American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-5, Issue-8, pp-294-299
www.ajer.org
Research Paper Open Access

An Analytical Model Formulation To Enhance The Green Logistics (GL) Operations: From The Perspective Of Vehicle Routing Problem (VRP)

Reshani P. Liyanage[1], Thashika D. Rupasinghe[1]
[1](*Department of Industrial Management*, University of Kelaniya, *Sri Lanka)*

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.To establish the field further, the purpose of this paper is twofold. First, it offers anextensive systematic review of literature on GL with a critical review of the studies that have been considered in the paper.Second, it offers a conceptual analytical model where the canonical capacitated vehicle routing problem is extended to add the measures of Carbon Dioxide (CO_2) emissions. The proposed, multi objective optimization model tackles the conflicting objectives of CO_2 emission reduction and cost minimization. The developed generic model integrates the traffic information in providing the user with opportunity to have more realistic solution. The model also enables strategic decision making to improve the GL operations while allowing greatercompetitive advantage.*
Keywords: *Analytical Modelling, CO_2 emission reduction, Green Logistics*

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 and scarcity of resources. 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]. 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 carbon foot-print 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].

Table 1 gives the critical review of the modelling techniquesused in the studies which consider CO_2 emission reduction and have the VRP perspective in it. The Table 2 shows the critical review of the modelling techniques of the studies which do not have the VRP perspective in it.

Table 1: Critical Review of the Modelling Techniqueswith the VRP perspective

Reference	Critical Review
Jabir et al.,2015[7]	• Has the flexibility to choose an appropriate solution from the set of solutions. • Assumes, that the individual demand of each customer cannot exceed the capacity of a vehicle.
Vinay et al., 2013[12]	• The routes generated by the model are sensitive towards the environmental impact. • Assumes, that the individual demand of each customer cannot exceed the capacity of a vehicle is a limitation. • Consider only the carbon emissions. Do not consider other GHGemissions, noise levels and so on.
Erdoĝan and Miller-Hooks, 2012[13]	• The tool support institutions in reducing their carbon footprint, given the currently available vehicle technologies and limited deployment of supporting infrastructure. • The formulation and solution techniques are applicable for any fuel choice. • The developed formulation and solution techniques presume that fuel usage is directly related to distance travelled which is always not practically correct.
Taha et al., 2014[14]	• The model uses an exact optimization method but the VRP is NP-hard combinatorial problem and the use of exact optimization methods may make it hard to solve these problems in acceptable CPU times, when the problem involves real-world data sets that are very large.
Zhang et al., 2016[15]	• The proposed model do not address logistics network design with uncertainty in the demand sides, as well as multi-period dynamic investment and pricing problems.

Table 2: Critical Review of the Modelling Techniqueswithout the VRP Perspective

Reference	Critical Review
Sundarakani et al.,2010[16]	• With the model firms can see what and where the areas of sensible heat flux and acceptable carbon emissions are. • Model development and analysis help managers to understand the total network of supply chains. • Do not take the cost of carbon emissions into account. • Analysis is limited to a simple four-echelon supply chain without considering the turbulent mixing of emissions in the atmosphere is also a limitation.

Table 3 depicts thecritical review of the modelling techniquesused in each studies related to analytical modeling perspective of the reverse logistics.

Table 3: Critical Review of the Modelling TechniquesUsed

Reference	Critical Review
Ko and Evans, 2007[10]	• Proposed a heuristic which has solved all the test problems considered within a reasonable amount of computational time
Srivastava, 2008[17]	• Developed a formal framework for analysing the network model and providing useful managerial insights. • The model determines the disposition decision forvarious grades of different products simultaneously with locationallocation and capacity decisions for facilities for a time horizon of 10 years. • The model deals only with supply side (returns) and returns' disposition but do not consider the co-ordination of the two markets. It follow a "push" system and do not consider controlling product returns.

Wadhwa et al., 2009[18]	• The proposed method is very flexible and provides more objective information for alternative selection in a Reverse Logistics System (RLS). • RLS system can be extensively affected by a lot of dynamic environmental and legislative issues that can affect the decision for the selection alternative. But they are not considered in the model. • The model faces issues due to the drawbacks owing to the fuzzy logic scheme.

Table 4 showsthe critical review of the modelling techniquesused in each studies related to analytical modeling perspective of waste management.

Table 4: Critical Review of the Modelling TechniquesUsed

Reference	Critical Review
Hu et al., 2002[6]	• The proposed method addresses the classical hazardous-waste treatment problem with a systematic management strategy rather than with waste-treatment technologies used traditionally. • The model takes the internal and external factorsinto account and thereby addresses the performance of a hazardous-waste reverse logistics system. • Can be used to determine the time-varying waste collection amounts and treatment amounts in response to the variety of waste demands from multiple waste resources. • Do not consider the cost minimization of hazardous-waste treatment.
Nema and Gupta, 2003[9]	• The proposed approach facilitates the decision making process by giving the choice of priority to minimize cost or risk and the opportunity to specify constraints as truly absolute or non-absolute. • The model may be used for analysing the trade-offs among site risk, transportation risk, and total risk. • The model does not consider the political and social issues. • Decision makers need find an optimal solution out of the given set of treatment and disposal facilities, and transportation routes may use the model as a tool. • The model do not facilitate to screen out the candidate sites, technologies, and transportation routes considering social and political issues but the decision makers need to first identify them and then use the mathematical model as an aid in selecting the final solution based on cost and risk considerations.

The global statistics show that this sector accounts for a large portion of the Green House Gas (GHG) emissions [19]. This causes GLto become an important concern today to reduce environmental pollution and to promote sustainability. This has created the need for more complex contributions, especially in the dissemination of models that will evaluate the GL function and paves the way to reduce emissions through which it foster sustainability. So the aim of this research is to develop and analytical model which can be used to evaluate the logistic function and to identify the best solution that would reduce emissions while not increasing the cost.

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. A flow diagram of the systematic review of literatureis shown in Fig. 1.

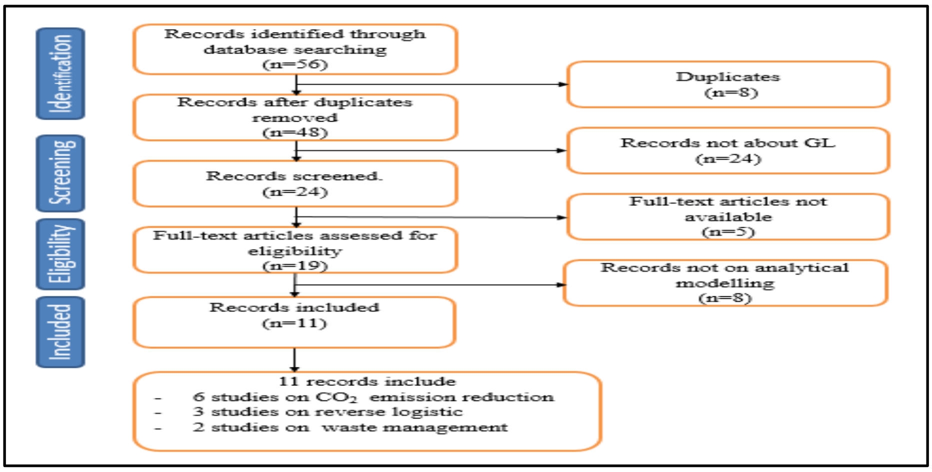

Figure 1: Flow diagram of literature review process

In this study, the authors report their novel multi objective optimization model and prior developing the model the assumptions related to the problem were identified. The relevant variables and the criteria for the model that optimize the fuel usage and the constraints are recognized and a single objective function was developed, compiling themultiple objectives.

III. RESULTS

After a thorough review of literature, we preset the aggregatedand expanded model in the below sections.The developed analytical model evaluates the Green Logistic function from the VRP perspective. Here, in this study a green VRP has been considered. Green VRP is a new category of the traditional VRP with the objective of minimizing the impact on the environment [20]. Ittakes parameters such as customer demand, distance from customer to depot to identify best route which minimized the CO_2 emission and cost.

In this study a multi-depot vehicle routing problem for a 2 echelon forward supply chain network is considered where there could be congestion in the route or in a part of the route. A model developed by [21]has been expanded in this work to get a more realistic results incorporating certain controllable costs and traffic. The formulation of the 2 echelon forward supply chain network with respect to VRP is shown in the Fig. 2 below.

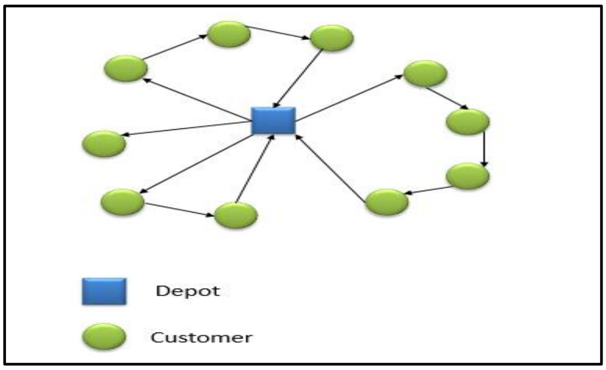

Figure 2: Two echelon forward supply chain network scheme

The developed model considers the following assumptions given in the Table 5.

Table 5: Assumptions of the Model

No.	Assumption
1	The fleet size is known.
2	Fleet is homogeneous.
3	Single depot in the network.
4	The demand is deterministic.
5	Demand oriented network.
6	Symmetric distances from depot to customer.

Following Table 6 depicts the notations used in the proposed model.

Table 6: Notations Used

I	Set of depots (i=1,2,…,i)
J	Set of customers (j=1,2,…,j)
K	Set of vehicles (k=1,2,…..,k)
q_j	Demand of customer j for all j ∈ J.
Q_k	Capacity of vehicle k.
e_{ij}	CO_2 emitted between i and j.
W_{CO2}	Weight of CO_2 emitted between i and j per litre consumption of fuel.
P_f	Diesel fuel price per unit volume
V_f	Volume of fuel consumption per unit distance per
P_{CO2}	Average price per unit weight of CO_2
d_{ij}	Distance between i and j.
eij	CO_2 emitted between i and j.
$X_{ijk}(t)$ =	1, if vehicle k is travelling from depot i to customer 0, otherwise
Y_{ijk} =	1, if customer j to assigned to depot i 0, otherwise
$Z_q(t)$ =	1, if the q^{th} link (part of the route) is congested 0, otherwise

Objective function is to minimize the CO_2 emission and the cost.
Minimize:

$$Z=\sum_{i=1}^{i}\sum_{j=1}^{j}\sum_{k=1}^{k} Xijk(t) \times Zq\ (t) \times eij+ \sum_{i=1}^{i}\sum_{j=1}^{j}\sum_{k=1}^{k} Xijk(t) \times Zq\ (t) \times d_{ij} \times V_f \times \left[P_f + P_{CO2} \times W_{CO2}\right] \quad (1)$$

Subjected to:
All the vehicles begin and end at the depot [21]:

$$\sum_{k=1}^{k} Yik = k \quad (2)$$

Each node, except the depot, is visited by a single vehicle:

$$\sum_{k=1}^{k} Yik = 1 \quad (3)$$

Each node, except the depot, is linked only with a pair of nodes, one preceding it and the other following it:

$$\sum_{i=1}^{i} Xijk = Yjk \quad \text{(for all j ∈J and k ∈ K)} \quad (4)$$

$$\sum_{i=1}^{i} Xijk = Yik \quad \text{(for all i∈I and k ∈ K)} \quad (5)$$

Vehicles cannot be overloaded:

$$\sum_{i=1}^{i}\sum_{j=1}^{j}\sum_{k=1}^{j} Xijk \times q_j \leq Q_k \quad (6)$$

$$Xijk \in \{0,1\} \quad \text{for all i∈I, j ∈J and k ∈ K)} \quad (7)$$

$$Yijk \in \{0,1\} \quad \text{for all i∈I, j ∈J and k ∈ K)} \quad (8)$$

$$Z_q\ (t) \in \{0,1\} \quad (9)$$

The model provides answers to someof the critical questions when making strategic decisions. Hence, this model provides the user with the opportunity to identify the most suitable routing option where the CO_2 emission and cost is at a minimum level.

IV. ANALYSIS, CONCLUSION AND FUTURE WORK

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.

The paper presents an extensive systematic review of literature, which both the practitioners in companies and academics might find it useful, as it outlines major lines of research in the field After doing thisthorough literature review, a conceptual analytical model has been developed in this study as presented afore in the paper. The model incorporates the real time traffic information and this would provide an added advantage to the user since it would enable the user to have a more realist view of the network. This would also help the company in reducing the CO2 emission as well as the cost due to emissions.So through this model, the user would be able to make more informed decisions by analyzing various options available and come up with the best decision. The analytical model developed enables strategic decision making where it provides answers to some critical questions such as shown in Table 7.

Table 7:Critical Questions for Which the Model Provide Answers

No.	Question
1	To which node the customer j should be assigned in order to reduce the total distance?
2	Which customers should be served by vehicle k?
3	The no. of vehicles that should be used?
4	Which route to be used in order to reduce the distance?
5	Whether there is congestion in the route or the link (part of the route)?
6	Which route or link is to be used when there is congestion in the normal route or link?
7	Amount that needs to be carried by each vehicle?

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

In the future research workthe other factors apart from the distance, which affect the fuel combustion such as speed, acceleration also could be incorporated to enhance the developed model. Also in this research the cost due to fuel emission only is captured in the model. Therefore the future researches could be formulated so as to capture this deficiency capturing the total costs in a more effective way and improve the developed model. A Metaheuristic approach could be used in the future to solve the above formulated model. As for the future research a simulation model could also be developed along with the above model which could be used to identify how the CO_2 emission and cost get affected with the type of the distribution of the parameters such as the arrival rate, departure rate, and delayswhen there is traffic at a particular point of the time on a route. This provides the user with the opportunity to make more informed decisions.

REFERENCES

[1]. "Pollution: Causes and Effects - Conserve Energy Future." [Online]. Available: http://www.conserve-energy-future.com/PollutionTypes.php.

[2]. U. U. Solomon, "ethics , law and education to determine which plays and protection," *Env. Dev Sustain*, vol. 12, pp. 1069–1080, 2010.

[3]. T. Ai, H. Hon, and Z. Sulaiman, "Green Supply Chain Management , Environmental Collaboration and Sustainability Performance," in *Procedia CIRP*, 2015, vol. 26, pp. 695–699.

[4]. O. N. Esinah, "Green supply chain management practices and supply chain performance in mobile phone firms in Kenya," UNIVERSITY OF NAIROBI., 2014.

[5]. M. Fleischmann, "Quantitative models for reverse logistics," Erasmus University Rotterdam, 2001.

[6]. T.-L. Hu, J.-B. Sheu, and K.-H. Huang, "A reverse logistics cost minimization model for the treatment of hazardous wastes," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 38, no. 6, pp. 457–473, 2002.

[7]. E. Jabir, V. V. Panicker, and R. Sridharan, "Multi-objective Optimization Model for a Green Vehicle Routing Problem," in *Procedia - Social and Behavioral Sciences*, 2015, vol. 189, pp. 33–39.

[8]. R. Zhao, Y. Liu, N. Zhang, and T. Huang, "An Optimization Model for Green Supply Chain Management by Using a Big Data Analytic Approach," *J. Clean. Prod.*, 2016.

[9]. A. Nema and S. Gupta, "Multiobjective Risk Analysis and Optimization of Regional Hazardous Waste Management System," *Pract. Period. Hazardous, Toxic, Radioact. Waste Manag.*, vol. 7, no. 2, pp. 69–77, 2003.

[10]. H. J. Ko and G. W. Evans, "A genetic algorithm-based heuristic for the dynamic integrated forward / reverse logistics network for 3PLs," *Comput. Oper. Res.*, vol. 34, pp. 346–366, 2007.

[11]. M. Adelzadeh, V. M. Asl, and M. Koosha, "A mathematical model and a solving procedure for multi-depot vehicle routing problem with fuzzy time window and heterogeneous vehicle," *Int J AdvManuf Technol 75793–802*, pp. 793–802, 2014.

[12]. J. E. Vinay, V. Panicker, and R. Sridharan, "Modelling and Analysis of a Green Vehicle Routing Problem," in *Twelfth AIMS International Conference on Management*, 2013, pp. 1310–1318.

[13]. S. Erdoĝan and E. Miller-Hooks, "A Green Vehicle Routing Problem," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 48, no. 1, pp. 100–114, 2012.

[14]. M. Taha, M. N. Fors, and A. a Shoukry, "An Exact Solution for a Class of Green Vehicle Routing Problem," *Int. Conf. Ind. Eng. Oper. Manag.*, pp. 1383–1390, 2014.

[15]. D. Zhang, Q. Zhan, Y. Chen, and S. Li, "Joint optimization of logistics infrastructure investments and subsidies in a regional logistics network with CO 2 emission reduction targets," *Transp. Res. Part D Transp. Environ.*, 2016.

[16]. B. Sundarakani, R. De Souza, M. Goh, S. M. Wagner, and S. Manikandan, "Int . J . Production Economics Modeling carbon footprints across the supply chain," *Intern. J. Prod. Econ.*, vol. 128, no. 1, pp. 43–50, 2010.

[17]. S. K. Srivastava, "Network design for reverse logistics," *Omega, Int. J. Manag. Sci.*, vol. 36, pp. 535–548, 2008.

[18]. S. Wadhwa, J. Madaan, and F. T. S. Chan, "Flexible decision modeling of reverse logistics system : A value adding MCDM approach for alternative selection," *Robot. Comput. Manuf. 25*, vol. 25, pp. 460–469, 2009.

[19]. "Key World Energy Statistics 2013."

[20]. P.L N.U. Corray and T. D. Rupasinghe, "An Analysis of Methodologies for Solving Green Vehicle Routing Problem A Systematic Review of Literature," in *International Conference on Research for Transportation and Logistics Industry (R4TLI), Proceedings*, 2016, ISSN 2513-2504, pp. 89- 93.

[21]. S. Úbeda, J. Faulin, A. Serrano, and F. J. Arcelus, "Solving the green capacitated vehicle routing problem using a tabu search algorithm," in *6th International Conference on Applied Operational Research, Proceedings*, 2014, vol. 6, pp. 141–149.