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Optimizing Carbon Footprint and cost of inbound logistics through milk-run: cloud-based carrier collaboration approach

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Abstract: *Sustainability and mitigation of carbon footprint has become a matter of strategic importance for all organizations today. As business is expanding in multiple geographies, it is often facing different laws and restrictions to comply with carbon emissions. Reinforcement of global climate agreements i.e. the Paris Agreement at local level often becomes compulsion for multinationals operating at local level to optimize their greenhouse emissions. Besides, lowering of carbon footprint is often associated with positive impacts on a firm's brand and reputation. Many developed nations have already introduced stringent emission policies like cap-and-trade system and carbon tax - which can directly penalize or incentivize a company's carbon performance. Low carbon emission initiatives - for example, switching to energy efficient assets, installing solar panels or setting up a green disposal system are often linked with high capital expenditures for business. However, operational optimizations too, may have significant contribution on carbon footprint mitigation with lesser cost. One such operational optimization can be implemented in existing supply chain inbound logistics – known as milk run. Milk-run logistics is commonly adopted by automobile, diary, beverages, airline and freight transportation industries for movement of raw material, spare parts and empties. As logistics and transportation activities are capable of emitting up to four times of greenhouse emissions of a company's normal emissions, better planning and collaboration with carriers can make a significant difference on company's overall carbon performance. Objective of this paper is to present a systematic approach of information sharing and collaboration with freight carriers using cloud platforms with special reference to milk run scenarios aiming to optimize carbon footprint and operational cost. Aim of this paper is also to highlight an emerging research area of cloud-based carrier collaboration having potential for betterment of environment and society.*

Keywords: *Milk run, Carrier collaboration, Cloud computing, Carbon footprint, Digital Supply Chain.*

I. INTRODUCTION:

It is said that running a profitable business is hard, but running a profitable business with negative carbon footprint is even harder. In a cut-throat competitive market, to achieve a highly sustainable business by sticking to lowest possible emission often becomes too costly affair for incumbent firms. But climate change damages economies, devastates customers, increases resource scarcity and impacts overall cost of doing business. So for simple business reasons firms have to initiate actions to reduce carbon footprints. Besides, multinational companies are often legally bound to meet emission caps enforced by local governments. Few of such regulatory programs like cap-and-trade, strict-cap-on-emission and carbon-tax have direct impact on a firm's balance sheet. In addition, more and more customers are interested to know the carbon footprint numbers from the businesses they work with. A survey has highlighted that almost 83% consumers worldwide want businesses to implement programs to safeguard environment (Neilson, 2011).The same survey, however, revealed that only 22% of consumers are ready to pay more for environment friendly products. This underlines a serious need for organizations to control their carbon footprints while remaining cost effective. Approximately 6% of total volumes of greenhouse gases generated by humans are due to the flow of products to consumers. Research shows that supply chains can be responsible for up to four times the greenhouse gas emissions of a company's normal operations excluding supply chain (Dixon, 2016), while transportation remains as the second highest emitter of greenhouse gases worldwide. The World Economic Forum estimates in its Supply Chain Decarbonization report that logistics and transportation sector has a carbon footprint of around 2,800 megatonnes. In absolute terms, road freight is the greatest part: constitutes at around 57% of the total (WEF, 2009). Also, logistics activities have a significant economic impact on countries and their societies. For example, these activities accounted for 8.3 per cent US gross domestic product (GDP) or US $1.45 trillion in 2014 and 6.8 per cent of GDP (€876 billion) across the European Union's (EU) 27 countries in 2012 (EC, 2015). Therefore, a small percentage of reduction in logistics activities may cause a major environmental impact from reduction of carbon emissions. Thus, it is evident that if business can accurately plan and optimize its logistics and transportation activities across supply chain, it will be able to achieve its carbon emission targets.

Optimization of logistics and transportation activities has often been discussed in many classical supply chain and operations management research papers. Typical problem statement for any such logistics optimization is simulated by Travelling Salesman Problem (TSP) and Vehicle Routing Problem (VRP). The vehicle routing problem (VRP) deals with the design of least cost delivery routes through a set of geographically scattered locations and is one of the most widely studied route optimization problems. The traveling salesman problem (TSP) is a special case of the VRP which can be solved for hundreds of locations. In contrary, the VRP is much more complex due to capacity constraints taken into consideration. As a special optimization scenario, this paper will consider inbound logistics – milk run scenario, which is commonly adopted by automobile, diary, beverages, airline and freight transportation industries for movement of raw material, spare parts and empties. A simple milk-run VRP scenario can be analyzed with the help of Clarke-Wright (C-W) algorithm principle and saving mileage can be calculated. However, solution becomes much more complex when capacity constraints come into picture. Let's elaborate this with a real-life inbound milk-run scenario:

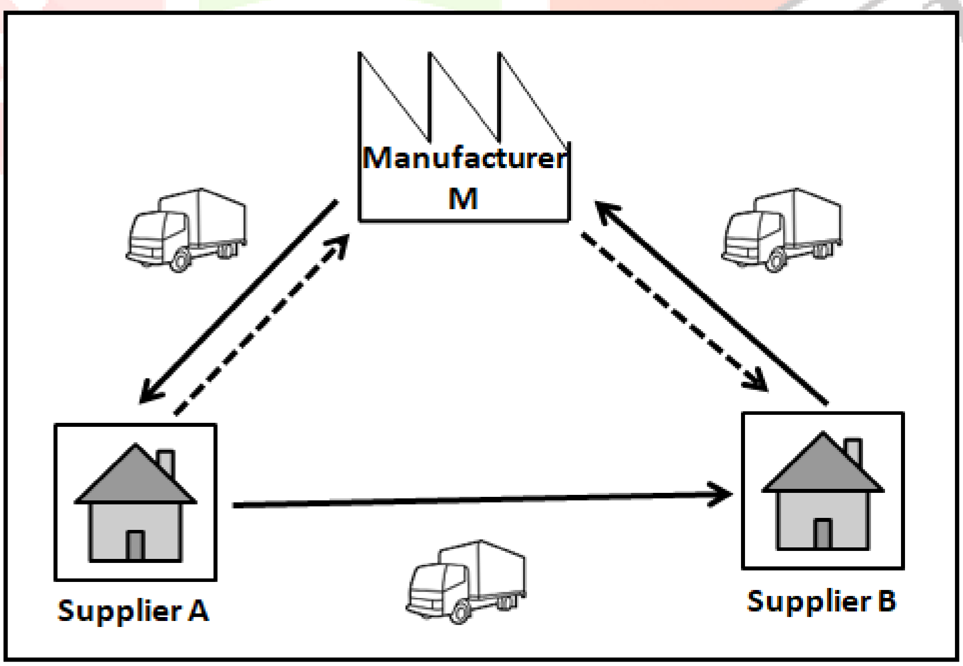

Fig.1: Typical inbound milk-run scenario with a manufacturer & two suppliers.

Manufacturer (M) needs to plan for an inbound pick up from two suppliers. Individual distances of the suppliers A, B from the manufacturer (M) are MA and MB respectively. For the sake of simplicity, if we ignore capacity constraints of the pickup vehicle and if vehicle goes for a milk-run (M-A-B-M) instead of individual pick-up and delivery, total transport vehicle mileage is: MA+AB+BM.

Thus the savings mileage as per C-W algorithm would be:

(2MA+2MB) – (MA+AB+BM) = MA+MB – AB > 0

This looks simple but, in real life scenario milk-run VRPs can be very complex to determine an optimal route when capacity constraints of multiple vehicles are taken into consideration with time window. For example, capacitated VRP (CVRP) where multiple vehicles' individual capacity limits needed to be considered in optimal route calculation and VRP with time window (VRPTW) where the material handling vehicle's pickup and delivery service at a supplier must be initiated and finished between the predefined time periods. Considering all constraints it is needless to say that merely calculating an optimal route will not be sufficient enough to execute optimized milk-run vehicle routings for minimizing carbon footprints and cost. Better communication and collaboration with carriers and suppliers can only ensure a flawless execution.

Technology can play a major role by enabling reliable communication and collaboration amongst manufacturer, suppliers and their carriers. During the last few decades, the use of information and communication technology (ICT) has revolutionized the way in which supply chain operates. Latest ICT technologies like: Electronic Data Interchange (EDI), Radio Frequency Identification (RFID) and real time tracking with Global Positioning System (GPS) has enabled supply chain to be more agile and resilient at the same time. Cloud computing is an emerging area of information and communication technology (ICT) where service provided by network of remote servers hosted on the internet to store, manage and process data, instead of local server or personal computer. Cloud computing services are cheaper, maintenance-free and flexible for end customer as they are 'on-demand' in nature and charged on 'pay-as-you-use' model. Small suppliers and carriers who may have a very low Capex capability can subscribe to cloud-based services at low cost. This paper is proposing the use of a cloud-based carrier collaboration platform as a first step to collaborate and share milk-run vehicle routing information (like: routes, schedules, vehicle capacity, vehicle frequency, temperature control, packaging, hazard etc) amongst manufacturer, suppliers and carriers in order to mitigate carbon footprint with lowest possible cost.

II. LITERATURE REVIEW:

Milk-run vehicle routing problem is one of the well-known optimization problems in logistics and transportation arena and numerous scholars and researchers have noted it in the past. G. B. Dantzig and J. H. Ramser discussed VRP in simple terms way back in 1959 in a paper as 'truck dispatching problem'. Various classical supply chain and operations management research papers have derived Travelling Salesman Problem (TSP) and Vehicle Routing Problem (VRP) as a simplified model for complex transportation planning scenarios. Few of the most recent work in VRP includes Pedro Munari et el (2016) who had laid out a generalized formulation for VRP including Capacitated VRP (CVRP) & VRP with time windows (VRPTW). Xiao-Hong Liu et el (2018) proposed Green Vehicle Routing Optimization Based on Carbon Emission which established clear relationship between VRP and carbon emission. This paper has also simulated a hybrid quantum immune algorithm to solve the multi-objective optimization problem. Huang Mei et el (2016) modeled milk-run vehicle routing problem based on improved Clarke-Wright (C-W) algorithm with time window. Several case studies and conference papers highlighted on the enhanced Clarke-Wright (C-W) algorithm for solving VRPs: Buyang Cao's (2012) conference paper on VRP optimization is an example of the same.

Contrary to Milk-run VRP, cloud computing is an emerging concept in information & communication technology (ICT) where network of remote computers hosted on the internet are used to store, manage and process data. Though popularization of cloud computing is attributed to Amazon for releasing its first cloud product in 2006, the term was coined as early as in 1996 by Compaq in their internal document. However, many believe that the first use of 'cloud computing' in its modern context happened in August 2006, when the then Google CEO Eric Schmidt introduced the term in a conference. Since inception, cloud computing was perceived as SaaS (Software-as-a-Service) platform and Educause (2009) predicted that the users of cloud computing will get increased reliability and cost decline due to economies-of-scale. Sultan (2009) identified three prominent areas of cloud services: IaaS (Infrastructure-as-a-Service), SaaS (Software-as-a-Service) and PaaS (Platform-as-a-Service). Cloud based ERP platforms started to grow since 2009 and many research literatures attempted to compare benefits of cloud vs. on premise ERP systems. Scavo et al (2012) chalked a comparative analysis between these two forms of ERPs and it was evidently clear that small businesses are benefited more from cloud based ERP platforms.

III. METHODOLOGY and IMPLEMENTATION:

Objective of this paper is to investigate if cloud-based carrier collaboration platforms can be effectively used to optimize milk-run VRP complexities (like: routes, vehicle capacity, vehicle frequency etc) by collaborating and sharing information in order to mitigate carbon footprint with lowest possible cost. To imitate a real life milk-run capacitated VRP where multiple vehicles' individual capacity limits needed to be considered in optimal route calculation, we are considering a single depot model (in Fig.2) – for the sake of ease of calculation and analysis. We are also considering at least two vehicles are involved in this inbound milk run in order to pick up from multiple suppliers (Fig.2).

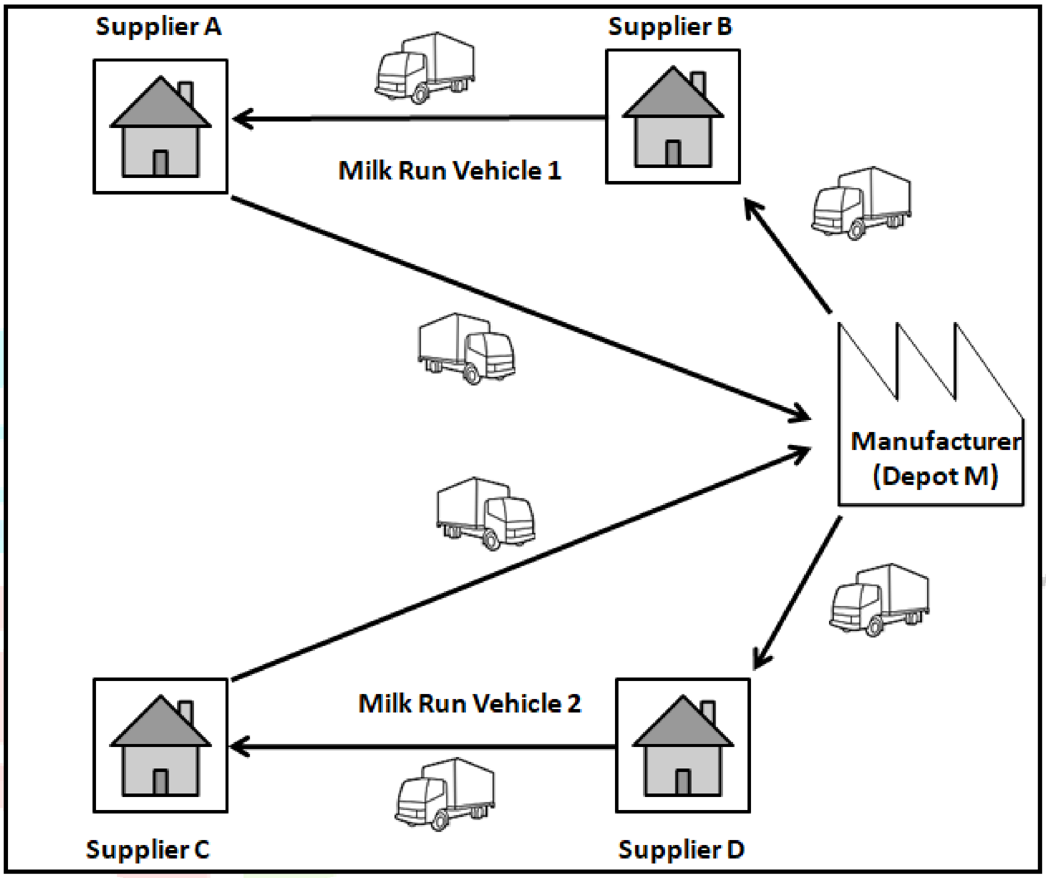

Fig.2: Single depot Multi vehicle milk-run with capacity constraints.

The complexities to be considered while planning a multi-vehicle-milk-run in order to optimize mileage and cost is as follows:

1. Which vehicle to go on for which supplier pick up and in what sequence? That is optimized allocation of vehicles to routes so that the total distance travelled by both vehicles is minimized.
2. Which vehicle is meeting the required capacity of all suppliers lying in a specific route?

Let's assume distances from Suppliers A, B, C, D to Depot (M) is 8, 2, 6, 3 KMs respectively and supplier to supplier distances AB, BD, DC, CA, AD, BC is 6, 8, 7, 9, 10, 9 KMs respectively. Then, following combinations with two vehicles are possible:

Vehicle1: MB+BA+AM= 2+6+8 = 16KM; Vehicle2: MD+DC+CM = 3+7+6 = 16 KM, Total 32KMs.

Vehicle1: MA+AC+CM= 8+9+6 = 23KM; Vehicle2: MB+BD+DM = 2+8+3 = 13 KM, Total 36KMs

Vehicle1: MA+AD+DM= 8+10+3= 21KM; Vehicle2: MB+BC+CM = 2+9+6 = 17 KM, Total 38KMs

We can easily chalk out that for the 1st route total distance travelled by both vehicles is minimized. But, this estimation becomes complex when capacity constraints are included. For example, if we assume Vehicle1 and Vehicle2 has volume capacity of 210 and 220 Liters respectively, whereas Suppliers A, B, C, D capacity varies in the range of 100 – 120 Liters then carrier planning accuracy falls sharply. On the above optimum mileage route (32KMs), on a specific day, if supplier A, B, C and D's to-be-carried capacity is 115, 100, 110, 105 Liters respectively, planning for a multi-vehicle-milk-run will fail. But, planning can be successful if Vehicle2 goes to route M-A-D-M and Vehicle1 goes to M-B-C-M route. Therefore, reviewing this example we can say optimum route determination becomes more complex when additional parameters like loading sequence, vehicle frequency, temperature control, packaging, schedules, hazard etc are considered for calculation.

Following equations help to express the complexities of Milk-Run Capacitated-VRP.

Let us consider a set of Suppliers represented by C = {1 . . . n}. To pick up from these suppliers, we have to design routes for a fleet with K vehicles available in a single depot. Each route must start at the depot, visit a subset of suppliers and then return to the depot. All suppliers must be visited exactly once. Each vehicle has a maximum capacity Q, which limits the number of suppliers it can visit before returning to the depot. For the sake of clarity, we assume a homogeneous fleet of vehicles, but the discussion presented ahead can be easily extended to a heterogeneous fleet.

Let us also represent the problem using a graph G (N, Ɛ), in which N = C U {0, n + 1} is the set of nodes associated to suppliers in C and to the depot nodes 0 and n + 1. We use two nodes to represent the same single depot and impose that all routes must start on 0 and return to n + 1. Set Ɛ contains the arcs (i, j) for each pair of nodes i, j Є N (we assume a complete graph). The cost of crossing an arc (i, j) Є Ɛ is denoted by Cij. Each node has a demand qi, such that qi > 0 for each i Є C and q0 = qn+1 = 0. The objective of the problem is to determine a set of minimal cost routes that satisfies all the requirements defined above.

Formulation of the Milk-Run CVRP is stated as:

$$\min \sum_{i=0}^{n+1}\sum_{j=0}^{n+1} c_{ij}x_{ij} \quad (2.1)$$

$$\text{s.t.} \sum_{\substack{j=1 \\ j\neq i}}^{n+1} x_{ij} = 1, \qquad i = 1,\ldots,n, \quad (2.2)$$

$$\sum_{\substack{i=0 \\ i\neq h}}^{n} x_{ih} - \sum_{\substack{j=1 \\ j\neq h}}^{n+1} x_{hj} = 0, \qquad h = 1,\ldots,n, \quad (2.3)$$

$$\sum_{j=1}^{n} x_{0j} \leq K, \quad (2.4)$$

$$y_j \geq y_i + q_j x_{ij} - Q(1 - x_{ij}), \qquad i,j = 0,\ldots,n+1, \quad (2.5)$$

$$d_i \leq y_i \leq Q, \qquad i = 0,\ldots,n+1, \quad (2.6)$$

$$x_{ij} \in \{0,1\}, \qquad i,j = 0,\ldots,n+1. \quad (2.7)$$

Constraints (2.2) ensure that all customers are visited exactly once. Constraints (2.3) guarantee the correct flow of vehicles through the arcs, by stating that if a vehicle arrives to a node h Є N, then it must depart from this node. Constraint (2.4) limits the maximum number of routes to K, the number of vehicles. Constraints (2.5) and (2.6) ensure together that the vehicle capacity is not exceeded. The objective function is defined by (2.1) and imposes that the total travel cost of the routes is minimized. Constraints (2.5) also avoid sub-tours in the solution, i.e. cycling routes that do not pass through the depot. Different types of constraints are proposed to impose vehicle capacities and/or avoid sub-tours. The advantage of using (2.5) and (2.6) is that the model has a polynomial number of constraints in terms of the number of customers.

The total carbon emission E, for any vehicle routing can be measured by the following equation:

$$E = \sum_{i=1}^{n} E_i = \sum_{i=1}^{n} f_i * \xi_i * F_i \quad F_i = \left[u * (w_0 + w) + \lambda * v^2\right] * d, \tag{1}$$

Where E is the total carbon emission. u is a constant relating to the condition of a road. w_0 is the empty weight of the transported vehicle. w is the carrying capacity of the transport vehicle. λ is the constant associated with the vehicle type of the vehicle. v is the speed of vehicle. d is the distance traveled by the vehicle.

Form the equations stated above, it is evident that be it route cost minimization or carbon footprint reduction, effective capacity planning is one of the critical success factors for an inbound logistics milk-run scenario. In other words, vehicle capacity needs to be precisely planned and matched with the summation of individual supplier's to-be-carried capacity in order to avoid less than container load (LCL) situation and thus overall cost minimization and carbon footprint reduction. Planning uncertainty in a typical milk-run capacitated VRP is often caused by lack of information and thus effective fleet information communication with carriers & suppliers is utmost important.

Implementation: Technology can play a major role in milk-run capacitated VRP scenarios enabling reliable communication and collaboration amongst carriers, suppliers and manufacturers. Cloud computing is an emerging area of information and communication technology (ICT) where service provided by network of remote servers hosted on the internet to store, manage and process data, instead of local server or personal computer. Cloud computing services are cheaper, maintenance-free and flexible for end customer as they are 'on-demand' in nature and charged on 'pay-as-you-use' model. A typical solution here could be a manufacturer's on-premise central ERP connected with a cloud platform of fleet partners (supplier and carrier), who can collaborate with manufacturer with a simple smartphone application (Fig-3).

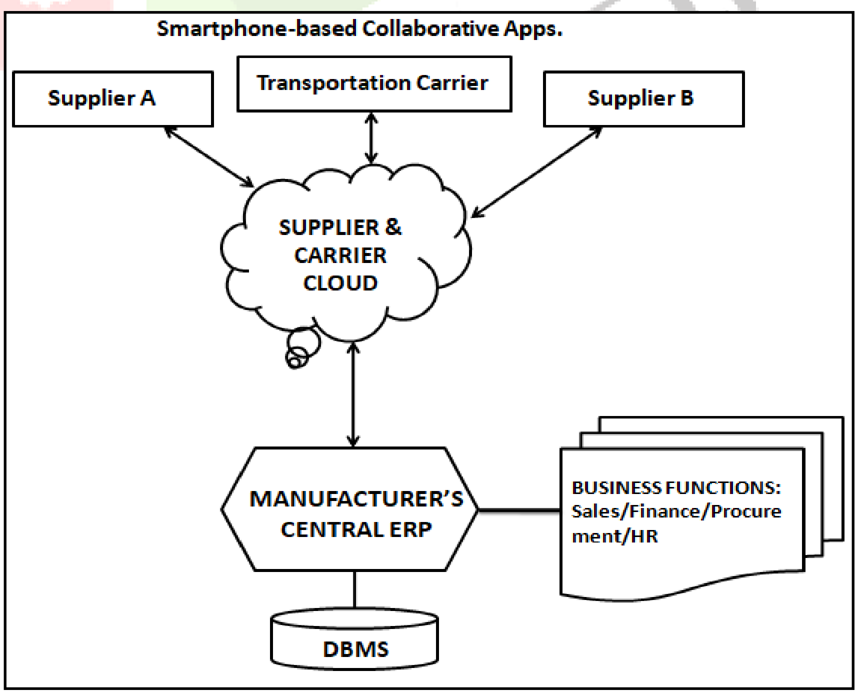

Fig.-3: Proposed cloud architecture for collaborating fleet partners with manufacturer.

Using the simple smartphone based applications, suppliers and carriers can share their respective capacities, pick-up schedules via cloud; which then fed to manufacturers central ERP where transportation planning is made. Once planning is completed - planned capacity, fleet schedule information can be shared with suppliers and carriers using the same cloud based smartphone applications. This way inbound milk-run vehicle routings can be efficiently collaborated and planned which in turn leads to efficient use of transportation fleet which then will help to optimize carbon footprint and freight transportation cost for the manufacturer. As real-time transportation information can be shared and collaborated at lowest possible cost through cloud, even small suppliers and carriers can afford cloud applications to achieve a sustainable competitive advantage by improving fleet performance using cloud applications as collaboration tool.

IV. ANALYSIS:

It is evident from above discussions that when the objective is carbon footprint mitigation and cost reduction, merely calculating an optimal route is not sufficient enough for inbound logistics milk-run vehicle routing scenarios. Several other constraints for example capacity, fleet schedule etc needs to be taken into calculation in order to achieve optimized emission and cost – which increases complexity. But a technology enabled efficient collaboration platform like cloud application can make the job easier for the transportation planner by providing real-time information from carriers and suppliers. The same cloud based applications can be utilized to dissipate planned capacity, planned pick-up schedule information with suppliers and carriers once transportation planning is completed by the manufacturer. Real time track and trace information of fleets can be enabled with GPS and shared via the same cloud platform

V. CONCLUSION:

This paper has attempted to present a systematic approach of information sharing and collaboration (using cloud platform) amongst manufacturer, carrier and supplier in order to mitigate carbon footprint and cost of inbound logistics through milk-run. Though this collaboration can be termed as 'career collaboration', supplier needs be an integral part of it to ensure effectiveness. As real-time capacity, route, schedule, packaging, hazard etc information can be shared and collaborated at lowest possible cost through cloud, even small carriers and suppliers can afford to achieve a sustainable competitive advantage by improving inbound logistics milk-run performance using cloud as a collaboration tool, and thus could mitigate carbon footprint of entire transportation network. Though precise measurement of carbon emission and cost saving in dollar value is out of scope, we expect this paper has provided basic insights and opened opportunities for future research in this area. This paper may also open up new product development opportunity for cloud application manufacturers and developers, who want to tap this low-cost niche market segment for small businesses.

VI. REFERENCES:

[1] Pedro Munari, Twan Dollevoet, Remy Spliet. A generalized formulation for vehicle routing problems. arXiv preprint arXiv:1606.01935, 2016 - arxiv.org.
[2] Xiao-Hong Liu, Mi-Yuan Shan, Ren-Long Zhang, Li-Hong Zhang. Green Vehicle Routing Optimization Based on Carbon Emission and Multiobjective Hybrid Quantum Immune Algorithm. Hindawi Mathematical Problems in Engineering. Volume 2018, Article ID 8961505. https://doi.org/10.1155/2018/8961505.
[3] G. B. Dantzig and J. H. Ramser. The Truck Dispatching Problem. Management Science, Vol. 6, No. 1 (Oct., 1959), pp. 80-91. http://www.jstor.org/stable/2627477.
[4] Antonio Regalado (2011). "Who Coined 'Cloud Computing'?". Technology Review. MIT. www.technologyreview.com.
[5] Educause (2009). 7 things you should know about cloud computing. Educause, August. URL: http://www.educause.edu.
[6] Sultan, N. (2009). Cloud computing for education: A new dawn. International Journal of Information Management, in press.
[7] Scavo, F., Newton, B. & Longwell, M. 2012. Choosing between cloud and hosted ERP, and why it matters. Computer Economics Report. Vol. 34 No. 8.
[8] Chen, F. Drezner, Z. Ryan, J.K. Smith-Levi, D. (2000a). Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times and information. Management Science, 46,