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Investigation of Green Logistics Strategies: A Case Study in Indian Context

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Abstract

The production, transportation, storage, and consumption of goods have all increased significantly as a result of globalisation. However, there is a negative impact on the environment as a result of increased traffic and logistics. With a staggering contribution of almost two-thirds of the total, the transportation sector is the main source of greenhouse gases in the atmosphere. Concept of logistics, solely focused on the economy, business, and door-to-door service, cannot be practised any longer. Instead, it is necessary to account for the effect on the environment while integrating them with the cost and time and this leads to the inception of term green logistics. Green logistics refers to the strategies and policies to make logistics more sustainable and to find a balance between ecology and economy. This paper presents different strategies of green logistics and a case study of transporting agricultural products in Prayagraj district with green supply chain perspective. Mathematical regression equations were developed for CO_2, N_2O, and CH_4 emissions and results were validated with an environment performance calculator. A comparative analysis has been carried out to demonstrate that emissions can be reduced significantly by modal split, and it is advised to use lesser number of bigger vehicle than large number of smaller vehicles.

Keywords

Transportation, Green logistics, Modal split

Introduction

Logistics is essential for economic growth. We can observe a sizable road and railroad network for transportation as well as numerous ambitious projects undertaken to advance the process. However, because there is a growing concern about environmental harm on a worldwide scale, logistics operations, one of the major sources of emissions, are under enormous pressure to meet human requirements while also taking into account the environment's health. Environment is the newly added parameter to study supply chain [1].

This paper presents the review of the green logistics, policies, and strategies implemented in the logistics system to make them more sustainable while reducing energy footprints starting with material management, transportation routes, with a special focus on mode selection all the way to reverse logistics. Some of the recent studies in this direction are route optimization [2], operation research [3], and multi objective problems [4] to reduces traffic congestion, fuel consumption, and delays on the road. Advanced green logistics studies today include mode of transport as an important factor [5]. In the purview of reducing CO_2 and other greenhouse gases, NTMCalc Basic 4.0 is used for nearby cities of Prayagraj to calculate and reduce emission. Despite the fact that surrounding cities and vil-

lages were the focus of this study, the results obtained apply to situations with similar shipment conditions and restrictions. But in a developing country like India, it is still a long way to go before implementing all of the green logistics solutions. There may be challenges in the form of unavailability of modern infrastructure and technologies to aid with optimization or routing. Huge cost of shifting to greener options, and delivery commitments are the factors behind being reliant on traditional options.

Need of green logistics

Various needs of green logistics are:

a) **Sustainability:** Green logistics result in lesser emissions while shipping, and lesser waste generation during the whole process, right from packaging to reusing the material.

b) **Awareness:** People are more aware of the environment than ever before, labelling and other information on the product show the methods how to discard the waste, regarding reducing reuse and recycling.

c) **Brand Value:** Being environmentally conscious boosts brand value and helps businesses gain a competitive edge by instilling in consumers the notion that by purchasing such products, they are doing their part to protect the environment.

d) **Cost savings:** Green logistics has the advantage of shorter hauls, less fuel consumption, higher efficiency, and better energy management.

e) **Future Prospects:** Deteriorating environment is forcing the environmental agencies and government to take strict measures and regulations in this area, adhering to it will give the company a competitive edge in the future because it will be prepared for stringent environmental regulations levied in the future.

Green logistics strategies

Two broad dimensions of green logistics strategies are material management and physical drivers.

Materials management on the first hand emphasizes reducing the detrimental footprints comprising production. Listed below are the techniques.

a) **Product design**. After the demand generation, the first place to cut down the harmful effects of any product is in the cradle stage, that is the type of material used for its synthesis and production keeping an eye on the carbon footprints, its longevity, and effectiveness.

b) **Reusable material**. Using the materials which can be recycled and input to the product should be such that the maximum chunk can be the portion of intersection in reverse logistics, be it parts of packaging or the product itself. Monitoring the safe handling and disposal with great responsibility.

c) **Local stores.** With the growing concept of last-mile delivery, keeping in mind the cost sensitiveness (due to transportation and inventory) of the product along with the environmental constraints present currently or are to pop up in days to come, it is more favourable to have local stores in the developed areas with the concept of spoke-and-hub network, and strategically developing potential areas in near future to cut down the huge transportation cost by delivering products from local stores and in lesser time, and to compete with legal restraints and another greener branding in future.

d) **Increasing the shipment density**. Try to cut down the volume of the packing, and the way of doing so to increase the density of shipment and increase the efficiency of logistics, this, in turn, can also reduce a load of reverse logistics on the system which again will aid to our aim of greener logistics.

Physical drivers

Our main focus will be on the transportation aspect, as logistics is the biggest contributor to the CO_2, SO_2, and N_2O emissions, to ensures that logistical operations relating to freight movement are carried out in a sustainable and environmentally friendly way. The principal techniques include:

a) **Pull logistics systems**. Method of manufacturing in which process starts only just after or in time when the demand is placed so that shipping is the result of demand expressed and its fulfilment tends to reduce returns alleviating the extra burden on logistics or the extra emissions generated in its management in inventory or warehouse for storage, preservation (heating or refrigeration).

b) **Minimise unnecessary trips:** Try to cut down on unnecessary journeys by batching the items on the same route in the right order for a smoother transport that doesn't require any delays or retracing the same route. This can be combined with precise navigation and routing strategies for improved outcomes and a switch from less than the truckload (LTL) to optimal or full truckload (FTL) for more effective and environmentally friendly logistics. In reality, to maximise haul capacity and minimise journeys, a notion of integrating various supply chains is growing these days.

c) **Incentivizing greener options:** Facilities, firms, and organisations that follow environmentally friendly options and provide carbon footprints with their products can compete in the market against those that do not follow the norms and produce or deliver cheaper products at the expense of the environment. Even the customers can be incentivized for greener purchases, like a lesser delivery charge if they can wait for one or two more days so that their item can be shipped along with the routine lot and unnecessary trips can be avoided by optimising batching. Levying taxes based on the carbon emissions of the vehicles is another measure under study.

d) **Optimized route** Minimizing the travel time and distance can reduce fuel consumption and, in turn,

emissions and reduce the overall in-hand cost of the product. This can be done by better utilisation of the resources available to us, like the transportation facilities and the warehouses. We can opt for optimised routes and stops to increase efficiency and choose route planners and routing applications to increase the fluidity of the shipment so that vehicles spend less time on the roads by avoiding the routes crowded or under construction, and hence the shipper has to pay less, the customer has to pay less, and the environment has to pay less. That is bilevel optimization for cost reduction and profit maximization. Multi-modal vehicle routing can be beneficial because different modes have different emission rates, and hence we can obtain an optimal route for the vehicles in the logistics network.

e) **Speed of the vehicle:** Another factor in greener logistics is the speed of the vehicle on the road, which is related to the relative consumption of fuel at different speeds. Xiaoren et al. conducted a study to show the relation between speed and time (Figure 7), indicating that as speed increases from 0 to 42 mph, the emission reduces by 59.47%, but after that, if speed is increased further, the emission starts increasing significantly [2]. Hence travel speed is also an important parameter to be considered to keep a check on emission

f) **Modal split**. Modal split can reduce the emission significantly. The idea is to choose the best possible option that is available to make the fleet more energy efficient as per the nature of goods, the network, the vehicles, and the geography of the area. On the narrower streets and roads with lower service levels, we can use smaller cargo vehicles with biofuels to cut down on emissions. For the cases in which a single mode is not appropriate, we go for intermodal shipping options. Though there may be delays due to consolidation and deconsolidation at transhipment points. But proper management, planning, scheduling, and infrastructure can alleviate the long wait hours.

Study based on modal split

Rising global temperature and other similar environmental concerns are global concern today, and vehicle emission is one of the major causes. In the response of the same govt of India has launched an emission calculator named E-AMRIT which takes input as vehicle type, journey distance, frequency and type of fuel and makes a comparison in the level of emission of CO_2 for the same distance by the electronic vehicle in the terms of "CO_2 emissions reductions during the lifecycle of the vehicle in tonnes". By this simple raw statistics govt is trying to spread awareness and the importance of greener fuels, and sustainability. Talking specifically about India where major logistics is done through conventional sources, we should look to increase the efficiency of the same along with the advancement being carried. One such calculator is developed by ICAO (International Civil Aviation Organization) taking inputs for route-specific data, type of aircraft, and load carried and gives the fuel burned and emissions in kg.

Generally, time-sensitive goods are transported through aircraft, and the emissions of air transport are way higher than any other mode, so here onwards, our study progresses with a special focus on the various modes currently involved in road logistics in India. For the routes having longer hauling distances, the goods can be consolidated and can be shipped to the destination by bigger trucks powered by more eco-friendly options if possible. If the alternative options of rail and/or inland shipping are available (near the coasts), that should be preferred. František et al. calculated the emissions of different transport services using NTMCalc Basic 4.0 to study different parameters [6], Korbelyiova et al. used it in areas of Kolkata and Bhubaneshwar to study the carbon footprints of Paper vs leaf [7].

To understand better how the emissions can be cut down by different modes and get workable data to make a fair comparison, we are going to use NTMCalc Basic 4.0. After checking the congruency of the data in the Indian conditions from the calculator and the report of Ashok Deo (2021 International Council on Clean Transportation) in which he mentioned the emissions of the vehicles in grams/km in Indian conditions. NTMCalc Basic 4.0 is an advanced environmental performance calculator which takes data input in terms of transportation modes (truck, train, ship, or aircraft) and asks for the route (origin and destination). It is Google-aided and hence finds the accurate distance and plots the route on the map with suggestions of alternative routes if available between the nodes given in input. Then it seeks the input of the type of vehicle as shown in the figure 1. Based on the type of vehicle given by us, it asks for the load input in tonnes, and with the help of the distance calculated earlier, it calculates the different emissions and their amount (Figure 3).

Now looking at the data set collected by NTMCalc Basic 4.0, visualise how the proper management and choice of an appropriate vehicle for a given leg can result in fewer pollution levels, hence making the logistics greener significantly. The raw data has also been presented in the form of charts to make it easier to comprehend the level of difference in emissions for the distance travelled by different vehicles (Figure 5, figure 6, and figure 7). Based on the data extracted from the calculator, linear regression has also been done to obtain the equation of three different emissions (CO_2, CH_4, and N_2O) and for three different vehicle conditions (Truck < 7.5 ft, Truck 14 - 20 ft, and Electric Cargo Train) to haul a load of 10 tonnes. In the latter part of the study, the same equations have been

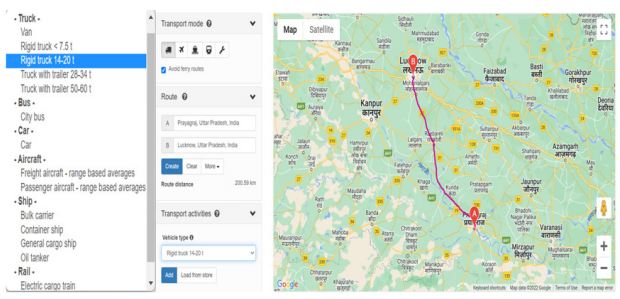


Figure 1: Route with distance in NTMCalc Basic 4.0.

used to calculate the emission for a different stretch and have been compared to the results obtained from the calculator for the same. A real-world problem has been solved to illustrate the importance of the appropriate choice of vehicle. To make a general comparison, all the data has been centered on Prayagraj and destined to some arbitrary nearby cities (Figure 4) accessible by both the railways and roadways to eliminate the incongruency in the data and assuming all other parameters are the same.

In the interface shown in figure 1, inputs have been provided and based on that, the distance and plotting have been done. Next, just give the weight to be shipped and the additional parameters section gives the result for the amount of emission (Figure 2).

The same has been carried out for 10 different cities, tables have been made and respective scatters have been plotted (Figure 5, figure 6, and figure 7) along with their equations (Table 1).

The results obtained shows, the cargo train is the best possible option amongst the shipment methods under consideration, and in that case, due to limitations such as, the route being partially connected with the railway line, the maximum possible distance should be covered with heavier trucks. Though it will require adequate management and development of transhipment points and may sometimes result in delays, it is highly advisable to opt for the environmentally friendly methods.

Now, before taking on the optimization problem, let us first check the decency of the equations obtained against the NTMCalc for an arbitrary route, say from Prayagraj to Gorakhpur, at a distance of 302 km. In the equations above, we will substitute x as 302 since it is the independent variable (distance) and y will give the value of the respective emissions. Hence, most of the results fit with great accuracy (Table 2), and hence the data obtained from the equation is coherent with the calculator. A little deviation in the data of the train emissions can be witnessed owing to the different path lengths of roads and railways and the different routes for the same destination by the rail itself.

With all this background, let us consider a very small real-world problem (Figure 3). With development taking place all over, the area for agricultural land is decreasing and if any remains, they are far away from the cities with less service level roads. A lot of agricultural products are shipped to cities, and many processed and industrial goods are shipped to villages. The problem lies in adequate management of vehicles or their integration. To alleviate this shortcoming, we can integrate different modes.

Take the example of village Manda Khas (A) and a similar bunch of villages 70 - 80 km from the core city of Allahabad (C), from where several tonnes of agricultural products are shipped every day. But, due to the lack of proper management and unavailability of railway lines or broad roads for the complete route, the major portion of goods is transported by mini trucks or local motorised vehicles. The farmers need to ship the product daily and as soon as possible to get a good return, so they do it individually. There are several flaws in this system

Figure 2: Nodal representation of places under study.

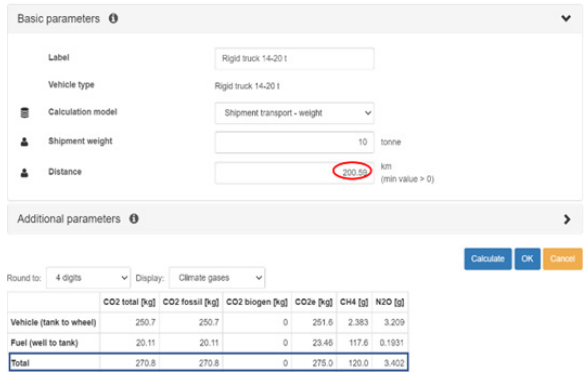


Figure 3: Result interface in NTMCalc Basic4.0.

Figure 4: Places under consideration for emission calculation.

Origin	Destination	Distance (km)	CO_2 (MINI)	CO_2 (HEAVY)	CO_2 (TRAIN)
PRAYAGRAJ	VARANASI	120.86	278.2	163.1	15.07
PRAYAGRAJ	LUCKNOW	200.59	461.8	270.8	24.92
PRAYAGRAJ	KANPUR	204	469.6	275.4	24.78
PRAYAGRAJ	DELHI	742.75	1710	1003	79.31
PRAYAGRAJ	BAREILLY	446.93	1029	603.3	54.89
PRAYAGRAJ	FIROZABAD	484.31	1115	653.8	52.12
PRAYAGRAJ	JAIPUR	761.32	1753	1028	101.7
PRAYAGRAJ	JHANSI	385.79	888.1	520.8	49.78
PRAYAGRAJ	PATNA	361.33	831.8	487.8	43.54
PRAYAGRAJ	NAGPUR	636.12	1464	858.7	115

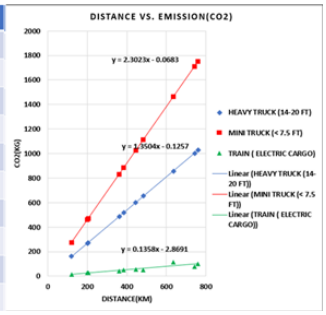


Figure 5: Amount of carbon dioxide gas emitted in different cases.

that go unnoticed.

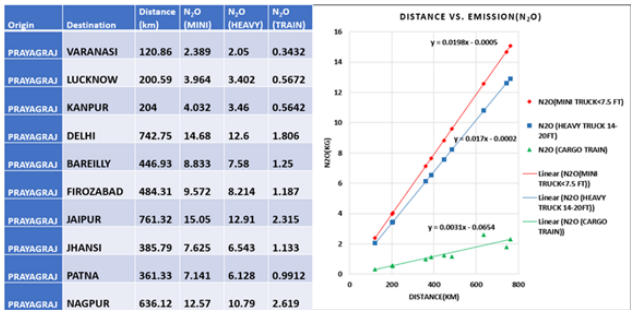
a) Higher emissions damage the quality of the environment as smaller vehicles in large numbers create more air pollution than larger vehicles or trains for shipping the same goods, as per the results obtained above, where the weight was 10 tonnes, but emissions were different.

Table 1: Regression equations for different cases.

Vehicle type	CO_2	CH_4	N_2O
Truck (< 7.5 feet)	y = 2.3023x - 0.0683	y = 1.0282x + 0.0466	y = 0.0198x - 0.0005
Truck (14 - 20 feet)	y = 1.3504x - 0.1257	y = 0.5982x - 0.0086	y = 0.017x - 0.0002
Train (cargo train)	y = 0.1358x - 2.8691	y = 0.2034x - 4.2841	y = 0.0031x - 0.0654

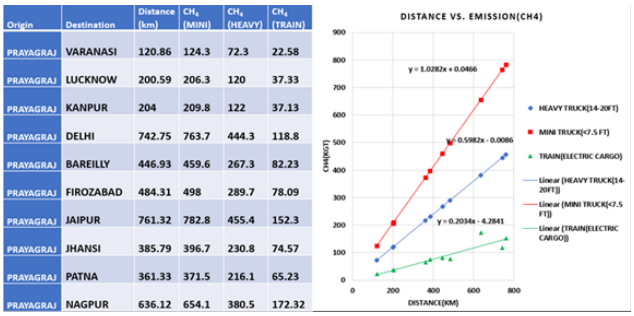
Table 2: Comparison of results with calculator and equations.

Vehicle type	CO_2		CH_4		N_2O	
	calculator	**formula**	**calculator**	**formula**	**calculator**	**formula**
Truck (< 7.5 feet)	694.8	695.45	310.3	310.563	5.965	5.98
Truck (14 - 20 feet)	407	407.6951	180.5	180.6478	5.119	5.134
Train (cargo train)	45.26	38.1425	67.81	57.1427	1.030	0.88



Origin	Destination	Distance (km)	N_2O (MINI)	N_2O (HEAVY)	N_2O (TRAIN)
PRAYAGRAJ	VARANASI	120.86	2.389	2.05	0.3432
PRAYAGRAJ	LUCKNOW	200.59	3.964	3.402	0.5672
PRAYAGRAJ	KANPUR	204	4.032	3.46	0.5642
PRAYAGRAJ	DELHI	742.75	14.68	12.6	1.806
PRAYAGRAJ	BAREILLY	446.93	8.833	7.58	1.25
PRAYAGRAJ	FIROZABAD	484.31	9.572	8.214	1.187
PRAYAGRAJ	JAIPUR	761.32	15.05	12.91	2.315
PRAYAGRAJ	JHANSI	385.79	7.625	6.543	1.133
PRAYAGRAJ	PATNA	361.33	7.141	6.128	0.9912
PRAYAGRAJ	NAGPUR	636.12	12.57	10.79	2.619

Figure 6: Amount of methane gas emitted in different cases.



Origin	Destination	Distance (km)	CH_4 (MINI)	CH_4 (HEAVY)	CH_4 (TRAIN)
PRAYAGRAJ	VARANASI	120.86	124.3	72.3	22.58
PRAYAGRAJ	LUCKNOW	200.59	206.3	120	37.33
PRAYAGRAJ	KANPUR	204	209.8	122	37.13
PRAYAGRAJ	DELHI	742.75	763.7	444.3	118.8
PRAYAGRAJ	BAREILLY	446.93	459.6	267.3	82.23
PRAYAGRAJ	FIROZABAD	484.31	498	289.7	78.09
PRAYAGRAJ	JAIPUR	761.32	782.8	455.4	152.3
PRAYAGRAJ	JHANSI	385.79	396.7	230.8	74.57
PRAYAGRAJ	PATNA	361.33	371.5	216.1	65.23
PRAYAGRAJ	NAGPUR	636.12	654.1	380.5	172.32

Figure 7: Amount of nitrous oxide gas emitted in different cases.

b) Due to improper coordination, many vehicles are not loaded to their full capacity, which could have been utilised.

c) A large number of vehicles on the roads again creates more traffic, which again reduces the serviceability and increases the waiting time for other vehicles, generating induced air pollution.

These problems could be tackled to a great extent, if not completely, by proper management and utilisation of appropriate choices available. Let us have a look at the figure 3. The goods are directly shipped from Manda Khas (A) to Prayagraj (C). The distance between these two nodes is 64.65 km. Let us say we need to ship just 10 tonnes from A to C using the mini trucks, as it is generally done by farmers, which will result in the emissions of 148.8 kg of CO_2, 66.48 kg of CH_4, and 1.278 kg of N_2O. But this emission can be cut down if we utilise the broader 2-lane RCC road for the distance it is available from the Manda Road (B) to C and take transhipment at B and use the heavy truck (14-20 feet). The total emissions, in this case, are 97.95 kg of CO_2 (decreases by 34.17%), 42.87 kg of CH_4 (decreases by 35.49 %), and 1.1354 kg of N_2O (decreases by 11.18%).

Another striking feature we can see, a railway line is also available for route B to C, and if the proper planning is done and an electric cargo train is used, then the emissions can be reduced by 70% from the initial case.

The only flaw is that sometimes this method might result in short delays, and the shipment of time-sensitive goods may suffer, but if we have to haul for a longer distance, the preference should be cargo trains, and second to it, heavier trucks should be preferred over mini trucks. This was the case when the hauling distance was only 64.5 km and the load to be carried was only 10 tonnes. The difference will be even bigger if the distance is longer and the load increases. The government can also assist in greener logistics by levying a lower tax rate on greener options.

Conclusion

In recent years, the supply chain and logistics systems also require considering sustainability, in addition to time and cost as important factors. The logistics industry is constantly expanding, and as one of the industries that contributes the most to greenhouse gas emissions, we cannot wait for technical development to meet the growing demands and worsening environment. Understanding the significance of optimization at each stage of the supply chain while making wise use of the resources we already have is the fundamental foundation of this effort. A real-world network has been analysed using the current infrastructure to evaluate the level of emissions produced by various-sized vehicles and freight trains while accounting for the present transportation pattern. The results show that, using larger trucks reduce greenhouse gases emissions significantly as compared to smaller ones for the same load, and trains are the most environmentally friendly alternative on land. Besides, this paper also highlights

the significance of businesses participating in greener logistics to support the future market and various legislative initiatives that may be used to promote greener logistics. Future extensions of this study could include localised simulation for better findings and comparative time and cost analysis.

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None.

Conflict of Interest

None.

Credit Author Statement

Nawdeep Maurya: Writing - original draft preparation, Writing - review and editing; Dr. Varun Singh and Dr. Venkateswara Rao Komma: Guidance. All the authors read and approved the manuscript.

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