted increasing attention due to its potential contribution to reduce the impact on environment(Rondinelli and Berry,2000). Research on transportation planning has been extensively reported in the literature(Macharis & Bontekoning,2004; Southworth and Peterson,2000; Hasan,2008; Yang et al.,2011). Some research has been reported on logistics planning considering environmental impact (Facanha and Horwath,2006; Lopez et al.,2009; Sadegheih et al.,2010; Hoen;2011).

However, research is still rare on interactions among the economic and ecological performance of the supply chains and the carbon control policies so that logistics services through multimodal transportation services can be optimized with various potential carbon control policies(Li et al.,2010).

This study is focused on a fresh fruit supply chain case in the UK and investigates the impact of different carbon emission control policies on operations of food service industry. The research aims to identify optimal strategies of multimodal transportation operations of the supply network under changing carbon policies, and provide a policy making reference that facilitate understanding of industrial reaction to government environmental policies on carbon emission. The research outcome is expected to have a generic contribution to multimodal transportation planning and government policy making in carbon emission control.

2. Sustainable Logistics Model

An optimization model as seen in equation 1 is proposed to generate the solutions and analyze behaviour of the supply network under different carbon control policies. Optimization models are widely used in solving multimodal freight transportation problem(Yamada et al.,2009; Caramia and Guerrioro, 2009). In this paper, a mixed-integer programming is developed with four main elements: cost, time, distance, and mode of transportation as proposed by Banomyang and Beresford(Banomyong and Beresford,2001). To analyze the economic and ecological performance of the logistics network, particularly the carbon emission policy impact on strategic options of the supply chain design. The objective function of the model is to minimise the total cost, with consideration of policies of carbon emissions trading and carbon tax(Sorrell and Sijm,2003). The different modes of transportation used in this study are road, rail, ship and their combinations.

Objective function:

Min total cost = transportation cost + carbon emissions cost.

$$\text{Min}CT = \sum_{k=1}^{p}\sum_{j=1}^{n}\sum_{i=1}^{m}\left(\left(TC_{i,j} * YT_{i,j,k}\right) + \left(CC_{i,j,k} * YT_{i,j,k} * YP_{i,j,k}\right)\right) * X_{i,j,k}$$

Subject to:

$$\sum_{k=1}^{p}\sum_{j=1}^{n}\sum_{i=1}^{m} CC_{i,j,k} * YT_{i,j,k} * YP_{i,j,k} * X_{i,j,k} = CL; \sum_{j=1}^{n} X_{i,j,k} = D_{i};$$

$$\sum_{j=1}^{n} TT_{i,j} * YT_{i,j,k} \le RT_{i}; X_{i,j,k} \ge 0; YT_{i,j,k} \epsilon \{0,1\}; YP_{i,j,k} \epsilon \{0,1\}.$$

Notations: i - centre index; j - transportation mode; k - carbon emissions policies;

CL = carbon limit; $TC_{i,j}$ - transportation cost to centre (maritime port, rail freight terminal or a regional distribution centre) i with transportation mode j;

RT_i – Required time for trip to a port or regional distribution centre i; $TT_{i,j}$ – time taken to centre i by transport mode j; $CC_{i,j,k}$ - carbon emissions cost to a centre i with transport mode j and carbon policy k; $YT_{i,j,k}$ - 1 if transportation mode j is used, 0 otherwise; $YP_{i,j,k}$ - 1 if policy k is chosen, 0 otherwise; D_i - demand at centre i.

Some interviews have been conducted with the operational team of a fresh produce logistics company which provides service of consolidation, warehousing, re-packaging and delivery. Primary data are obtained from the company such as locations of regional distribution centres (RDC), demands and capacity for each RDC, costs, etc. in the network. The distance and time between each port and RDC were obtained from public media such as Google maps and National Rail website. Six ports are used as distribution point s in the UK. The carbon emission factor for transportation is from WRAP(WRAP,2008). Carbon emission price and carbon tax are obtained from the public media.

At present, the logistics companies in this case have been mainly using road transportation for distribution of fresh produce in the UK. Road transportation has an advantage of door to door delivery with faster services. 40-foot refrigerated containers are normally used with heavy goods vehicles (HGVs) for this service. HGVs consumes enormous amount of fuels and creates environmental issues. Through the optimization analysis, solutions of the logistics service network with different carbon policies can be identified and compared to provide insight into the policy impact and best strategies of the business to take.

3. Analysis and Finding

Firstly the model is optimized without considering carbon emission and associated costs. The model suggests distribution of fresh produce from all ports to all RDCs using road transportation. The minimum cost can be obtained by the road only option. All the allocations in the solution are actually sent by trucks from main UK ports to closest RDCs in the country. When carbon emission is considered, there is a significant impact on the present transportation practice. With carbon tax, multimodal options are selected (77% for road only and 23% for multimodal with rail plus road). On the other hand, with carbon emission trading, the best solution is suggesting road only and multimodal allocation for the UK mainland being 87% and 13% respectively.

Carbon tax has a greater impact due to higher direct cost to be added to the operations at a given carbon price level. In the following sections, further details of the policy impacts on economic and ecological performance are analysed.

3.1. Carbon Tax vs. Carbon Emission Trading

Two major carbon control policies are involved in this research, Cap-and-trade approach in carbon emission trading scheme and carbon tax scheme. Cap-and-trade approach has a fixed number of annual allowances allocated to the participants as a cap. Participants who face high abatement costs can continue emission by buying additional allowances, while participants who face low abatement costs can take abatement action and sell their surplus allowances for a profit [15]. The trade is based on the price of carbon emission price at the trade market. Carbon tax is based on consumption of fossil fuels and according to their carbon content. The two policies are commonly employed by governments.

To identify potential business reactions or behaviour with government carbon control policies, the analysis is performed with different carbon charge rates as sensitivity analysis through the optimization model. For carbon emission trading policy, different carbon limits from 50k to 150k ton are used in the analysis. As the limit or carbon emission cap increases, the optimal carbon price associated with the minimum total cost is also increasing.

The optimum carbon charges by carbon tax and carbon emission trading is investigated in the research as seen in Fig. 1. As carbon charges are highly dependent on government policies, the government enforcement therefore plays a significant role in managing carbon emissions. The analysis with the optimization model uses different rate of carbon charges so that the sensitivity of the logistics performance to the carbon policy can be reserved. The total cost includes transportation cost and carbon cost with consideration of time. The analysis of total cost demonstrated optimum carbon charges with different carbon emission limit (CET in the Fig. 1) and carbon tax.

With different carbon limit, the graph pattern of the total cost is almost the same, but with different minimum point. As the cap increases, the optimal carbon charge for minimum total cost also increases. The carbon tax scheme in this case has the lowest optimal carbon charge.

3.2. Time Performance

For fresh produce supply chains, time is an important factor. Therefore the performance in overall delivery time is analyzed in this research. The time spent in the transportation processes with different carbon charging rates is shown in Fig. 2. In the optimization model, time is a constraint for a trip to ensure food product shelf-life requirements being met. As seen in Fig. 2, the travel time for each journey increases as the price of carbon mission increases. Therefore, the carbon charge is positively related to the logistics network performance in time.

3.3. Transportation Mode Selection with Carbon Costs

To investigate the impact of carbon control policy on transportation network configuration, the percentage of deliveries in the supply network with different carbon charges is analyzed in Fig 3. Result shows that the higher the carbon price, the higher the percentage of multimodal transportation is chosen in the network.

The optimum carbon charge is observed when carbon tax is chosen at the rate of £7 per ton of carbon emission, with the overall travel time of 64,245 hours per week. Multimodal transportation accounted at 8% with the remaining 92% is suggested for road only option. If carbon emission trading is chosen, with 50,000 ton of carbon limit, the optimum cost is at the price of £15 per ton of carbon emission. This option produces total travel time of 74,316 hours per week.

When the carbon limit is setting at 100,000 ton and above, total cost is decreasing until at the point of carbon price at £30, which is the optimum price with these limits. After this point, total cost starts to increase as carbon price increases. Total travel time at this optimum point is 89,626 hours per week. At this price multimodal transportation becomes important than road only transportation.

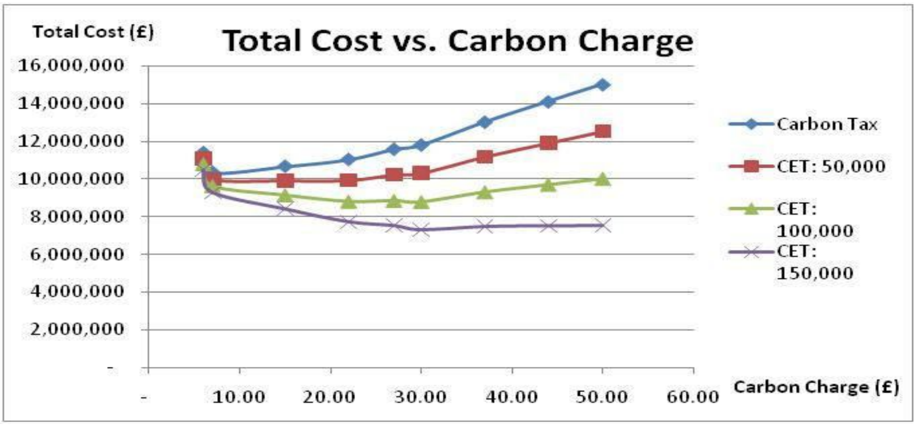

Fig.1: Total cost fluctuations with different carbon charge

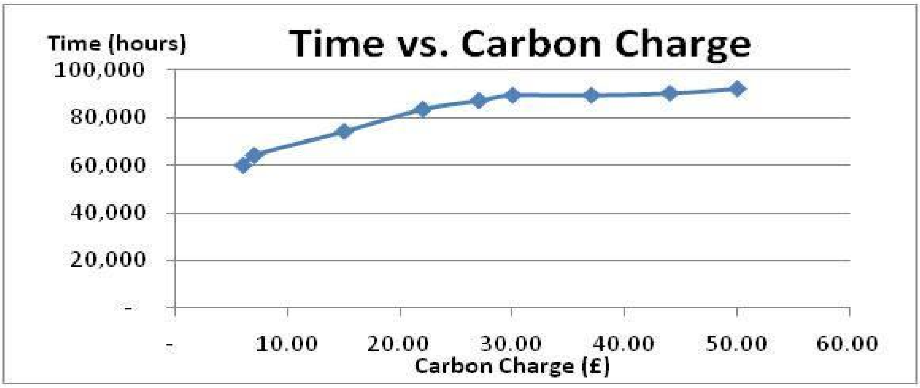

Fig. 2: Travel time with different carbon charge

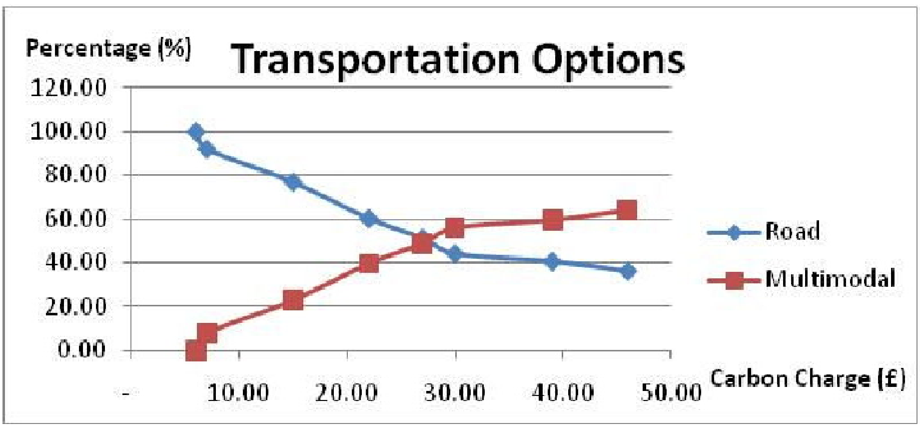

Fig. 3: Transportation options between road only and multimodal

4. Conclusion

This research has investigated impacts of the carbon emission policies on transportation operations for fresh produce industry. Through the research, an optimal network design approach for the fresh produce logistics services under carbon emission control is established. If carbon policy is introduced, the optimal decision on transportation planning in fresh produce logistics will be affected by types of policies applied, carbon emission limits and the carbon price involved. The higher the charge on carbon emission, the more the allocation should be made to multimodal transportation in deliveries. But the time spent may be increased in such cases, due to time spent in transportation mode transfer. The performance in costs can be optimized with given carbon charges and carbon policy through transportation mode selection. On the other hand, optimal carbon charges can be set to obtain lowest overall costs in the logistics operations.

It can be seen that the policy applied by governments can play an effective role to shape the logistics network and affect economic and ecologic performance of business. This research outcome can be generalized to other industries developing strategies with given carbon control policies, and for government to set up policies to encourage best business practice.

References

Banomyong, R. & Beresford, A. K. C.(2001).Multimodal transport: The case of Laotian garment exporters.*International Journal of Physical Distribution & Logistics*, 31(9), 663-685.

Caramia, M. & Guerrioro, F. (2009).A heuristic approach to long-haul freight transportation with multiple objective functions. *Omega*, 37(3), 600-614.

EFFP.(2010).*Driving change in the fresh produce sector*, Final Report.

Facanha, C. & Horwath, A.(2006).Environmental assessment of freight transportation in the U.S..*International Journal of Life Cycle Assessment*,11(4), 229-239.

Hasan, M. K.(2008).Multimodal, multicommodity international freight simultaneous transportation network equilibrium model.*Springer Telecommunication Systems*, 40, 39-54.

Hoen, K. M. R., Tan, T., Fransoo, J. C. & van Houtum, G. J. (2011).Effect of carbon emission regulations on transport mode selection under stochastic demand. *Flexible Services and Manufacturing Journal*, to appear. DOI: 10.1007/s10696-012-9151-6.

Li, D., Hanafi, Z. & Drake, P.(2010).logistics network optimization under carbon emission control for the paper recycling industry.*Proceedings of LRN2010*, Harrogate, UK.

Lópeza, I., Rodrígueza, J., Buróna, J. M. & Garcíab, A.(2009).A methodology for evaluating environmental impacts of railway freight transportation policies.*Energy Policy*,37(12), 5393–5398.

Macharis, C. & Bontekoning, Y. M.(2004).Opportunities for OR in intermodal freight transport research: A review.*European Journal of Operational Research*, 153(2),400-416.

Rondinelli, D. & Berry, M. (2000).Multimodal transportation, logistics and the environment: Managing interactions in a global economy.*European Management Journal*,18(4), 398-410.

Sadegheih, A., Li, D., Sribenjachot, S. & Drake, P.R. (2010).Applying mixed integer programming for green supply chain management.*South African Journal of Industrial Engineering*, 21(2), 13-24.

Sorrell, S. & Sijm, J.(2003).Carbon trading in the policy mix.*Oxford Review of Economic Policy*,19(3),420-437.

Southworth F. & Peterson, B. E.(2000).Intermodal and international freight network modelling.*Transportation Research Part C*, 8,147-166.

WRAP.(2008).*CO2 impacts of transporting the UK's recovered paper and plastic bottles to China*, Market Situation Report.

Yamada, T., Russ, B. F., Castro, J. & Taniguchi, E.(2009).Designing multimodal freight transport networks: A heuristic approach and applications. *Transportation Science*, 43(2), 129-143.

Yang, X., Low, J. M. W. & Tang, L. C. (2011).Analysis of intermodal freight from China to Indian Ocean: A goal programming approach.*Journal of Transport Geography*,19, 515-527.