A Simulation Approach to Enhance the Green Logistics (GL) Operations

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***Abstract*—: This paper is focused on the growing need of integrating environmentally sound choices into supply-chain management. The concept of green economic practices driven by the environmental sustainability challenges posed the concept of green logistics, to evolve in the last few decades. In this study, a simulation approach has been used to reduce Carbon Dioxide (CO_2) emissions of a two-echelon multi depot distribution network. The proposed, simulation approach tackles the conflicting objectives of CO_2 emission reduction and cost minimization. This would enable the organizations to do strategic decision making to improve the GL operation while allowing for competitive advantage.**

Keywords: CO_2 emission reduction, Green Logistics, Simulation

I. INTRODUCTION

As globalization makes the world become smaller, it becomes increasingly easy to see how the lives of human everywhere are closely synced up with one another. Due to the rapid industrialization, environment pollution happens at an increased pace [1]. This has led to many adverse implications such as increase in temperature, scarcity of resources etc. These issues have built awareness among consumers and stringent laws that are more environment conscious [2].

This increased consumer awareness, legislations, standards on environment such as ISO 14001,competitiveness, external influencers and greater concern on environment have pushed environmental issues into the spotlight, making it imperative for organizations to have a plan of action for "going green" [3]. Proactive companies are reaping benefits in the form of cost savings, favorable public opinion and access to clean-energy stimulus funds. Meanwhile, laggards risk expensive consequences since they will lose the market share as environmentally conscious buyers continue to vote with their money [3].

Within the past few decades, the concept of "Going Green" became popular among the practitioners and researchers. So when it comes to Supply Chain Management (SCM), a new area known as Green Supply Chain Management (GSCM) was emerged [4]. In studying the effects of green practices, all phases from production to the point of sale needs to be taken into account. Among the activities of a typical SCM, transport and logistics have a greater impact on the environment making GL to become a significant area of study [4].

Through the analysis of literature it could be seen that many researchers had focused their attention to the areas of green-house gas (GHG) emission reduction and energy conservation through vehicle routing, scheduling and network optimization, reverse logistics, and waste disposal pertaining to Green Logistics (GL) [5]–[9]. Literature highlights, that techniques such as, simulation modelling, mixed integer programming, multi-objective linear programming, Lagrange relaxation, genetic algorithm-based heuristics, fuzzy mathematical programming modelling methods etc. have been used to model the aforementioned aspects [7], [10], [11].

Globally the transport and logistic sectors accounts for a large portion of the Green House Gas (GHG) emissions. Among the greenhouse gases, CO_2 has the major share in a global basis. Therefore, among the different areas of focus in GL, CO_2 emission reduction takes a prominent place. With the increase of CO_2 emissions, it will lead to the environmental pollution and thus would increase the cost to the organization concerning the environment. In this study, the considered environmental externality is CO_2 and a simulation approach has been used to reduce the emissions within the network due to transportation.

II. METHODOLOGY

First and foremost, a thorough literature review has been conducted to discover the studies that have been already done in order to clearly identify the concepts of green logistics, the objectives, the methods and models they have used in arriving at the solutions. Also the factors affecting the CO_2 emissions in transportation was identified through the literature review. Literature highlights that distance is one of the main factors that affects the amount of CO_2 emissions. Apart to this, the other factors affecting the amount of CO_2 emitted, could be categorized into three types as vehicle related factor, environment related factors and traffic related factors [12]. Vehicle related factors would include Total vehicle mass, gasoline type, engine size, oil viscosity etc. Road gradient, surface condition are some environment related factors affecting the CO_2 emissions. Speed and acceleration would account for the traffic related factors.

CO_2 emissions are proportional to fuel consumption. Fuel consumption is related to distance traveled, speed, vehicle curb weight and load, slopes, road surface, wind, engine

Submitted on September 19, 2016. This work was carried out as part of the course module: Modelling and Simulation taught by Dr. Thashika Rupasinghe to fulfil the curriculum requirements of the B.Sc. degree in MIT, Department of Industrial Management, University of Kelaniya)

efficiency, accessories, driving style, acceleration and deceleration, etc. [12]

In this work, CO_2 emissions were studied with regard to the distance travelled, speed of the vehicle load. Different scenarios were created within the model to identify the effect of each of the above factors to the amount of CO_2 emitted and the transportation cost.

In this study a two echelon multidipot distribution network [13] has been considered in the model development. The proposed simulation model was developed using the Supply Chain Guru (Acedamic version) simulation software. Using the simulation software the network was implemented as shown in Figure 1 below.

Figure 1: Distribution network

First, this network was optimized including all the scenarios with the objectives of reducing total transportation cost and the total CO_2 emissions and then it was simulated to identify the results.

III. RESULTS

In the proposed simulation model, effect of speed of the vehicle and load on CO_2 emissions were identified, creating different scenarios within the model. The distance travelled was reduced through the network optimization.

Table 1 shows the results obtained for different scenarios with regard to the vehicle speed.

Table 1: CO_2 footprint for different scenarios of speed

Scenario	Speed (km/h)	Carbon footprint of the network
1	20	10,548,293
2	30	10,467,853
3	40	10,243,284
4	50	9,950,938
5	60	10,403,075
6	70	10,729,430
7	80	11,520,578
8	90	12,168,912

It could be seen that although initially the speed was low carbon footprint is higher due to the other factors that affect the CO_2 emission such as vehicle load.

As per the results 50 is the best speed that needs to travel so as to reduce the CO_2 emissions and the cost.

Table 2 shows the results obtained for different scenarios with regard to the vehicle load.

Table 2: CO_2 footprint for different scenarios of load

Scenario	Load(tons)	Carbon footprint of the network
1	0	2,619,645
2	250	7,843,743
3	350	8,579,543
4	400	9,384, 163
5	450	10,403,075
6	500	11,023,673
7	550	11,934,148
8	600	13,003,734

Although, the load in the truck was zero still it would emit CO_2 due the other factors that affect the CO_2 emission. It could be seen that when the truck load increase the carbon footprint also increase.

IV. CONCLUSIONS

Today, the whole world is moving towards the concept of "Green." Therefore, it is very crucial for organizations to make their functions greener and stay attractive in the eyes of the customers and withstand the competition. The present study shows the potential of the introduction of green approaches in transportation management.

Through this simulation model, user would be able to make more informed decisions by analyzing various options available and come up with the best decision. This approach enables strategic decision making where it provides answers to some critical questions such as shown in Table 7,

Table 3: Critical Questions for Which the Model Provide Answers

No.	Question
1	What is the best truck load that reduces CO2emission as well as the cost?
2	What is the best speed for the truck that reduces CO2emission as well as the cost?

Therefore, the organizations could use this model to better evaluate their green logistic function by recognizing the best option under several scenarios with the minimum CO_2 emission that would cut down their negative environmental effects and take strategic decisions.

In this study, it consider only the speed and load as the factors that affect CO_2 emission. So the future studies could be formulated so as to capture other factors apart from the speed and load, which affect the CO_2 emission such as acceleration, road gradient etc. also can be considered in future research

work.This provides the user with the opportunity to make more informed decisions.

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