Sustainable Last-Mile Logistics Operation in the Era of E-Commerce

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Abstract

Last-mile Logistics is considered as the most expensive and polluting segment in the entire supply chain network. With increasing concerns over the impact of this segment on environment, necessary steps were taken to reduce the Greenhouse Gas (GHG) emissions. But, with rapid increase in customer demand for Last Mile Logistics, innovative strategies need to be developed to limit the GHG emissions. The paper aims to develop a framework to further reduce the GHG emissions, focusing primarily on CO_2 emissions, for sustainable logistics. The framework focuses on innovative strategies that were successful in reducing CO_2 emissions and could be implemented in Last-Mile Logistics. The paper describes the use of alternative fuel sources, e-vehicles, optimization techniques, stricter government regulations among others as possible strategies for reducing CO_2 emissions. Extensive literature review coupled with feasibility study was done to build the framework. Our results indicate that these innovative strategies, if implemented, can significantly reduce the CO_2 emissions in Last-mile Logistics.

Keywords
Last–mile Logistics, Greenhouse Gas, Sustainable logistics, Alternative fuel, e-vehicles.

1. Introduction
The term logistics is often confused as something solely related to transportation of goods or humans. But in actual, logistics not only involves transportation but also includes storage, material handling, inventory, security and in some cases value added services such as packaging (McKinnon, 2010a). Logistics is the forward and reverse movement of goods, services and related information between point of origin and the point of consumption in order to meet customer's requirements. A typical supply chain consists of 5 major stages- Supplier, Plant (Manufacturer), Distribution center, Retailer and Customer as shown in the Exhibit 1 below. In the supply chain, material moves downstream and information flow upstream from customers to manufacturer. Last mile logistics is literally the last stage in a supply chain and is defined as the delivery of the product to consumers home. The last mile logistics focuses on delivery of products in minimal time possible with maximum profit and customer satisfaction. The last mile delivery is primarily done using light vehicle trucks. With tremendous growth of e-commerce industry in recent times, the last mile logistics sector has grown significantly and it's considered the most challenging stage for all the e-commerce giants. It is considered as the most expensive stage of supply chain. The costs of last mile delivery are between 13% and 75% of the total supply chain costs (Gevaers, Van de Voorde, & Vanelslander, 2011). It's a challenge not just in terms of costs, but also in terms of the environmental impact. Greenhouse gas and specially CO_2 emissions from transportation have become a global issue and these emissions are expected to increase in the near future. Hence, there is a need to come up with innovative ideas and solutions to minimize these emissions.
The paper is organized as follows: Section 2 describes the Research Motivation, then section 3 summarizes the Problem Statement. Section 4 summarizes the Methods/Strategies incorporated to reduce the CO_2 emissions and section 5 presents the Conclusions.

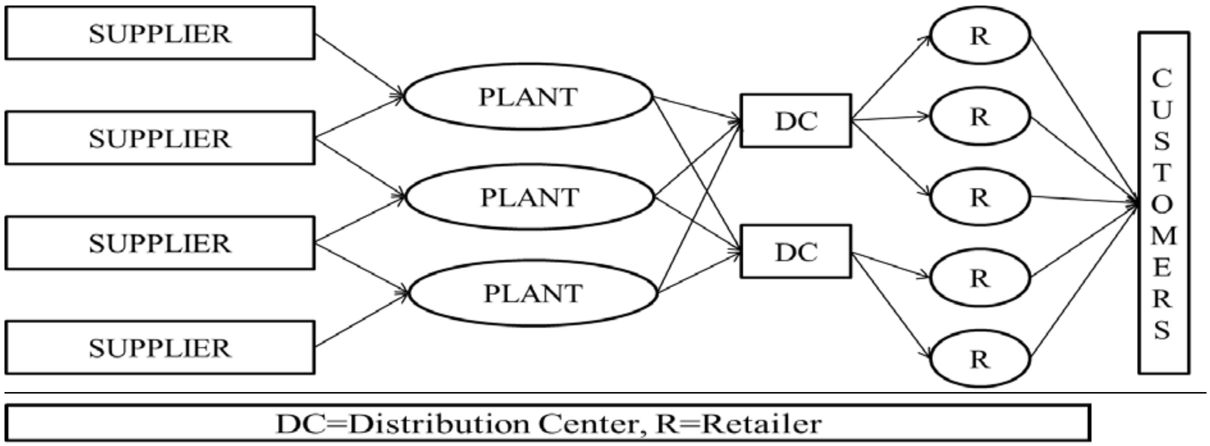

Figure 1**.** A typical E-commerce Delivery Supply chain (Ravindran & Warsing Jr, 2012**)**

2. Research Motivation

Recently, Sustainable logistics has gained significant interest due to the increase in CO_2 emissions from transportation sector and especially from last mile logistics operations. Sustainable logistics is defined as a system that measures, analyses and mitigates the impact of logistics operations. It is a promising method to reduce the impacts of CO_2 emissions because of logistics activities and focuses on methods or solutions that can reduce the impacts of CO_2 emissions. The top 10 Fortune 500 companies have taken measures towards Sustainable logistics and they estimate their carbon footprints with an aim to reduce their CO_2 emissions. They report the annual CO_2 emissions in their annual carbon Disclosure project (Piecyk, 2010).

The European Union (EU) has committed to a long-term goal of limiting the rise of 2^0 Celsius in global average temperature. The United States has agreed to collaborate with over 180 nations under the United Nation (UN) Framework convention on climate change to bring about the "stabilization of greenhouse gas concentration in the atmosphere to a level that would prevent dangerous anthropogenic interference with the climate system". It has been found that for more than 2^0 Celsius rise in global temperature, there are severe risks to natural systems and human health. Continued rise of this level could even lead to extinction of many species and rise in the global sea level between 12 and 40 feet (Amy L. Luers & Michael D. Mastrandrea, 2007). These numbers are high and alarming and with increasing concerns on global warming, the government across globe has decided to work towards reducing the CO_2 emissions. It has been studied that to avoid temperatures rising above 2^0 Celsius, countries must stabilize concentration of heat trapping gases in the atmosphere at or below 450 parts per million CO_2. For this target to be achieved, the U.S. must reduce its emissions by a minimum of 80 per cent below the 2000 levels by the end of 2050. With the forecasted rise in sales in e-commerce industry being so high and with such far-fetched targets for emissions reductions, the companies are forced to develop initiatives to control their CO_2 emissions. Various initiatives have been taken by companies across globe to reduce CO_2 emissions.

3. Problem Statement

Transportation sector contributes about 37% of total CO_2 emissions in United States which is evident from the exhibit 2 shown below (as of 2017). The data has been taken from U.S. Energy Information Administration. Transportation is a major contributor to CO_2 emission and the emissions are likely to increase in the future. So, there is a need for logistics companies to come up with solutions to reduce the emissions and at the same time keep their operational cost low (Vélazquez-Martínez, Fransoo, Blanco, & Mora-Vargas, 2014). With the advent of e-commerce sector there is a significant increase in the number of home deliveries because customers have the opportunity to purchase small orders from different website and this leads to increased vehicle movement leading to increased CO_2 emissions. Also, since the customers have the opportunity to buy multi items in a single order, and delivery companies cannot deliver all the products in one go so they have to make additional rounds to deliver the products to the same location. This extra trip generates extra cost and emits more CO_2. Generally most of the product delivery is done through diesel vehicles and with increase in the number of customers demand for delivery of end products, there is an increase in the fuel consumption and CO_2 emission. (Edwards, Wang, Potter, & Cullinane, 2010). Exhibit 2 shown below shows the %CO_2 emissions for different sectors in 2017. These emissions directly impact the environment and contribute to climate change.

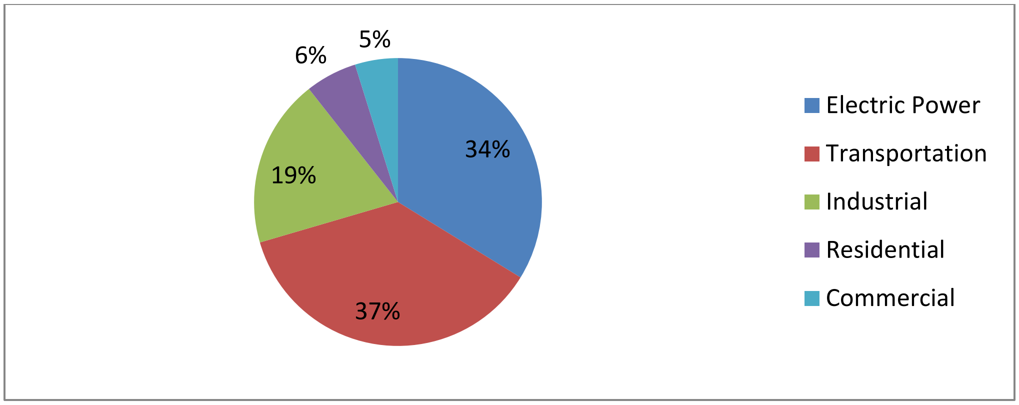

Figure 2. Per cent CO_2 emissions of different sectors of United States in 2017 (Energy Information Administration,2018)

4. Methodology

One way of reducing the emissions and making the environment less polluted is shifting to greener modes of transportation such as delivery of products to customers using e vehicles and use of urban consolidation centers, shifting to using alternative fuels, optimization techniques for vehicle routing, are some strategies for reducing CO_2 emissions. The growing demands of customers for last mile delivery necessitate the need of such innovations in technology. The innovations are not only the results of growing customer demands but are also due to stricter policies imposed by the government. In the United States the emission standards are managed by Environmental protection agency (EPA). Failing to adhere to their standards can result in large penalties to the vehicle manufacturers. Volkswagen "Diesel dupe" depicts the perfect example of not adhering to the EPA standards and facing major recall of its vehicles. Volkswagen had to recall around 8.5 million cars in Europe only, and around 500,000 in the US as a result of the emissions scandal (Hotten, 2015). This section talks in detail about the various methods to reduce the CO_2 emissions

4.1 Allocation of vehicles to Delivery location

Velázquez-Martínez et al., (2016) explained the different factors on road transportation that lead to CO_2 emissions and came up with a statistical-mathematical method of assigning the right vehicle to the right location in order to reduce the CO_2 emissions. The factors under consideration were the type of vehicle such as engine power, torque, fuel type, aerodynamic drag coefficient and delivery operation such as type of road, slope, vehicle speed, load, traffic and driving style. They studied the effect of delivery conditions on the vehicle performance by taking into account factors such as diverse geographical locations, Traffic congestion, driving styles among others. They applied their approach for a parcel company in Mexico City and showed that using their method; they were able to reduce around 40 tons of CO_2 emissions. Such a model can be adopted by all logistics companies delivering goods to the customers in United States to reduce the CO_2 emissions. The variations in geographical location, number of vehicles in the area, the number of customers served in the city, the road conditions and the driving style could be the barrier in applying such a model in all cities to reduce the CO_2 emissions.

4.2 Use of E vehicles for delivery

Doucette et al., (2011) modeled the CO_2 emissions from Electric vehicles (EVs) and Plug in Hybrid vehicles (PHEVs) and compared the results with CO_2 emitted by a conventional vehicle based on an Internal combustion engine (ICE).They showed that for a low CO_2 intensity country, EVs emits the least amount of CO_2 when compared with PHEVs and Conventional vehicles. For a mid-range CO_2 intensity country, PHEVs were found to be better than EVs when used in electric mode and for a high CO_2 intensity country, PHEVs were the best among three to emit the least amount of CO_2.This research result can be used in last mile logistics for different countries to deliver goods to the customers based on the CO_2 intensity. The only problem with bringing Electric vehicles to market is their low range distance travelling capacity and the time taken for the batteries to charge. Moreover, the number of charging stations are also limited as this technology is very new. Sweden has a solution for this problem. The country opened a 1.2 miles electrified road that will recharge the cars and trucks batteries driving on it. This initiative is a part of the country's target to reduce its dependence on fossil fuel by 2030. The technology solves two problems at once – Charge the electric vehicles and also keep the battery affordable (Boffey, 2018). Another interesting solution for the challenge faced is the use of a super capacitor instead of the conventional Li-ion batteries. The Graphene super capacitors has high power output which reduces the charging time to few minutes , takes limited space and thereby makes vehicle lighter. In a single charge the vehicle is estimated to travel up to 310 miles which is similar to a gasoline powered car and almost double the capacity of a current electric car. Another added advantage of super capacitors when compared with Li-ion batteries is they are environment friendly when discarded ("Graphene-Based Supercapacitors Could Lead To Battery-Free Electric Cars Within 5 Years,").

4.3 Amazon Air Borne Fulfillment Centre (AFC)

Reducing CO_2 content in Last mile logistics requires technological innovation and the e-commerce giant "Amazon" has come up with such an innovation. The company came up with an idea of "airborne fulfillment center (AFC)" which has a capability to fly at 45,000 feet or more and will store items for delivery to customers purchased through their website. The delivery to the customers will be done using drones that will pick up the light weight items for delivery. The AFCs will store inventories of product that it sells online. A logistics shuttle would be used to carry the drones and any new product requirement to and from the AFC. Another advantage of AFCs is its flexibility as it is not fixed on ground and can move to different areas depending on weather conditions and Demand. The company speculates that the innovation could be an added benefit for easing the material handling and its ability to move to different locations because of its flexibility. The company envisions that the delivery of items through drones will significantly reduce the CO_2 emissions when compared with Last mile delivery via light diesel vehicles (Kim & Awwad, 2017).

4.4 Proper Fleet Planning

A major problem in delivering of goods to the end customers in e-commerce business is that customers generally purchase items in fragments and expect a quick delivery, thereby forcing the companies to respond quickly to satisfy customer's demand. This responsiveness by the companies to satisfy the customer demand generally results in underutilization of the truck load capacity of the vehicle leading to increased cost and CO_2 emissions. Hence, there exists an opportunity to optimize the fleet planning for e-commerce Last mile Logistics. (Ubeda, Arcelus, & Faulin, 2011) worked to solve the problem and focused on reducing the environmental impact by optimizing the fleet planning by incorporating changes in their logistics system such as reduction in number of trips via backhauling, improvising their delivery route schedule and by developing sustainable methods to solve the routing problem. They showed their methodology using a case study for a Spanish company called Eroski and suggested that by incorporating these methods, CO_2 emissions can be reduced significantly. So, the model developed by them can be adopted for Last mile logistics to reduce the CO_2 emissions. Similar to Eroski case study, if backhauling is incorporated in Last mile logistics i.e. collecting return items in their way back to depot then it can reduce both the distance travelled and the CO_2 emitted as there would be a considerable decrease in the number of empty-running trips. So, backhauling is beneficial both from economic as well as environmental point of view. By optimizing the fleet, we can expect to increase the efficiency of fleet and at the same time could reduce the CO_2 emissions in Last mile logistics (Ubeda et al., 2011).Improvising the delivery route schedule is another important factor to reduce the CO_2 emissions. By re-designing routes in a manner that reduces CO_2 emissions can lead to cleaner environment. Example of such a delivery route improvisation is the "Minimal left turn Policy by UPS". UPS vehicles avoid turning left through at a traffic junction. UPS vehicle routing software eliminates as many left-hand turns as possible (in countries with right-hand traffic). The result of implementing this policy is 10 million gallons less fuel used, 20,000 tons less CO_2 emission and 350,000 more packages delivered annually. The model even helped them to reduce around 1,100 trucks they use; thereby reducing the total distance travelled by 28.5 million miles and reduces the time wasted and the number of accidents (Kendall, 2017).

4.5 Reducing Number of Failed Home Deliveries

The carriers delivering the product to customers provide information about the day of delivery and not about the estimated time for delivery. This forces the customer to stay at home for long hours to receive the products. If the customers do not stay at home, the delivery companies have to make another trial to deliver the product to the customers. Smaller products that fit into the delivery mailbox do not create a problem, but for larger products not fitting into a mailbox, there is a 12% chance of failed delivery. This failed delivery increase the cost of the carrier and also emits CO_2 into the environment. On an estimate, the failed home deliveries results in a total cost of approximately £850 million in 2012 and adds to excess CO_2 emissions.

The solution for the problem includes using

4.5.1 Reception boxes: These are the boxes fixed on a wall that permits access only through a password/code or a key. If a product is delivered into a reception box, the customers will be notified of the delivery either through email or through SMS. The only drawback of reception boxes could be the installation cost which has to be borne by the customers.

4.5.2 Delivery boxes: These are the boxes that are owned by the delivery companies. The products to be delivered are put into the box at the distribution center and then the box is attached temporarily to the customer's home in a secure place. The delivery companies collect the empty delivery boxes or boxes with returned product either in their next delivery or separate collection drive. Here, the collection of delivery boxes as a separate trip might be a problem as it would emit approximately the same amount of CO_2.

4.5.3 Collection points: These points are generally located to places easily accessible by the customers. These places might be a supermarket or mall or the nearest post office which are open till late in night. The delivery companies deliver the products to these collection points and intimate the customer that the product is ready to be collected. The collection points provide the benefit as the delivery companies have to drop products in one location instead of dropping to multiple locations thereby reducing the trips and CO_2 emissions (S Iwan ,2016).The problem with Collection points might be lack of parking space for the customer who comes to collect their goods

4.6 Carbon Emissions Trading

Another initiative to reduce the Emission of Greenhouse gases (GHG) started in 2003 through the introduction of the Chicago Climate Exchange (CCX) which was first of its kind trading system for Greenhouse gas emissions in North America. The CCX concept interested corporate companies, educational institutions, state and municipalities, farmers and their organizations and even passenger rail corporations, all trying to reduce the emissions of GHGs to the atmosphere. These organizations pledged to reduce their aggregate emissions by 6% by 2010. CCX had an aggregate baseline of 680 million metric tons of CO_2 equivalent. But unfortunately because of lack of participation from the organizations the CCX had to be ceased by the end of 2010. The CCX was only able to trade for 7 years from the time of its inception in 2003 ("Chicago Climate Exchange,"). Such an initiative needs to be revived or similar initiatives need to be brought in order to limit the CO_2 emissions. These initiatives could contribute significantly in minimizing the emissions in transportation sector and especially in last mile logistics sector.

4.7 Use of Alternative Fuels

This section discusses about the use of alternative fuels in last mile logistics and compares the CO_2 emissions from these alternative fuels to conventional fuels. The section talks about use of alternative fuels –and focuses the interest on Biofuels. There has been an enormous worldwide investment in biofuels which is evident from the investment amount rising from 2004 to 2017. The stats taken from Stastica, are shown below

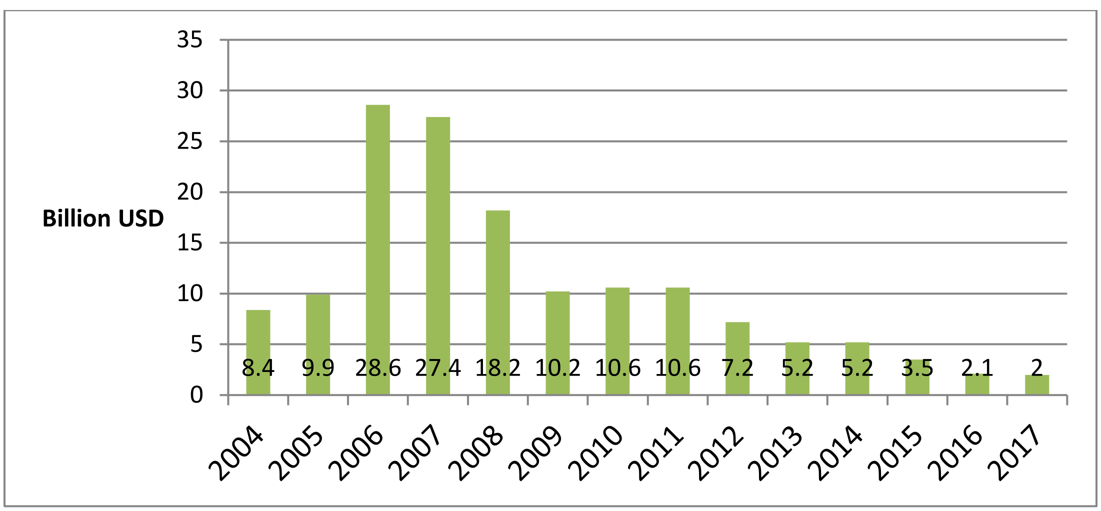

Figure3**.** Investment(in billion U.S. dollars) in biofuel technologies worldwide from 2004 to 2017 (Stastica,2018)

A total of 149.1 Billion U.S. dollars have been invested from 2004 to 2017.

Biofuels are basically fuels that are produced from living matters. There are two main types of biofuel: - Biodiesel and Bioethanol. The main benefit of using low blend biofuels is that they can be used directly in vehicle without any need to retrofit the engine. Also, the refueling is done through normal fuel pumps making it easier and convenient. The main reason for the shift towards biofuels was because of their low CO_2 emissions when compared to emissions from fossil fuels (Cullinane & Edwards, 2010).The Exhibit 3 above shows the global investment in biofuel technologies between 2004 and 2017. About 2 billion USD were invested in 2017, but the graph also shows that there is a decline in the investment in biofuels. Let's consider the case where biofuels are produced from algae. Algae are organisms that live in water and generate energy through CO_2 and sunlight. Biofuels are produced by conversion from fat, which is derived from single celled microalgae. Another advantage of generating biofuels from algae is because of their rapid growth leading to high productivity of Biofuel (Ridley, 2016).There was a rise in investment in the year 2006 and 2007 as shown in the graph above. But in the last decade, there has been a dip in the investment for the development of Biofuels from algae. This drop may be attributed to struggles faced by algal biofuels companies in being highly productive at a larger scale. So, either a low cost photo-bioreactors need to be developed which can be deployed in large scale, or biologists must develop species that grow efficiently in low-cost systems. Extraction of oil is another challenge. The technologies present as of today are very expensive in terms of equipment or energy required for oil extraction. Even if these two challenges are solved, the land mass required to address the demand per day in the year 2008 is estimated to be about 30 million acres. The quantity of water required and the amount of nutrient are the other areas of challenges that have to be overcome to all together make biofuel production from algae as a viable source of alternative (Hannon, Gimpel, Tran, Rasala, & Mayfield, 2010) But, even with all the problems associate with biofuels it has the solution for both high oil price as well as carbon emission and this biofuel can be used in vehicles for delivering products for last mile logistics.

4.8 Urban Consolidation centers

Another interesting initiative adopted recently is the development of urban consolidation centers (UCCs). UCCs are defined as facilities that are situated near an urban area or near areas that serve key places in a city as shown in Exhibit 4 below. These centers help companies in consolidating deliveries, avoiding poorly loaded vehicles, regulating movement of freight inside the city resulting in a decrease in the number of vehicles entering the city and hence led to a decrease in the CO_2 emissions. The concept of freight Consolidation Centers has been in existence since the 1970's. If the load factor of the delivery vehicles is improved, UCCs makes it easier to deliver goods in populated areas like urban cities as well as reduces the CO_2 emissions as the total distance travelled by the vehicle is reduced. Although the idea is prevalent in European countries, such an idea can also be implemented in United States to reduce the CO_2 emissions. The only challenge the idea of UCCs can face might be the initial cost of building one and its expected return of Investment in long run (Allen, Browne, Woodburn, & Leonardi, 2012). Setting up UCCs involves high costs associated with its development and running. Since products from a wide range of suppliers get consolidated a single point, it calls for a highly complex and effective product storing and picking system to be put in place to avoid any mix up or errors. Most importantly, the companies must agree to come together to develop the UCCs. E-commerce companies differentiate themselves in the aspect of delivery. For example, Amazon offers premium one day delivery. Amazon has its own logistic fleet services. Such companies might have to compromise on certain aspects. The government can offer incentives to such companies to come together and setup UCCs and serve a better cause of a greener environment (Van Duin, Quak, & Muñuzuri, 2010).
Another method to reduce CO_2 emissions is the use of urban consolidation center (UCC) in combination with e-vehicles. In London, a trial has been conducted by a stationary and offices supplies company over the usage of urban consolidation centers in combination with e-vehicles such as cargo tricycles and electric vans for delivery. The results of this trial showed that the total distance travelled and the CO_2 emissions per parcel delivered fell by 20% by using cargo tricycles and by 40% using electric vans, against that emitted by diesel vehicles. A constraint faced by the company was that, the total distance to be travelled to deliver a package had increased owing to the smaller capacity of the e-vehicles in terms of weight and volume as against a diesel vehicle. On the other hand, the company did virtually eliminate the CO_2 emissions per parcel delivered. The trail was successful for the company from the point of transport, environment and finance. Hence, the company continued the operations using UCC and e-vehicles post the trails and had officially launched the method as part of its delivery operations in 2010(Browne, Allen, & Leonardi, 2011)

4.9 Government Policies

Government's policies and actions play a pivotal role in reducing the CO_2 emissions. The government support capital investment by companies in new equipment or infrastructure, and subsidize greener freight modes. In 2009, San Antonio region confronted major freight bottleneck challenges when the development of a toll way to alleviate congestion on US-281 stalled. This was due to complications that arose during the review of environmental impact of this initiative. The local government funded a project of $5.2 million that was driven by a local engineering firm

which came out with an innovative solution to address the issue. The solution reduced the traffic delays and thereby indirectly resulted in reduction of CO_2 emissions.
In UK, the government sponsored a programme called Safe and Fuel Efficient Driving (SAFED). The objective of the programme was to train truck and van drivers to drive safely and efficiently, for which truck simulators were used. Case studies of the companies that have been using this programme indicate fuel savings ranging from 2.6 to 12 per cent McKinnon (2010b). Governments across many countries have created programs to promote adoption of good environmental practices in logistics sector. UK Freight Best Practice Programme (FBP) is a programme that provides advice to organizations on a broad range of measures that improve efficiency and reduce environmental impact of freight transport operations (Lawson, Michaelis, & Waldron, 2007).
These initiatives could be extended to Last Mile Logistics in e-commerce sector. Government could subsidize costs of e-vehicles to promote their use for delivery, which would directly lead to a cut down on CO_2 emissions. The U.S. government is already funding in research & development of Plug-In Electric Vehicles
A challenge that exists for the Government is to pool in funds for these high investment initiatives. The government could enforce companies to use e-vehicles for last mile logistics sector and in return could make it cost effective for companies by giving tax incentives and other financial incentives in place for using e-vehicles ("Electric Vehicles: Tax Credits and Other Incentives,")

5. Conclusion

Last mile logistics is the last stage in a supply chain and focuses on delivery of products in minimal time possible with maximum profit and customer satisfaction. With the advent of e-commerce, the number of last mile logistics deliveries increased. This increased the number of trips the vehicle makes to deliver the product to the customers and increases the CO_2 emission. There does not exist a panacea to all the problems caused due to last mile logistics. So, a set of solutions need to be implemented to reduce the CO_2 emissions. The paper summarizes some of the solutions such as statistical method to allocate vehicles to delivery location, use of e-vehicles, airborne fulfillment center, reducing the number of failed deliveries, proper fleet planning, carbon emission trading , use of alternative fuels and use of urban consolidation centers have the potential to reduce the CO_2 emissions. But, the solutions also have barriers associated with them which can be considered as future research opportunities. So, in order to develop a sustainable, smart and efficient logistics system, these ideas need to be put together and should be used as one.

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