

# A SUSTAINABLE LOGISTICS NETWORK FRAMEWORK DEVELOPMENT

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## **1.Introduction/Background**

Currently a conceptual framework of sustainable logistics network considering both economic and environmental performances is an important research topic. Increased awareness of environmental issues (Ortolani et al. 2009) acknowledged by enterprises has resulted in sustainable logistics planning. In general the economic costs directly incur debt while the environmental costs have been considerably ignored. Notwithstanding this, a lot of environmental problems have impacted on human health. These reasons make many governments and academics concerned about environmental logistics planning optimization, which accounts for the trade-off between the economic costs and the environmental impacts.

A conceptual framework of sustainable logistics planning typically depends on the current logistics practices in long term objectives. The distribution of commodities in a logistics system generates CO<sub>2</sub> which makes a lot of environmental impacts on the ecosystem. It is difficult to get rid of these factors but these factors can be minimized by the optimization mode based on a conceptual framework. The fundamental idea behind this conceptual framework is to incorporate the economic and environmental issues in the optimization model. In order to address the mentioned problems, this paper attempts to present a conceptual framework for the environmental logistics network. Then this conceptual framework is introduced, there is a demonstration of its relationship and the basic guidelines for model development. The remainder of this paper is organized as follows; Section 2 describes literature reviews. Problem formulation is clarified in section 3. In the following section, a conceptual framework of sustainable logistics network is proposed in order to provide some insights for an environmentally sensitive conceptual model. Then model assumption is defined in section 5. Then the discussion of the guideline from a conceptual framework is presented leading to the guideline for model development. Finally, a conclusion is redrawn and guidelines for further research are suggested in the last section.

## **2.Literature Reviews**

Over the last decade there has been a growing awareness of environmental concerns triggered by climate change and global warming. They have resulted in a green supply chain and environmentally sustainable logistics planning (ESLP). From literature surveys as to logistics planning under environmental considerations, Parajuli, Ferreira & Bunker (2005) stated that in an energy efficiency model that unless the fuel consumption relationships are established, the development and application

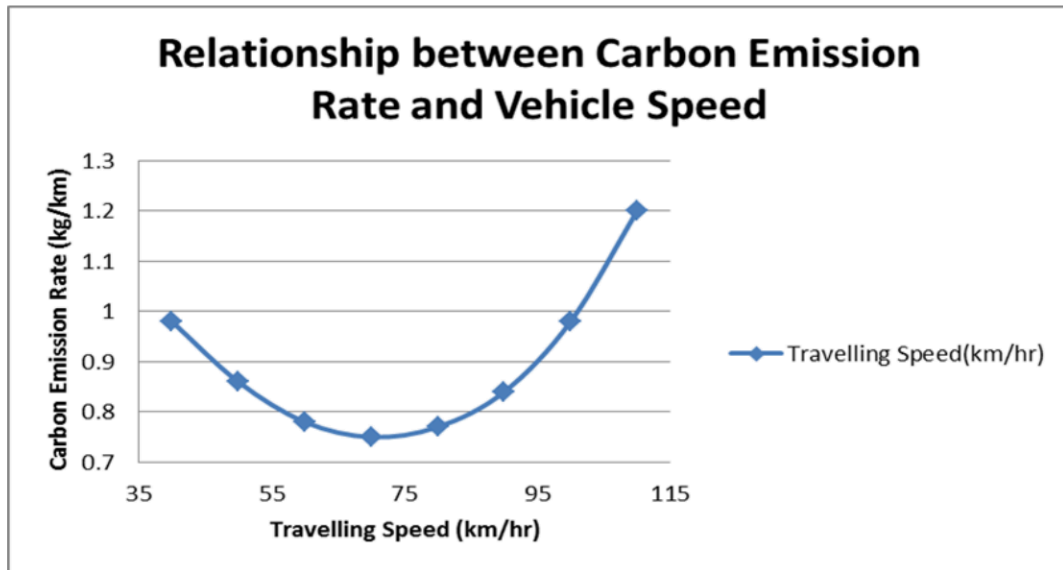
of transportation and logistics become computationally prohibitive. This is the origin of transportation & logistics network framework development, which leads to development outlined in several papers. Forkenbrock (1999) generated four types of external cost for a ton-mile of freight shipped by trucks: accidents; emissions; noise; and unrecovered costs associated with operation and maintenance of public infrastructure. The four external costs of Forkenbrock (1999) can be applied with the concept of model development of Parajuli, Ferreira & Bunker (2005). The environmental optimization of supply chain network is initiated by Beamon (1999). His research comprised investigating the environmental factors leading to the development of an extended sustainable supply chain framework. It included something from the extended supply chain with the traditional supply chain. Finally he attempted to develop a general procedure towards achieving and maintaining the green supply chain. Recently over the last five years there are a few papers concerning the green supply chain. Mula et al. (2010) has indicated that a research gap for trading off between CO<sub>2</sub> emissions, fuel consumption, noise levels as well as external factors leading to his extending the traditional logistics network objective function to account for wider environmental factors rather than only the economic cost. Ortolani et al. (2009) attempted to study the environmental impact on the transport sector by dividing the research into transportation cost and environmental cost. This model was applied with the food transport sector and reverse logistics of industrial liquid wastes. Fahimnia et al. (2013) employed the concept of Forkenbrock (1999) and Ortolani et al. (2009), They selected a medium size automotive chemical provider as a case study in Australia in order to investigate the cost implication and carbon reduction potentials of the carbon-pricing scheme in Australia. A nonlinear programming model is improved in the trade-off between transportation cost, carbon emission cost and fuel consumption cost. These associated costs are expressed as functions of vehicle speed. Then piecewise function (Gujarati 2003) is adopted to linearize the improved model. The obtained results found that a minor increase in overall logistics costs may be inadequate to drive an important shift in transport behaviour in Australia. In addition to the chemical area in the green supply chain, the green supply chain was conducted in other areas such as the aluminium green supply chain of Ferretti et al. (2007) etc. Wang et al. (2011) supported Fahimnia et al. (2013) and were concentrating on the environmental investment decision but they focused the multi objectives of the optimization model, which captures the trade-off between economic cost and environmental influence.

The literature survey as described found that there were few papers attempting to provide the conceptual framework, which can be a guideline for the basis of a sustainable logistics network model development. Consequently, to the best of our knowledge, this is the first paper attempting to establish a conceptual framework, which provides the fundamental guideline for the development of a sustainable logistics network model. This guideline for model development will be very useful for model development in the environmental logistics network field in the future.

### **3. Problem formulation**

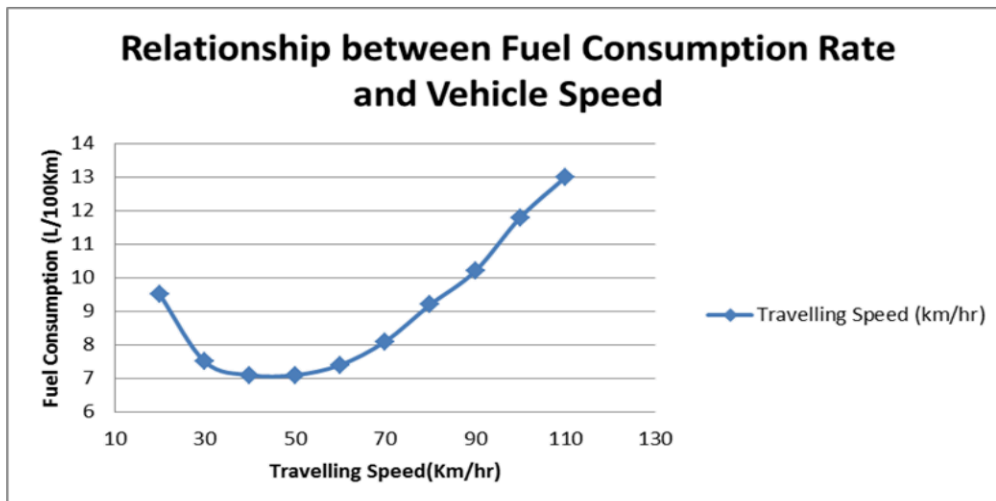
It is known in the environmental problem on logistics planning that each truck emits a certain amount of carbon dioxide. Carbon emission depends on speed under unchanged characteristics (See model

assumption). A speed function improved by the European Commission (1999) and Jost et al.1994) is employed in this study as shown in figure 1, which explains the relationship between CO<sub>2</sub> emissions versus speed.



**Figure 1:** Relationship between carbon emission rate and vehicle speed for a light truck. (Adopted from European Commission 1999 and Jost et al.1994).

Meanwhile each truck consumes diesel oil, which depends on speed similar to the case of CO<sub>2</sub> emissions. This study employs the study of the relationship between consumed fuel (L/100km) versus speed (Km/hr) of Bektas and Laporte, (2011) as shown in figure 2.



**Figure 2:** Relationship between fuel consumption rate VS speed (Adopted from Bektas and Laporte,2011)

From both figures above, the fuel consumption cost element and carbon emission cost are expressed as a nonlinear function of vehicle traveling speed (Fahimnia et al. 2013). Two graphs are merged into the optimization model based on the concept of sustainability focusing on the incorporation of the major economic cost elements and the environmental responses. Logistics structure typically incorporates several suppliers, manufacturers and customers during multiple time periods to satisfy deterministic market demands at customer location, which must be satisfied by the end of the planning

horizon. The model output in each period of planning horizon comprises transportation quantities, storage quantities, fuel consumption, carbon emission.

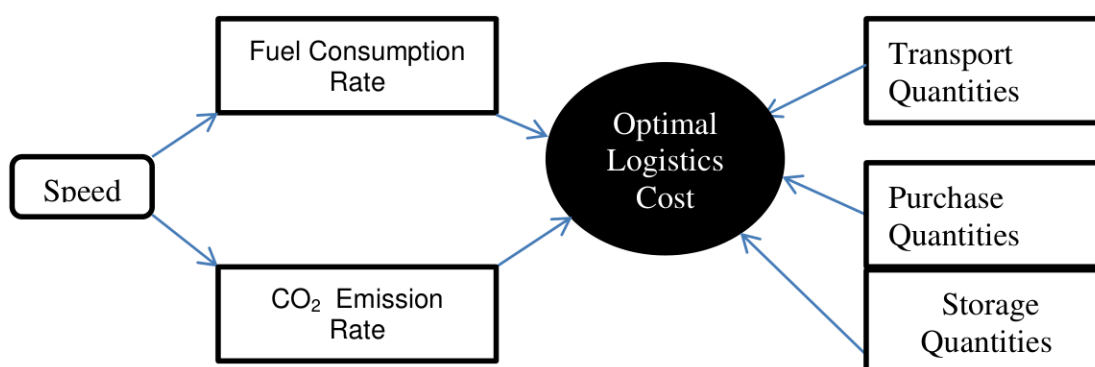
#### **4. Model assumptions**

From the concepts and the problem formulation as described above, the conceptual framework involved is complex and there is a need to simplify the model assumptions so as to arrange the conceptual framework in an easier way. The Model assumptions can be stated as follows

- 1) The number of locations and capacity of suppliers , customer , distance , initial inventory ,restriction on maximum and minimum of speed including customer demand are known.
- 2) There is only a traveling trip from suppliers to distribution centres and from distribution centres to the customers in the logistics structure at time t. (Two sequential echelons of Material flow)
- 3) The transportation cost is proportional to distance and the quantity of commodity.
- 4) The fuel consumption and carbon emission are defined and expressed as a nonlinear function of vehicle traveling speed.
- 5) Unchanged Traveling characteristics (e.g. road gradient, altitude, road roughness, ambient temperature and degradation of pollution controls etc.)

#### **5. Conceptual Framework**

In a conceptual sustainable logistics framework, the relationship between the variables with its optimal logistics cost, is proposed according to the proposition of the ecological-economical integration (Helmig et.al. 2011). Based on the nonlinear function of speed, nonlinear programming (NLP) is employed in this framework. All independent variables such as CO<sub>2</sub> emission, fuel consumption as well as amount of both transportation and storage under model constraints are encapsulated in the overall framework. This conceptual model represents the trade-off between transportation cost and carbon emission cost which are expressed as nonlinear function of vehicle speed. In order to solve the optimal solution, piecewise function (Gugarati 2003) is adopted to linearize. Then mixed integer programming (MIP) model (Taha 2003) is applied to solve the optimal solution. All independent variables within proposed conceptual model are optimized simultaneously so as to minimize logistics cost. Finally the principle of the fundamental development of this environmental conceptual framework is discussed in detail, and this will be a guideline for model development in the future. The conceptual framework can be demonstrated as in figure 3.



**Figure 3:** Conceptual Framework of sustainable logistics network

## **6. Discussion of the guideline for model development from the conceptual framework**

Based on the proposed conceptual framework and literature review, the discussion about the guideline for model development found that the significant feature of the environmental logistics network research is the consideration of the trade-offs between operational and environmental factors for transporting products. A nonlinear programming model approach is adapted to the logistic network problem in a realistic situation.

The environmental conceptual framework of logistics network, based on literature surveys, shows that there are some gaps on the application of both carbon emission based models and fuel based model in sustainable logistics network optimization problems. Both models are expressed as the nonlinear function of vehicle speed (Fahimnia et al 2013). Indeed, there were several sustainable logistics network frameworks in literature reviews that fail to appropriately incorporate environmental factors such as CO<sub>2</sub> emission and the more traditional operational and economic objectives. Over the last decade, there were few studies of green supply chain optimization models merging sustainability variables directly or indirectly into their conceptual model or their mathematical models.

The important issue of sustainable logistic model development is to link both operational cost and carbon emission's reduction through their relationship with vehicle speed (Parajuli, Ferreira & Bunker 2005). There are several factors from the general green optimization model such as fuel consumption, carbon emission, transportation cost, pollutions etc. and some factors from unchanged traveling characteristics of model assumption such as vehicle load, road roughness etc. These factors are considered as important factors in the development of sustainable logistics network models. These factors are related to comprehensive objective function and model constraints. The objective function is measured and minimized the emission cost along with the operational costs of transportation, fuel consumption, storage, distribution, noise etc. Consequently this concept, based on model development from these factors, will lead to various environmental model developments of sustainable logistics networks. This conceptual framework development is meant to environmentally support long term logistics decisions. It will serve as a framework prototype to suggest minimal cost flow and environmental damage under the economic and ecological points of view. This paper provides an outline of the great benefits and increased efficiency in ongoing logistics planning so providing managerial insights on economic savings of environmentally conscious logistics management.

## **7. Conclusion and further research**

Currently logistics enterprises need more effective approaches to address CO<sub>2</sub> emission problems together with high operational cost problem. Hence, this paper proposes and generates the guidelines for model development about a sustainable logistics network framework. The aim of this paper is to present and discuss a conceptual model development including demonstrating the relationship among

all independent variables within this framework. The rationale for this model development is based on attempts to decrease both operational costs and carbon emissions through the nonlinear relationship of vehicle speed. The different speed scenarios, each have their own CO<sub>2</sub> emissions, fuel consumptions and associated costs. In addition, all important variables, which are focused on each individual interest for model development, from general supply chain model or from model assumption are considered as the critical keys for model development under the relationship between the comprehensive objective function and its model constraints

The obtained results from the fundamental guideline for model development are not just to decrease the cost of CO<sub>2</sub> emission and the economics cost, it is also to develop the conceptual framework of a sustainable logistics network for solving various issues, either economic or ecological. . Finally future research could take place to improve and to apply the model to realistic logistics problems. In fact, the previous scant attention that has been paid to how logistics network can now be developed and this will affect other useful aspects for human such as environmental or social logistics planning(Manzini et al. 2008).

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