

Truck Platooning—An Overview Study with Time Constraints

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Abstract: *The truck platoon has a significant impact on modern society. As fuel costs increase daily, vehicles can be driven in a pattern to reduce fuel consumption. Vehicle routing problem is discussed in literature with taking only single objective and not considering other objectives. Multiple objectives are hard to solve. If the environment changes then vehicle routine problem gets a new route hence problem becomes challenging. In theory the data about customers and route to reach the customer will be known before but the real case scenario the request from customer changes so the environment is dynamic. The dynamic vehicle routing problem is discussed in this study with time window where which customer has to visit in what time is included. Multiple objectives such as the waiting time of the customer and minimizing routing distance to reach the customer are considered here. Hence there are multiple objectives in the dynamic environment an ensemble learning to obtain an optimization problem is discussed here ie; EL-DMOEA. Other algorithms to solve vehicle routing problem along with their comparison additionally different types of platoons, comparison of platoon with other types of the transportation is also discussed in this report.*

Keywords: Vehicle Platoon, vehicle routing, vehicle , truck , dynamic vehicle routing problem, time window, multi-objective optimization.

I. INTRODUCTION

As the main aim of minimizing fuel consumption by helping the world economic fuel crisis, transportation can be improved by forming a truck platoon pattern. Platooning means driving vehicles together, and they are linked via different aspects. This can be done in different methods, and a platoon can form in various manners. This study is about the various types of platoons, their characteristics, and the objectives that how a platoon can be scheduled. The advantage of truck platooning is that it minimizes fuel consumption as the gap between trucks or the vehicles in the platoon is minimized. Furthermore, as fuel consumption is reduced, fuel emission is also considerably reduced with efficient driving. Moreover, the drivers in the truck platoon will have an overall idea about the platoon formation and routes that they should be followed.

The truck platooning and vehicle routing problems had a significant impact since the emergence of automated driving. Automated driving enables the trucks to form a platoon that can virtually link. The truck platoon can be planned via itineraries or previously scheduled time plans [1]. The truck platoon discussed here is a good approach through multiple advantages for the transportation system, as the gap between the vehicles reduces the capacity of the road and can be utilized efficiently. This results in reduced road traffic as a result of efficient driving.

As the trucks form a platoon, the goods transportation corporation has profit in transporting goods , with a concepts of vehicle-to-vehicle communication [2]. The technology used for forming or communicating can be Bluetooth or GPS. A platoon can be formed at any point, and the trucks in the platoon communicate via GPS and inform the other truck which wants to join the platoon. These possibilities can improve the profit gain of the transportation system and the economy of the transportation system as this cost can be reduced for goods transportation. The trucks in a platoon can be communicated through a different scenario discussed here. Any truck can join the platoon when proper



communications are done. However, the concepts of human-machine interaction are demonstrated. In the following part, the vehicle routing problem is discussed with variants. A variant of the vehicle platoon problem is the vehicle routing problem. The vehicle routing problem is an optimization problem. The study regarding vehicle routing problems has been conducted since the beginning of the 20th century, a variety of vehicle routing problems has been discussed in the literature. An extension of the vehicle routing problems with a time window is also discussed here. The vehicle routing problem can be abbreviated as VRP. VRP with a time window can be written as VRPTW[3]. In VRPTW, the individual customer is visited at a specific time. VRP can be divided into static and dynamic routing problems. In this study, the main focus is on dynamic VRP. The main difference between static and dynamic is, in static the platoon scheduling time and plans are known before. On the other hand, the schedule of plans occurs dynamically, i.e., the customer's position and routes change according to the time. Therefore, the dynamic vehicle problem is challenging.

Another significant influence on fuel reduction is the air pressure between the trucks; as the air drag between the truck is reduced, the fuel burn is reduced. The critical component is reducing fuel to improve cost efficiency by minimizing the route distance. Many countries are still now not legally allowing the concept of the platoon. However, the European Union has successfully worked on it and have tried many varieties of routing problem. Still, literature surveys are going on the same topic to improve the efficiency of routing problems by incorporating different concepts. This study compares the vehicle routing problem with time limitations and various algorithms.

Towards the end of this study, new concepts like human intervention in driving and platooning are conferred. Future related studies such as forming platoons with fully automated and semi-automated driving additionally the driver less platoon are mentioned. Moreover, the constant distance and velocity

[4] between the vehicles when considering fully automated driving platoons. As the velocity is maintained, it is the responsibility of the leading vehicle to inform the following ones if the speed changes. If the climate is not favorable, it is the responsibility of the leading vehicle to maintain relatively significant gaps additionally low acceleration so that risk of danger is avoided. This approach can be adapted to platoons formed by different vehicles. That is, all the vehicles need not be identical mechanisms and ownership.

Planning the truck platoon is a risk. However, these are compared with other forms of transportation. Freight consolidation and ride-sharing are the most common transportation [5] which have similar technologies, and are cost effective when driving in city areas rather than a rural areas. How truck platoons are flexible in picking up the load and delivering. Ride sharing aims for similar goals that truck platoons have, effectively utilize the seat that not keeping any seats blank, so that new vehicles are not used for the same route. Moreover, the freight consolidation and ride sharing are discussed in the context of the platoon.

II. RELATED WORKS

When the customer request comes in real time that is when there is change in the plan, the cost of transportation increases because of the tremendous growth of fuel charge, which will be affecting the goods' transportation companies and world economy. The heavy road charge and the duty that truck owners should pay is considerably increasing, so forming a truck platoon is an existing solution for many of the discussed issues so far. Minimizing the fuel consumption which leads to lesser emissions and improves the road transportation safety. While linking trucks with close proximity, there are some important factors that need to be considered, such as the medium of communication, time of platoon, scheduling process and so on.

To form the platoon wireless communication is adopted, in this current era which is in practice. In [6] energy saving in heavy vehicles in addition to the safety concerns are the important aspects that need to be considered are discussed so far. Safety is an important aspect that should be considered when dealing with a heavy vehicles like trucks, especially when they transport too far with heavy load. Even though the number of vehicles is increasing by days the road safety is still a risky factor. Safety should be considered when a truck is joining or multiple trucks forming a platoon with proximity and carrying a heavy loads to destinations are discussed in [6]. The communication between the trucks needs



to be done accurately and spontaneously in a way that the leading vehicle must communicate with the others so reliability is assured, as quick response is a compulsory factor in taking action in dynamic planning of schedules. Each truck has an antenna and camera as an essential for keeping the distance between the trucks in the platoon. In recent progress Lidar systems were implemented to improve effective communication.

The drivers of the following truck have only lesser efforts, will be another added benefits to reduce the workload of the drivers, the work load can be reduced or distributed among the drivers easily when these techniques are implemented. When there is a work load the driver takes break in between which can leads to increase in waiting time of the customer. When the trucks are driving close to each other, the fuel consumption are reduced and air pollution is controlled, which demands higher for forming platoon and it has been a famous study in the logistic literature. As per the global study the carbon dioxide emission by the heavy vehicles are 5% in total when compared with other transportation. As fuel consumption can be reduced by driving close to which leads to lesser emission and can improve the environmental conditions. Better environmental conditions can be ensured, because as per the study from European Union the road transportation [7] vehicles are emitting more gas, especially carbon dioxide, which can cause environmental problems are the studies that have been done in this project.

Artificial intelligence is implemented for the ease of vehicle-to-vehicle communication is discussed in [8]. Together with artificial intelligence and vehicle-to-vehicle communication have been enhanced safety, effortless driving and less pollution. How artificial intelligence can be incorporated to achieve intelligent transport system begins a mode of question in the literature. As part of the survey vehicle to vehicle communication and vehicle to many communication is studied. Moreover vehicle to many other paradigms is observed in this paper. Artificial intelligence is an effective tool to handle data that are complex and random. When the vehicle is communicating with not only with other vehicles but also responding to another signal like road traffic signals, live location sharing, and so on. The data gathered in this multiple formats can be organized and used in the AI scenes and make the work effective. There are different dedicated communication systems that transfer data in a secure and reliable manner. Intelligent transport system is a modern wireless communication system to enhance the formation of the platoon has a significant role and studied in [9]. Vehicle networking architecture is discussed to analyze the communication between the vehicles in platoon, control them moreover compute it and take necessary actions to ensure the stability and robustness of the platoon. In this manner, the data or signals can be sent from one vehicle to one or one to many.

One of the other main characteristics of truck platooning is planning process. The planning can be done in different ways, by collecting the information about each truck that needs to be linked together so that the leading truck gets the information about following truck that will join the platoon, so that the leading truck will get the data about the trucks that need to be follow the place and time route and sequence of the truck that the leading truck driver is following. However, when there is a sudden change in route, the data will be informed to the leading truck and the following trucks needs to be follow the leading truck. The sudden changes make the problem dynamic in nature which is hard to solve.

Planning can be done in many ways, the planning routes can be scheduled by beforehand by the transportation company, where they explicitly mention everything about the trucks and routes and conditions that need to be followed. These data are informed to the drivers that are specially trained. The trucks that join the platoon, the time at which the truck joins and other relevant factors. These planning are known earlier, hence they are static planning. However, on the other hand dynamic platoon planning where the details of the trucks and routes are not known ahead of time. The leading truck has data about the origin and destinations, the following trucks will join the platoon at their desired points of connection. The main objective of the truck platooning is to reduced fuel consumption and increase the number of trucks that cloud link together, it is mainly decided by the truck companies. The distance between truck should be maintained, that is trucks may not be driving through a straight road all the time, when it comes to uphill or downhill the distance between trucks cannot be stabilize as in a normal road. Hence, the platoon cannot be maintained, similar other variant is when a desired destination of a follower truck is reached, it will stop the platoon, so the platoon is broken and the alignment of the vehicles is lost.



In [10], one of the other important key factors in the platoon the formation is aerodynamics. By forming the platoon, the aerodynamics drag between the trucks should be a factor of consideration because it has a great impact on fuel reduction. In recent years the autonomous or driverless platoon has been driving more attention in logistic projects. Sensors are implemented in each truck, which is a common thing in the transportation system which can sense not only the vehicles but also the environment and respond to it simultaneously.

In the late twenties, the researchers were interested in the study of air drag between the trucks, wind tunnel tests were conducted to reduce the air drag between the trucks when platoon. The one crucial thing noticed was as the separation distance between the trucks increases the air drag also increase. In practical aspects, the platoon is not aligned perfectly as in the descriptions. The trucks have different mechanics and engineering. It will be tough to maintain the distance as it is, when platoon dynamically, that is not as per the schedules. When a truck joins an existing platoon or when a truck reached its destination, the link between then trucks are broken and the stability of the distance between trucks or vehicles in the platoon are no longer maintained. As the safety concern it is recommended when joining and exiting the platoon there should be minimum distance to be maintained, if the distance is too small some sort of road disaster can be expected. As distance being the factor of consideration due to aim to fuel consumption. When the distance is reduced, the consumption of fuel is reduced too. 2.7% to 5.3% of the fuel is reduced when the platoons are maintained at 20 to 50 feet of distance.

III. METHODS- VEHICLE ROUTING PROBLEM WITH TIME WINDOW

A. Dynamic behavior of vehicle routing problem

The vehicle routing problem is a well-known combinatorial optimization problem. The vehicle routing problem can be categorized or extended to various other problems that incorporate some kind of constraint. For instance, vehicle routing problem with time constraints, and route or path constraints are famous studies in the research area. Vehicle routing problem with time windows has an impact on the literature study for a long back. The VRPTW can mainly classify on the basis of their involvement of schedules, static vehicle routing problem and dynamic vehicle problem. When the time window is considered there involve a constraint of time. Each customer needs to be visited by the given amount of time or a defined time slot that is assigned to them. In static vehicle routing problem time schedules of each customer is known beforehand as in the schedule platoon planning. The customers are visited exactly once and the cost of the traveling is correlated with travel distance. Hence, it is understood that the trucks will be more likely to choose the shortest path to reach their destinations with minimum time, so it consumes less fuel, which results in lesser emission.

The vehicle routing problem is a combinatorial optimization problem and it is NP-hard [11]. Many studies have been so far conducted with the variation in dynamic VRP problems. In dynamic mode the orders and demands of the customers are taking into the account at time which the trucks start from the origin, which means the routing problem is activated. As the orders are taken, they has to be added to the schedule. Mostly the customer orders are taken dynamically that is in real time and some of them may even cancel in between. As the result of order taking and cancellation, the route and planning of the scheduled routes will be changed accordingly. This is practically happening as unlike the theories explain routing problem. This is a challenge that can be solved by algorithms described in the literature. In this study the dynamical behavior with a time window of various aspects are discussed. Many heuristic methods are relevant today for solving this kind of problem additionally, in meta heuristic methods such as hybrid solvers, which is the combination of common methods. When the dynamic changing environment is tough to solve, multi-objective ant colony optimization problem. In this study two ant colonies are introduced, one for include minimum colonies and second for the minimize the travel cost. In the end both the colonies are combined together to find the optimal solution. Traveling salesman problems is one of the famous NP-hard problem is a variant of these problems, which is applicable for static vehicle routing problem, cause it follows the same route assigned to it in the beginning which is not the case when coming to the practical side. On the other hand ant colony optimization problem is



used to solve the dynamic routing problems because dynamic behaviors are hard to solve, as the plans keep changing because the decisions are made in real time.

When considering the the dynamic vehicle routing problem, time windows are incorporated in this study [12]. The idea of time window is that each customer have to be visited by the vehicle for a given period time .The customers' orders are arriving at a real time basis, that is which not planned in the schedules. As the customers place an order or cancel the order in real-time, the cost of the route and service time will dramatically affect the routing problem. As the vehicles need to be visited and serve the customers in the defined time win-dow which ensures customer satisfaction cancellation brings the routing problem some kind of issues. This can be solved in numerous ways, and many studies are being conducted to improve the efficiency of the algorithm for optimizing the results.The dynamic characteristics are obtained from the static benchmark problems where the environments do not change.This can be used to generate a dynamic environment, which can be represented as two vector notations where one indicates the total customers and the other the magnitude of changes. So as the route changes in real time, the new distance of the route is noted.

Another factor considering is when the position of the customer changes , ie; customers are not fixed in the any position they change.To solve this problem with time windows, a new proposal, which has been discussed in Europe so far is introduced which is called ensemble learning. An algorithm is derived. In this algorithm the a population is initialized and looking for new routes. It will predict the new outcomes and update the existing distance. The ensemble method is incorporated with the multi-objective optimization evolution-ary algorithm to improve the efficiency of the algorithm and later this algorithm is compared with other algorithms to test the efficiency.it is abbreviated to EL- DMOEA.To solve this problem it is mostly used the population initialization method for obtaining a feasible solution when considering the time window.The initial population can be generated randomly and it is a genetic algorithmic method to solve from a subset of all possible current solutions.The customers are selected randomly , so there is a chance of obtaining an infeasible solution as if the distance gets longer or when the visited customers visit again.

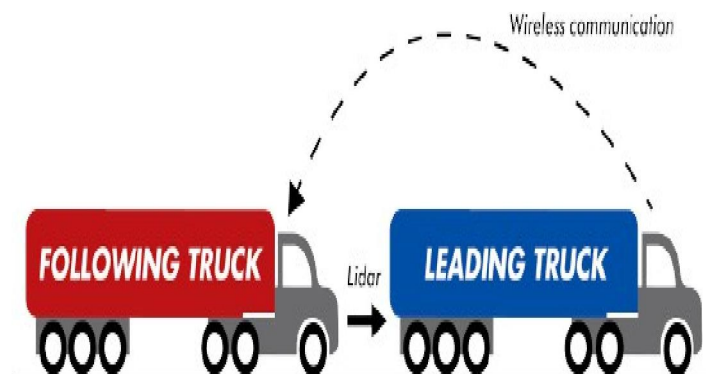


Figure 1. Graphical Representation of truck platoon

The figure 1 depicts the Platoon of two trucks fig 1[13]. The minimum requirement for forming the platoon is at least one following truck with a leading vehicle.The lead-ing vehicle will communicate with the following vehicle in different means.The wireless communication of the platoon will improve the efficiency of the formation of the platoon , here the leading vehicle and the following vehicle is linked by lidar moreover it is described that the proximity of the vehicle doesn't cause any safety issue.



IV. PROBLEM DEFINITION OF VRP PROBLEM WITH TIME WINDOW

The definition of the vehicle routing problem with time window is, it is considered a directed graph. The directed graph $G = (V, E)$ where V be the set of vertex $V = v_0, v_1, v_2, \dots, v_n$. v_0 be the initial depot from where the vehicles start and end their routes. And each vertices represents the customer nodes, the edge $E = (c_i, C_j)$, $(c_i, C_j) \forall i, j$ be the edge set. There is a non-negative distance between each edge that represent the distance between each customer in the plan. The customer can place the demand, and service time and a time window is set. The time window is $[e_i, l_i]$, where the e_i and l_i be the initial and final time, that is a vehicle cannot start before e_i and after the l_i . In this study the customer location is changes hence a new route is obtained and the problem becomes dynamic in nature.

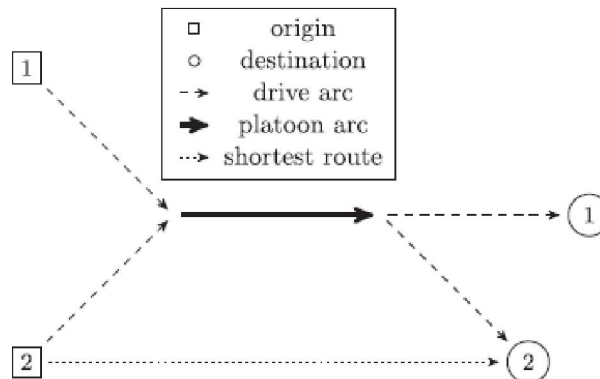


Figure 2. Platoon formation of two trucks in graphical notation

Figure 2 described in [14] shows that the numbered square boxes on the left side as the start point of two trucks and circles as the right as the endpoints. The picture itself explain as the trucks meet at a point called the merging point and form a platoon drive a certain point and then at diverge at a point to reach their destinations. This can be depicted as directed graphs as the origin and endpoints as the vertices and platoon arc as the edges.

The vehicles arrive early and there will be a waiting time and that point will be the merging point. When a vehicle comes early, it has to wait until the customer's time has started, until that time it cannot start. So, a waiting time is incorporated into it. And the customers are not allowed to visit more than once. To improve the efficiency of a concept mentioned earlier the multi-objective optimization problem

[15] is introduced and additionally with the different dynamic condition. Finding a small path to reach the customer to transport goods is the main objective discussed in this paper. Multi-objective evolutionary algorithm is introduced here to find the resemblance with the all other existing algorithms to obtain a feasible solution. Evolutionary algorithm is a direct way for using multi-objective problems. By direct methods, an optimal solution can find out for small routes or even for a lesser number of customers. But for a large number of customers the computational complexity is much higher to find an optimal solution. The optimal solution for smaller distances is related to the fuel cost and less time to reach the customers can be obtained by the Euclidean distance formula [15]. The major objectives of the VRP with a time window is to utilize the road capacity maximum by minimizing the route distance and also the minimize waiting time of the customer. So, the customer satisfaction is ensured. By minimizing the waiting time of the customer, the product is arriving each one by the required time hence they are satisfied. One of the important thing when computing the problems are the vehicles can not be late, that is waiting time should be neglected, for customer satisfaction. However early arrivals are not a big issue. In that case the vehicle that arrives early should wait for the other vehicle to merge or to join the platoon.

The main objective of truck platooning discussed in [14] are considered in this report.

- Minimize the total route distance, hence consumption of road is reduced results in less fuel usage.
- Improve customer satisfaction by delivering goods at time as the waiting time of the customer is reduced
- Efficiency of the platoon can be maintained by increasing the number of trucks in the platoons.



A. Multi-objective optimization Model for VRP

The main objective of the multi objective optimization problem is combining two or more objective functions to obtain optimizes results, mostly they have multiple goals to achieve. In this study, the main objective of the problem is to minimize the total distance traveled by the vehicle and mini-mize the customer waiting time so that customer satisfaction is improved as the distance traveling by the vehicles reduce fuel consumption reduced too. As in the literature considering multiple objectives are difficult to solve hence only consider single objectives.

The evolutionary algorithms are used with multi-objective functions and obtain a good solution. To solve the dynamic VRP TW first needs to initialize the populations. Selection is the first step, selection re-qualify the best performing routes, and construct the next set of routes. Initialization of the pop-ulation is the important aspect of the solution to the dynamic vehicle routing problem [12]. The time window should be satisfied when initializing the population, that is, the vehicle can reach earlier and wait until the time of new customer has started, but cannot be delayed, and then a feasible solution is obtained.

Generative algorithms are used to generate the sequences, the sequence of the customer routes is randomly selected, and the routes are divided into several sub-routes and to generate the next route. The best possible routes are selected. The next step is the crossover, where the first selected routes are the parents with values from the optimization problem, through random selection. The best-performed values are selected, to the next routes. The values are combined. The values that are not included are included in the next step, and thus the feasibility of route is maintained. There are many advantages in using the multi-objective optimization problem, the number of vehicles and the total distance traveled are taken as two different entities. Moreover, when minimizing the distance, the labor cost and human efforts are also minimized and hence the fuel consumption is reduced too [16]. The vehicle routing problem is NP-complete. When there are more number of cus-tomers to visit the problem become more complex and hence hard to find an optimal solution. This problem is genuine in real-world application. Since this is economically paramount, when time is included, there are some limitation. As stated earlier the vehicles can arrive early but not late. As the vehicle is late the customer will have to wait and there is a waiting time is included. But there are some cases that accept the late arrival of the vehicle, in that case a penalty is assigned to the vehicles to solve the problem optimally. Such time windows are called soft time windows, that is it can include early and late service time. But in practice, the literature focused on hard time window, which does the opposite. In this paper, time constraints are violated if the vehicle capacity is begin exceeds by the total sum of the customer demands.

The multi objective optimization is computationally ben-eficial and the result gained from these methods are comparatively acceptable. The VRPTW is an a multi-objective optimization problem, and heuristic methods are used to solve it. Moreover, in many research areas, vehicle routing problem is studied, but adding constrain a time window where the customers waiting time is not considered so far, so DVRPTW is studied as the application of multi-objective optimization problem. For ease of solving, the objectives are solved separately and then combined to obtain the optimal solution. To obtain the feasible solution, the objective function is to minimize the total distance traveled by the vehicle.

Ant colony optimization problem is one of the heuristic method used to solve this dynamic problem. Particle swarm optimization is another one. Which is also defined in this study. These algorithms are used to obtain the shortest path and, hence efficiency of the solution is guaranteed. The variation of ant colony optimization problems are discussed in the coming session.

B. Algorithms to Solve dynamic vehicle routing Problem

Ensemble[7] is co-founded by European commission for research work related to the platoon aiming the development of multi- brand development for truck platooning. The main target is to form platoon of trucks with different brands which certify maximum utilization of road to reduce traffic, reduced in the fuel consumption, hence fuel economy is improved. The demo of project ensemble encountered by seven trucks with different models and capacity of fuel which can carry. The initialization of the criteria are checked against them when they are on the road. For successful



encountering of the project the commission has been introduced several multi objectives platoon for their interoperability.

Dynamic multi objective evolutionary algorithm is incorpo-rated with ensemble learning is a new approach, where an new algorithm is introduced with evolutionary algorithm. The EL-DMOEA is compared with other algorithms mentioned in[12] to compare the efficiency and working. The EL-DMOEA is a new approach to the DVRPTW. The time window is included and customer's waiting time is taken into account. The ant colony optimization algorithm is one of the algorithms which used for evaluating and finding the approximate solution for different hard problems here the vehicle routing problems with dynamic behavior. The algorithms which are comparing here is based on ant colony optimization. Ant colony optimization are generally designed for static optimization problems. But this is not the real case. The static optimization problems are easy to find optimal solution. In dynamic environment solutions are tough to optimize as they keep changing. This has been successfully improved by comprise the previous knowledge. As it resemblance the ant in real life, which is dynamically change it's route. While using the previous knowledge the optimization process can be done easily and faster. There are multiple immigrant schema for ant colony optimization problem. Many strategies has been included with ant colony optimization to improve the optimization results. Some of the strategies are dynamic schema, which gives a good results for optimization problem. This can be obtain better solution for vehicle routing problem in dynamic behavior.

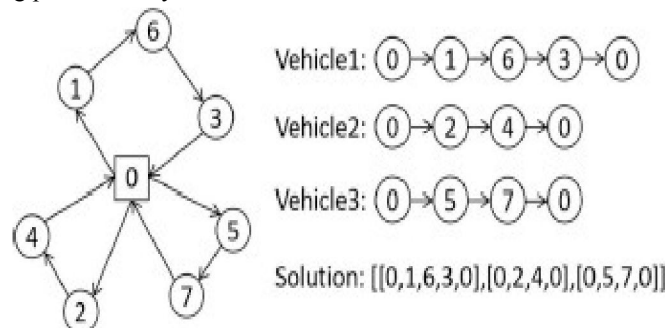


Figure 3. The directed graph for generating the solution using EL-DMOEA

The figure 3 explained in[12] describe the directed graph that different trucks starts from the depot which is the centre "0" and go around different routes. The directed lines in the graphs show the routes the trucks take to reach each destination at the end back to the depot. Vehicle one takes the takes the 1-6-3 route and the others as follows. This approach is adapted to find the solution for the EL-DMOEA. This can be solved by three steps, Encoding, Population initialization, and solution generation.

These schemas are compared with other existing schemas in the literature to verify the feasibility of the algorithm proposed in population initialization. The immigrant schemas are discussed and compared with the EL-DMOEA. The main immigrant schemas are random, elitism and memory-based [17]. The traditional ant colony optimization is designed for stationary problems and they converge fast and obtain optimum solutions. However, when considering the dynamic optimization problems to obtain the solution there needs to consider the instance of the static optimization problem because the pheromone trails of the previous routes will have a high chance of creating bias. Re-initialize the pheromone trails, use the previous knowledge is used to obtain the results.

Out of these the random and elitism are compared with the proposed algorithm EL-DMOEA. The main difference between these methods is the way the immigrants are generated. The random immigrant ACO and elitism immigrant ACO are mainly applied to a dynamic vehicle routing problems, that is the pattern changes randomly. An optimum value for the dynamically changing environment is hard to find. Sometimes it is not available because the environment is changing dy-namically. Moreover, the DVRP is compared with real-world traffic. The memory-based immigration pattern changes are cyclic, which is not discussed here. The dynamic variant of VRP is really the extension of real-world application. That customers needs are not known in advance, if there occurs a new request the planned plans or



routes should be re-plan which can include the new routes that arise from the new customer. As a result, the cost of the route and time taken to complete the route are not found optimally beforehand. The application of ant colony optimization is widely used in solving the combinatorial optimization problem. As the name implies, the algorithm works as same as the behaviors of ants going to find their food.

This result is considered to be an optimal on as considering the other vehicle routing problem as multiple objectives are considered here. As the position of the customer is changing in this case swapping the customer with weight, the distance is changed and route is changed also. The population is initialized first and checking whether there is any change is happening or not. If the position of customer is detected the population is archived and use an Adaboost for ensemble learning and predict a new population. When the customer changes the routes there is a new route then to obtain a feasible solution the customer routes can be divided into several sub routes in a random order and the depot is not added to each route.

C. Comparison of EL-DMOEA with other algorithms

Random immigrant ACO [17] the immigrants are generated randomly here and the diversity is maintained. The working of random immigrant is as follows the first depot is selected and the customers that is not visited is randomly chosen. Thus, a route is formed, repeat the process until a customer in the route violates the capacity constraints of the routes. Once they are violated another customer is selected and a new route is started. When all the customers are satisfies a solution that satisfy the results for VRP is obtained. Additionally, there is no limitation in adding a new route, in random immigrants the routes or the customer can be added at any point.

Elitism immigrant ACO works differently than a random immigrant, the diversity is generated not randomly but from the previous best ant route selected and is used to generate the immigrant of the elitism. In this immigrant the ant with the least performance is removed and select only the best so far ant is selected and updated the pheromone route. The customers in different routes are not swapped in between as it results in an infeasible solution. Both algorithms are having a significant impact on random dynamic vehicle routing problems. RIACO have better diversity but the EIACO have useful when considering the previous knowledge hence will be better for the changing environment. The algorithms discussed so far have a quite good impact when considering their performance. The way the random and elitism immigrant is generated is one of the key factor. Selection of ant and replace it with the previously selected ant from the memory to generate the memory based immigrant.

The main working of the ant colony optimization should be stated here when considering the pheromone trails. For planning and scheduling routes for vehicles, many algorithms are available and studied in the literature, meta-heuristic, heuristics, and randomized algorithms are some of the important ones. Meta-heuristic algorithms are ant colony optimization and particle swarm optimization (PSO). The Ant colony algorithm is one of the oldest algorithms discussed in literature. The algorithms work exactly as the ants seeking for their food. As observing nature, it is seen that the ants are forming a particular route [18]. The ants can be finding the shortest path for reaching their food. As it can form many routes, when ants goes through a particular route it releases a chemical substance called pheromone, as the number of ants goes through the same path the amount of pheromone de-positd will increase, so the shortest path has more pheromone. Similarly, this phenomenon is obtained here the routes are selected that in the way that the shortest path will be the path where more vehicles traveled. Similar to the pheromone deposit. The approach ant colony optimization, it will construct a road map and find the best path from it. Here the shortest path is required so less fuel is consumed.

The other meta-heuristic approach is the particle swarm optimization algorithm. Similar to the ant colony optimization, the particle swarm optimization algorithm observes the movement of a group of particles to the particular direction, the particles are also called the agents which move around the search space to obtain a feasible solution. The particles are observed as population-based. The swarm observe the quality, proximity response and stability of the system [19]. The PSO algorithm is used for the first time for the dynamic behavior in this study. The observation can derive the algorithms to an optimal solution.



V. ADVANTAGES OF PLATOON

The main objective of the truck platoon problems discussed is to reduce the total route distance and reduce the customer waiting time moreover it improves customer satisfaction. When considering the route distance, with less route distance the systems –wide fuel cost can be reduced and maximize the number of vehicles in the platoon[14]. Forming or the following a platoon is not so good when they go through the tunnel. The main advantages of truck platooning are for the following truck is more than the leading trucks', the following trucks fuel consumption is reduced than the leading one. Hence there are benefits for the commercial companies that plan and schedule the trucks which need to be linked together and travel long distance. Efficient truck drivers are employed in the leading truck; hence the safety concern is reduced to an extent. The main aspects that need to be considered are inter-vehicle communication, control strategies, and string stability [6]. There are many communication patterns or the major communication pattern of depending on their data flow. The data flow for the communication will happen in between the leading truck and the following truck, following trucks to the leading trucks and from each truck to its successors. The pattern is a vehicle to many is adapted in real-time, when the trucks travel on the road. This can be incorporated to the trucks with drivers and driverless which is discussed in the coming session. The drivers in the platoon are highly efficient and they are trained specially to communicating with other vehicles in the platoon. The platoon is controlled by an external agent, works on pre-schedules. On the other side, autonomous driving is where there is no human involvement. Many countries have arisen problem regarding fully autonomous driving as it creates a safety concern when driving on urban roads with a heavy loads. When describing the technical aspects, the autonomous vehicle should communicate with all other vehicles in the platoon and to the environment. The trucks that drive autonomously should communicate with all other trucks to avoid the collision and other unexpected intuitive happens. The communication between the trucks can be improved by incorporating the infra-red technology and the accuracy and robustness of the communication are ensured. As it is recommended in this paper trucks platooning is optimal up to maximum of four trucks. When there are more vehicles and long routes it may cause difficulties in maintaining road sharing for other vehicles. Wireless communication is adapted for the communication between the vehicles via sensors on the vehicles.

Several projects and studies have been conducted so far to understand the human behavior towards truck platooning while the reduction in fuel consumption and safety are the key factors. One of the European Commission Co-Funded FP7 named as SARTRE [20] project was to analyze the application road transportation with regards to human interventions. The main category of the human influences by the positions of the drivers in the leading and following trucks and the humans in the other vehicles on the road. In this study, the lead vehicles are driven by drivers with efficient driving skills and training. The drivers in the following vehicles are capable of or can engage in other activities due to the automated driving techniques. That is full attention is not required, this can utilize in the plan-making when the change in the route occurs. The concept of this project was defining the concepts that and studying the human-machine interaction. For implementation the concepts were analyzed the road safety, improved the leading and following trucks by integrating sensors for communication moreover human machine interaction. The following vehicles can drive at any speed without any restriction, with the benefit of automated driving. The system includes some emergency violations that the vehicles in the platoon can take so that the accidents are reduced to an extent. In that sense the vehicle can do several possibilities, such as it can exit from the platoon if an obstacle is found, so that road risk is avoided, moreover, the vehicles can change the route at any point in time, with no exact trajectory is needed to be followed and also can stop at a particular instance at emergency. To form the platoon the minimum requirement is there should be a leading truck followed by at least one following truck. Another important factor is, that the light vehicles cannot be leading vehicles, that is a truck or bus cannot follow a car or similar small vehicles, with also varying gaps between the vehicles. The project was successfully implemented and the results are used for further studies. The main aims such as reduce fuel consumption with increased road safety and human interaction towards the automated driving. The three-year project was performed with a maximum of five vehicles with sensors included and the study is conducted for different approaches.



When vehicles are platooning together there are numerous benefits rather than reduced fuel consumption. The air and noise pollution is also reduced. The platoon can be formed and stopped at any point as mentioned previously. The termination of the platoon is occurring when the driver reaches their destination or the driver takes a break. For the efficient communication should be done between the trucks, for that application program interface can be merged not obviously to all the trucks in the platoon but in the leading trucks [21]. Efficient road usage is obtained in corporative driving. In-tervehicle communication was initially implemented between the -vehicles rather than wireless communication. For that small sensors are used. But inter vehicle communication is not too mandatory in automated driving techniques. Later, when wireless communication was widely used, it was adopted with GPS for forming platoon.

In automated driving and semi-automated driving, the safety is ensured and the vehicles can communicate via radio signals. Communication can be done in many manners, distributed, decentralized and centralized [22] are used when the trucks are forming at a different time schedules. The data are not exchanged in between vehicles, such pattern is called decen-tralized communications. In centralized pattern the leading truck is responsible for communication and coordination of the path. The distributed system the vehicles are communicated each other. One of the notable features discussed here is join strategy. There is a high risk when a vehicle joins in between the platoon. While joining the platoon in a gap of other vehicles may cause accidents if not communicated properly and the brake system of the vehicle doesn't work well. In this scenario the vehicles are following the mannerism of the SARTRE project. Sometimes the message or data are transmitted via one-to-one format only. The process of joining the platoon in the middle of an existing platoon works as, by sending the signal to the leading vehicle when it came to know there is a platoon exists. The response from the leading vehicle need to be on time and the communication should be robust. When the possibility of a join occur the leading vehicle send a positive acknowledgment to the vehicle that needs to join else negative feedback as cannot join the platoon is mentioned. As the positive feedback includes the position of the platoon where the vehicle can join the platoon which is the insertion point. Slowing down of the vehicles may cause danger, so better communication between all the vehicles in the platoon is recommended. The simulation is performed for the performance of this particular pattern more or less the changes is observed when the vehicles are joining at the end or beginning of the platoon.

Fuel reduction in truck platooning is a significant factor for companies that transport large goods to long distances as discussed so far. As aiming for fuel reduction, the main concern is the reduction in the emission of carbon dioxide which is a great threat to the environment. As far as 20% of the total the reduction has been achieved in total for the leading trucks [23]. As per the studies the main goal is to achieve a 60% of reduction in the carbon emission. The main criteria for the reduction of the carbon emission are not only the distance between the trucks but also the speed of the vehicles. As the speed is increased the amount fuel burned is also increased. The fuel consumed is always proportional to the emission of carbon. It is stated in the paper that as the heavy vehicles drive at a speed of 80 kmh fuel reduction of 21% is calculated when driving with a 10-meter distance between them and the when they drive at 16 meters the reduction of fuel is observed to 16%. As the distance is reduced in parallel to carbon emission, the safety of the trucks on roads should be knee fact. The traffic problems are considerably reduced as they are linked via technologies to maintain the distance between the trucks, As the distance between the vehicles is reduced the aerodynamic drag is no longer reduced. As the vehicle platooning problem is an NP hard problem the computational complexity for the deterministic problem, unless $P=NP$ it is hard to find the solution for these problems. One of the main ideas behind is to make the starting of all the trucks in the platoon is same. This problem formulating to an integer linear problem and solved by existing linear problems. This solution can be implemented to solve real world existing problem with a greater number of trucks. Different computational complexity of various platooning problem is calculated and an optimal solution is obtained because the problem is considered as NP complete.

The aerodynamic pressure between the inner vehicles, and the front and the end vehicles plays a significant role when considering the fuel consumption. When distance between the vehicles is lesser then the aerodynamic drag will be considerably low [24]. Once the aerodynamics is maintained positively the carbon emission is reduced considerably.



Ve-hicles that have a low distance in between the platoons are good in keeping the road capacity. When considering the inner vehicles, they experience relatively lesser aerodynamic pressure rather than the ones that drive at the front and back. The leading vehicles always have the strong pressure against the air in front of it and the least following ones also have the pull from the air behind it. In other words, the inner vehicles can experience a positive effect of aerodynamics from the ones that drive front and behind it. Companies that depend on the road for transporting their freight have various types of trucks with different fuel capacities, linking heavy-load vehicles for transporting goods be a challenge for this aspect. However, numerous mathematical heuristic studies are carried out to link the trucks with gains for the companies. As there are dissimilar heavy vehicles that are carrying goods more over if multiple companies are involved in the transportation, effective platooning is more challenging for obtaining an optimal solution. The corporation of the companies is a vital role when planning the platoons, the practical impacts are cost efficiency moreover the corporation of the companies decide the position of their vehicles in the platoons, as aerodynamics plays a part in the cost, fuel and emission reductions.

Strict rules and regulations are planned and implemented around the world to reduce the carbon emission. When considering transportation companies when transporting the bulk amounts of goods via different mediums emit carbon dioxide have to cooperate with these rules for the reduction in the emission. The possible ways are to build an efficient engine that uses less fuel and other is maintain or reduce the aerodynamic drag of the trucks. As the aerodynamic drag has almost 50% of the effect in energy consumption. The trucks or heavy duty vehicles are built a bulky manner so that maximum cubic meters can be used and the road regulation rules are obeyed. In general, lower aerodynamic drag is better. As the drag coefficient is reduced the aerodynamic resistance is also reduced with lesser fuel consumption, which is a massive profit for the companies. The truck model also acts a substantial role in reduction of the aerodynamic drag. Conventional trucks with boxy type front areas have higher aerodynamic drag than the ones with a slight curve in the front area. These studies were considered when multiple companies were involved in the formation of the platoon. As the number of vehicles involved in the platoon increases with a variety of trucks the aerodynamic drag and the fuel consumption by different capacity vehicles have been discussed in the literature studies.

VI. COMPARISON OF VEHICLE PLATOON WITH OTHER TRANSPORTATION SYSTEM

Driving the trucks or other vehicles in a closed link to reduce several drawbacks can be compared with the other transportation system, which also have a great impact on recent research areas. Real-time ride-sharing is an example for that [25]. In platoon formation, the reduction of fuel is aimed and when ride sharing the ride is constructed in a way that the a maximum number of seat occupation is ensured. An optimal solution is obtained without taking an additional car. Some of the cases the vehicles and the routes are fixed for a set of people. That is a specific vehicle is assigned to the particular route. As cloud communication is enabled, the ride sharing has been widely accepted, but when riding from the start point to the other points, various disadvantages are more than advantages. The car drivers must plan the schedule ahead of time. In such a case, the dynamic behavior is not considering. But in reality there are dynamic and static ride-sharing are in practice. This has been a pave the way for the literature study. When it comes to global ride sharing, the users data and location is shared globally, which is a challenge when the privacy of the users are concern. Similar to ride sharing is freight consolidation. Large amount of goods are transported or shipped to a longer distances. When platoons are included in freight transportation, the transportation companies will gain profit. Multiple companies involved in business need to plan ahead, because, unlike platoon, the loads are transported in between. In freight transportation large amount of goods are transported with high risk.

VII. CONCLUSION AND OUTLOOK

In this report the ensemble learning model for dynamic vehicle routing problem is studied, this method have much more capacity in including change environment such as the customer change their position. While customer changes



their position the problem becomes dynamic additionally the new environment is obtained. There are new population can be predicted which can be results in accurate solution with good quality, because it can use the information of previous populations. So this study can be concluded as EL-DMOEA is best than other algorithms as it can be accurately predict the solution for dynamic vehicle routing problem with real time scenario. This study included real time examples taking the customer request at the time of executing the routing problem. To find an optimal solution, this learning method is compared with other existing heuristic methods. By introducing different constraints for instance time and minimum distance as discussed here can contribute to the development of the transportation community.

The literature references taken in this study is mainly from IEEE, Springer and other computer science search engines. This area of study where a lot of scope for future work. In the beginning, the study shows how a platoon is formed, and what are objectives for forming the platoon. The main objectives discussed are reduction of the fuel consumption by reducing the route of platoon. The next objective concentrated was to reduce the waiting time of the customers so that the customers are satisfied, when the goods are delivered on time. These objectives are frequently studied as fuel consumption is a crucial part of the transportation and logistics companies. As the cost of fuel is increasing day by day, this study is much more relevant. Different kinds of approaches have been discussed here which mainly focused on lesser consumption of fuel hence lesser gas emission which ensures less pollution. In the future, studies that involve driver less vehicles, also called autonomously and semi-autonomous driving methods have scope.

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