“Design and Optimization of Milk-Run Material Supply System with Simultaneous Pickups and Deliveries in Time Windows”

Synopsis

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1. Abstract

Material handling is one of the most crucial issues that should be taken into account for eliminating waste, reducing the cost and just in time based delivery of the product. Many industries spending millions of bucks for the transportation of the goods. An effective transportation management system has to be implemented to control the cost of transportation and inventory. Optimised milk-run concept can be utilise to overcome the issue related to the supply chain management system. Milk-run material supply system is the cyclic trips, where either goods are collected from several suppliers and delivered to one customer, or goods are collected from one supplier and delivered to several customers. The objective of this research is the minimization of the total material handling and inventory holding cost. It is also concentrated on just in time delivery to enhance the customer satisfaction. These saving of cost could be either use for reduction of the product cost, which will boost up the sales or to lift the profit margin of the organisation.

The purpose of this research is to develop a mathematical model and a heuristic approach, which is utilise to construct the routes, calculate the associated cost and determine the service period for the design of a milk-run material supply system with simultaneous pick-up and delivery. The material supply by this system occurs on a just-in-time basis from a regional offices to several stations of the courier service. Besides, the proposed heuristic approach intends to construct routes based on an initial service period value and attempts to improve the solution by considering different period values. Furthermore the scheduling of the vehicles is calculated based on demands and routes of network. The most optimum solution is decided on the basis of the least total transportation cost and minimum time. Genetic algorithm is proposed to solve the vehicle routing with simultaneous pickup and delivery within time frame (VRPTWSPD) problem related to milk-run concept. Algorithm is applied by the help of Matlab and results are presented. The result showed the performance and effectiveness of the algorithm.

2. Introduction

Material handling is a field of growing interest of both industries and research institutions. Enormous rivalry in today’s global markets, the range of products with shorter life cycles, and the higher expectations of consumer markets have enforced suppliers to concentration on their supply chains services. This, together with innovation and invention in communications and transportation technologies have encouraged the continuous evolution of the supply chain techniques. Consequently, to shrink cost and enhance service facility, operational supply chain policies need to take into account. The supply chain, which is also referred to as the logistics
network involves bunch of varieties of management (suppliers, manufacturing unit, warehouses, distribution point, and retail outlets). The material supply system includes the movement of goods from a supplier to a customer, as well as any customer returns to the supplier in a logistic distribution network. It involves supply, storage and control of materials and products throughout distribution in the system. Material supply system plays an important role in manufacturing and logistic. The vehicle routing problem is a common central problem in operations research arise in various fields, required to optimally route a fleet of vehicle to several set of consumers with simultaneous pickup and delivery. The environment in which industries nowadays accomplish their supply chain is highly vigorous.

If a good material handling system design is accomplished, it is claimed that the cost will be reduced in between 10% and 30% [2]. In a typical industry, material handling composes the 25% of the workers, 55% of the factory area, and 87% of the production time [3] as transportation cost has a significant impact in total production cost.

3. Objective of Research Work

The main goal of the study is to investigate the implementation of milk-run material supply system in local courier industry with simultaneous pick-up and delivery within time limitation and examine its effects on overall performance and total cost. Our aim is that the conduction of the research provides optimization of the supply chain network for the development of milk-run supply system in courier industry as an alternative system. For suppliers and researchers, it is hoped that the study also contributes to better understanding of inventory management. Besides, research will contribute to set up a feasible routes and offer quickest respond to the demand of the customers.

The overall objective of research work are as following:

- Determine the scheduling of vehicle, period of the pick-up and delivery services and quantity of vehicles.
- Construction of the routes based on lowest time and cost required to travel to facilitate both distribution and collection.
- Optimization of total material handling and inventory holding cost.
- To deliver the products on just in time to achieve higher customer satisfaction.
- To reduce of the carbon dioxide and carbon monoxide emission in the environment by optimizing vehicles utilisation in transportation network.

4. Scope of Work

The proposed model is focuses on building robust optimisation approach for the courier supply chain network. The model mainly concentrate on construction of the routes and scheduling of
vehicle to optimize the transportation cost, inventory holding cost and travelling time. The optimized model can be successfully implemented in the transportation services which involve simultaneous pick-up and delivery within certain time limit, such as courier services, grocery chain services, perishable supply, industrial supply chain management etc.

The scope of the research is defined as:

- Conventional material supply system for the courier services has been studied to understand the previous construction of routes, location of the stations, average demand and supply on daily basis and scheduling and number of vehicle in supply network.
- Routes have been constructed based on milk-run material supply system to optimize transportation cost and travelling time.
- Number of vehicle are determined for the network based on the demand of the consumer with optimized fixed cost.
- Scheduling of the vehicles are determined based on the frequency for the reduction of the penalty cost and inventory holding cost.
- User friendly application for the android handset has been developed for the easy assessment of the overall system.
- Database has been developed based on the previous record to forecast the average demand of the consumer and determine average travelling time and cost between each stations.
- Overall surveillance of the whole network by Global Positioning System (GPS) system located in each vehicle.

5. Literature Review

- Angelelli E, Mansini R. “The vehicle routing problem with time windows and simultaneous pickup and delivery.” Formulated a mixed-integer non-linear model of the VRP with time windows and simultaneous pickup and delivery. The term of “time windows” means that the material handling vehicle's pickup and delivery service at a supplier must be started and completed between the predefined time points.
- Jafari-Eskandari M, Sadjadi SJ, Jabalameli MS, Bozorgi-Amiri A. “A robust optimization approach for the milk run problem with time window and simultaneous pickups and deliveries.” A mathematical formulation was developed for the problem of robust resource milk run, as a mixed integer approach to manage supply chain problems.
The robust optimization method was employed and the results was compared with the optimal solutions of the proposed milk run method.

- Mei-shiang Chang, Shyang-ruey Chen, Che-fu Hsueh. “Real-time vehicle routing problem with time windows and simultaneous delivery/pickup demands.” A heuristic comprising of route construction, route improvement and tabu search is proposed. The real-time vehicle routing problem with time windows and simultaneous delivery/pickup demands (RT-VRPTWSDP) is formulated as a mixed integer programming model, which is repeatedly solved in the rolling time horizon.

- Liang Chun-Hua, Zhou Hong, Zhao Jian. “Vehicle routing problem with time windows and simultaneous pickups and deliveries.” A mathematical model is proposed for VRPTWSPD and developed a genetic algorithm to solve it. They have demonstrated the significance of introducing time windows.

- Jing Fan “Vehicle routing problem with simultaneous pickups and deliveries based on customer satisfaction.” VRPTWSPD is modelled to solve the minimization of the total length of vehicle’s paths and maximization of all customer satisfaction. Initial solution obtained by the nearest neighbour method and improved by tabu search algorithm.

- Anand Subramaniam, Lucidio Cabral “An ILS based heuristic for the vehicle routing problem with simultaneous pickup and delivery and time limit.” An Iterated Local Search (ILS) procedure to perform the local search is proposed. The algorithm was applied to test problem and found to produce better result.

- Theeratham Meethet, Manoj Lohatepanont. “Vehicle routing in milk-run operations: A column generation based approach.” Authors proposed optimization techniques to find the cost minimizing milk-run plan. Proposed a column generation based algorithm.

- Toshinori Nemotoa, Katsuhiko Hayashib, Masataka Hashimotoc. “Milk-Run logistics by Japanese automobile manufacturers in Thailand (Case study).” The case study on Japanese automobile manufactures in Thailand revealed that reduction of the number of trucks dispatched and improvement in transportation cost.

6. Research Gap

It has been observed that many companies around the world aim to implement milk-run material supply approach though very few have successfully adopted it into the logistic network. Milk-run supply system studies usually involve formulating a mathematical model of the associated VRPTWSPD and attempt to solve it using heuristics approach, since it is difficult to get optimum solution especially in real world setting. The study of literature review demonstrated that various heuristic approaches have been attempted by the researchers so far,
such as Robust optimisation approach, Route construction algorithm, Iterated local search, Differential evolution algorithm, Genetic algorithm, Nearest neighbour method, Multi swarm optimisation algorithm, Branch and cut algorithm, Variable neighbourhood descent method, Modified saving algorithm, Simulated annealing, Greedy algorithm, Dynamic programming, Taboo search etc. However, there is often conflict for selection of an appropriate heuristic model, as it has impact on optimality of the solution. Thus, there is a considerable requirement of studies that intend to design optimum milk-run supply systems. Therefore, the contribution of this research will be significant to both the industry and the literature.

Study of extensive literature review illustrate that with all the progress in the design of milk-run material supply systems have made over the last few years, it still has some major challenges, which are described as following.

- Some of automobile industries have adopted milk-run material supply system, though it is still challenging issue by other industries to adopt milk-run in logistic network.
- The Milk-Run logistics requires accurate management based on the operational plan. In case of poor planning the number of extra trips may increase that lead to additional transportation cost.
- In case of, handling split, consolidation or heterogeneous goods may increase the number of trip that leads to additional transportation cost. It is challenging to achieve optimal solution in such scenario.
- Customer waiting time and penalty cost have not been considered in the overall transportation cost, if delivery does not takes place in predefined time period.
- Dynamic, fuzzy, and stochastic goods with different processing routes can make problem more difficult and cumbersome to solve.
- It has been observed that when the demand is very small, the pure milk run strategy can be used, however it cannot be effectively implemented in real world continuous large scale demand problem.
- The studies of environmental pollution (amount of carbon emission) issues have not been observed and calculated.
- There are many uncertainties existing in practice environment, such as delivery reliability, customer demand, etc. These uncertainties influence on vehicle scheduling, which has not been attempted.
- There are several open issues that deserve attention to extend VRPSPD problem, which include more practical considerations, such as time windows, multiple objectives and travel times to move the problem even closer to real world problems.
Although minimizing total cost is an important criterion but for some services, criteria such as minimizing customer inconvenience and minimizing response time may be equally more important that has to be accounted.

**Hypothesis**

Design and development of the milk-run material system for the courier services to reduce the material handling and inventory holding cost at an extent level by using the mathematical model and genetic algorithm. It will able to establish the routes, determine the scheduling of vehicle for simultaneous pick-up and delivery services, calculation of the no. of routes, no. of vehicles and period of the routes.

**7. Problem Statement**

To address the problem of having route construction algorithm for milk-run supply system, optimized mathematical model and heuristic approach need to be developed that constructs the routes and determines the number of vehicle, scheduling and service period on just-in-time basis to minimize material handling and total inventory holding cost.

**8. Methodology of research**

**8.1 Research Methodology**

The methodology adopted for the development of milk-run material supply system is described step by step as below;

- Conventional material supply system has been studied and transportation cost are calculated for the courier services.
- Location of stations, number of routes and vehicles in transportation networks are studied and analysed.
- Identification of the quantity of the product to be pick up and deliver on everyday basis on each stations.
- Establishment of the routes according to milk-run supply system for the pick-up and delivery service.
- The routes should follow the time frame constraints otherwise penalty cost is imposed.
- Adjustment of the similar routes for the delivery of the product (according to time frame).
- Establishment of the period of delivery and pick up services.
- Calculation of no. of vehicle need to be required in each routes.
- Scheduling of vehicle on the basis of demand and number of vehicle.
- Determination of the overall cost (Transportation cost, fixed cost and penalty cost) and evaluation of the performance of the model.
➢ Development and evaluation of milk run alternatives.
➢ Implementation of milk runs.

8.2 Formulation of mathematical model

The mathematical model of the milk-run supply system is formulated to analyse the problem, according to the necessity and application of the logistic chain of courier industry. The mathematical model helps to explain the system and to study the effect of different parameters in overall transportation cost.

8.2.1 Objective Function

The objective function of the mathematical model is to minimize the total cost. The first part of the objective function indicates total transportation cost. The second part explains the total fixed cost of the vehicle (Initial cost of vehicle, Taxes, Insurance charges, Vehicle permit charges etc.) according to the milk-run. The third part shows the penalty cost if the delivery time.

\[
\text{Minimize } Z = \sum_{k=1}^{K} \sum_{i=0}^{n} \sum_{j=0}^{n} c_{ij} x_{ijk} + \sum_{k=1}^{K} c_{f,k} + \sum_{i=1}^{n} p_{i} t_{i} \quad (1)
\]

8.2.2 Constraints

Subject to,

\[
\sum_{k=1}^{K} \sum_{i=0}^{n} x_{ij,k} \geq 1, \quad i = 1,2, ..., n \quad (2)
\]

\[
\sum_{k=1}^{K} x_{ijk} \geq 1, \quad j = 1,2, ..., n \quad (3)
\]

Each Point is visited by minimum one vehicle.

\[
\sum_{i=0}^{n} x_{ijk} - \sum_{i=0}^{n} x_{jik} = 0, \quad j = 0,1, ..., n \quad k = 1,2, ..., K \quad (4)
\]

Same vehicle arrive and depart from each point between the node i and j.

\[
X_{ir} = X_{jr} \quad (5)
\]

The related stock point assigned to a same “r” route.

\[
q_{i} = t_{fixed}. X_{ir} \quad (6)
\]

The total demand of a point “i” at “r” route is determined.
\[ q_i \leq c_k, \quad \text{if } x_{ijk} = 1 \quad (7) \]

The vehicle capacity should be higher than demand.

\[ q_i \leq c_{ik}, \quad \text{if } x_{ijk} = 1 \quad (8) \]

Each vehicle have free capacity at the arrival at point “i”. It should be greater than pick up demand at that respective point.

\[ b_o \leq a_i \leq t_o \quad (9) \]

Arrival time must be within time frame.

\[ w_i = d_i - (a_i + s_i) \quad (10) \]

Calculate the waiting time before the departure at point “i”.

### 8.2.3 Notations

The necessary notations are defined for the formulation of mathematical model, which are explained in following sections.

**Indices**

- \( k \) = Vehicle index
- \( t \) = Time period
- \( i, j \) = Pick-up and delivery point indexes
- \( n \) = Set of clients
- \( r \) = Route index
- \( K \) = Maximum number of vehicles in distribution centres

**Parameter**

- \( c_k \) = Capacity of vehicle “k”
- \( c_{ik} \) = Free capacity of vehicle “k” on arrival at node “i”
- \( q_i \) = Pick-up and delivery demand at point “i”
- \( b_o \) = Bottom end of the time frame at point “i”
- \( t_o \) = Top end of the time frame at point “i”
- \( s_i \) = Service time at point “i”
- \( d_o \) = The output and input ratio of point “i”
- \( t_{fixed} \) = The determined time period

**Variable**

- \( c_{ij} \) = Delivery cost between “i” and “j”
- \( x_{ijk} \) = 1 if vehicle “k” departs point “i” to point “j”; 0 otherwise
\( c_{fk} \) = Fixed cost of the vehicle “k”  
\( X_{ir} \) = Point “i” is assigned or not assigned to route “r” (1 or 0)  
\( X_{jr} \) = Point “j” is assigned or not assigned to route “r” (1 or 0)  
\( a_i \) = Arrival time at node “i”  
\( w_i \) = Waiting time before departure  
\( d_i \) = Departure time from point “i”  
\( p_i \) = Penalty cost per unit time from tardiness of point “i”  
\( t_i \) = Tardiness for point “i”

### 8.3 Heuristic Approach

As explained earlier, the design of the milk-run material supply system requires construction of routes, scheduling of vehicle and determination of the service period. Mathematical models are typically formulated and attempted to be solved by heuristics approach for the route construction. The proposed mathematical model of the JITVRPSPD is non-linear due to the continuous large scale demand of the each stations. Vaidyanathan et al. [4] described that the problem size increases exponentially with the increasing in number of vehicles and stations that makes even small scale problem difficult to solve. Hence, a heuristic approach is useful to reach at a close to optimal solution, through short computational times. An algorithm are developed based on the proposed approach. The assumptions of the mathematical model are valid also for the proposed heuristic approach.

Initially four various algorithms are tried and tested by considering the small region of the problem to find an optimal solution (Tabu search algorithm, Prim algorithm, Simulated annealing and Genetic algorithm). The optimal solution achieved by each algorithms are evaluated and compared to choose the most suitable algorithm for the concern problem. Out of the four different algorithms, genetic algorithm are found to be more suitable and accurate for the nature of our problem. Based on the comparison, Genetic algorithm are selected to study and analyse the entire problem.

A genetic algorithm is a metaheuristic approach to solve mathematical optimization problems based on a natural selection process that based on biological evolution theory. The algorithm repeatedly modifies individual solutions by producing the children for the next generation from their parents called current generation. Genetic algorithms generates optimised solutions by relying on bio-inspired operators such as mutation, crossover and selection. Over successive generations, the population "evolves" toward an optimal solution.
9. Results and Discussions
Genetic algorithm is applied to resolve the current routing problem in the courier industry using the milk-run material supply system. Input data are used to solve the problem are;

- Matrix of distance, position and travelling time of each stations zone wise
- Demand data of each station (Volume per cycle) with the cycle

9.1 Development of Routes
The routes have been constructed by genetic algorithm in matlab based on the geographical location and distance between each stations. The algorithm performed using graphic user interface to display the routes, scheduling, total cost, distance and time of travelling of each zone. The Gujarat state are considered for solving the vehicle routing problem in courier industry. The state are basically divided in five different zone based on location of the regional offices i.e. Mehsana, Ahmedabad, Rajkot, Vadodara and Surat. Each zonal offices covers the nearby stations or area. The routes are developed in cyclic manner based on milk-run material supply system for various zones. Fig. 1 shows the map of Gujarat with all major cities. The location of five regional offices cover almost all major area of state.

**FIGURE 1: Map of Gujarat**

**Mehsana Zone**
Mehsana regional office covers the area of north Gujarat. It distributes and collect goods to 20 cities around the northern area of state. Couple of routes are developed by genetic algorithm based on location of stations. Following Fig. 2 to Fig. 4 show the routes, total cost, scheduling of vehicles, travelling distance and travelling time.
FIGURE 2: Scheduling and routing of route 1

FIGURE 3: Scheduling and routing of route 2

FIGURE 4: Scheduling and routing of Mehsana zone
Ahmedabad Zone
Ahmedabad regional office is a heart of Gujarat state. It is one of the busiest station of state. It covers the area of middle Gujarat and Kutch region. It runs service to 29 cities around the middle-west area of state. Three routes are developed by genetic algorithm based on location of stations. Following Fig. 5 to Fig. 8 show all three routes, total cost, scheduling of vehicles, travelling distance and travelling time.

FIGURE 5: Scheduling and routing of route 1

FIGURE 6: Scheduling and routing of route 2


**Rajkot Zone**

Rajkot regional office covers the area of Saurashtra region. It has to go through the longest travelling distance. It distributes and collects goods to 27 cities around the southern-east part of state. Four routes are developed by genetic algorithm based on location of stations. Following Fig. 9 to Fig. 13 show the routes, total cost, scheduling of vehicles, travelling distance and travelling time.

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**FIGURE 7: Scheduling and routing of route 3**

**FIGURE 8: Scheduling and routing of Ahmedabad zone**
FIGURE 9: Scheduling and routing of route 1

FIGURE 10: Scheduling and routing of route 2

FIGURE 11: Scheduling and routing of route 3
Vadodara Zone

Vadodara regional office covers the area of south Gujarat. It runs service to 16 cities around the southern part of state. Two routes are developed by genetic algorithm based on location of stations. Following Fig. 14 to Fig. 16 show the routes, total cost, scheduling of vehicles, travelling distance and travelling time.
FIGURE 14: Scheduling and routing of route 1

FIGURE 15: Scheduling and routing of route 2

FIGURE 16: Scheduling and routing of Vadodara zone
**Surat Zone**

Surat regional office covers the area of south Gujarat. It distributes and collects the goods to 10 cities around the southern part of state. Two routes are developed by genetic algorithm based on location of stations. Following Fig. 17 to Fig. 19 show the routes, total cost, scheduling of vehicles, travelling distance and travelling time.

**FIGURE 17: Scheduling and routing of route 1**

**FIGURE 18: Scheduling and routing of route 2**
Based on output of the program, Table 1 shows the decreasing of total travelling distance and transportation cost per day for supplier location in all Gujarat region. The current transportation system has a total travelling distance and transportation cost are 7435 km. and Rs. 59480 per day in Gujarat state respectively. It is way too high as compare to the optimal total travelling distance and transportation cost which are 5555 km. and Rs. 48730 per day respectively by milk-run material system. It can be concluded form below table that milk-run supply system can optimized the travelling distance by 25.28 % or 1880 km. in a day and total transportation cost as Rs. 10750 or 18.07 % per day.

**TABLE 1: Comparison of Conventional Supply System and Milk-Run Material Supply System (Distance and Overall Cost)**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Conventional supply system (km.)</th>
<th>Milk-run supply system (km.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mehsana Zone</td>
<td>1020</td>
<td>643</td>
</tr>
<tr>
<td>Ahmedabad Zone</td>
<td>2000</td>
<td>1753</td>
</tr>
<tr>
<td>Rajkot Zone</td>
<td>2580</td>
<td>2047</td>
</tr>
<tr>
<td>Vadodara Zone</td>
<td>965</td>
<td>611</td>
</tr>
<tr>
<td>Surat Zone</td>
<td>870</td>
<td>501</td>
</tr>
<tr>
<td><strong>Total Distance</strong></td>
<td><strong>7435</strong></td>
<td><strong>5555</strong></td>
</tr>
<tr>
<td><strong>Transportation Cost (Rs./Day)</strong></td>
<td><strong>59480</strong></td>
<td><strong>48730</strong></td>
</tr>
</tbody>
</table>

In linear correlation between travelling distance and travelling time, Table 2 represents reduction in total travelling time. It can be seen form below table that milk-run supply system
can optimized the travelling time by 24.40% in a day in all zones. According to current material supply system the total travelling time is 184.20 Hrs., which can be reduce to 139.25 Hrs. by successfully implementing milk-run material supply system.

**TABLE 2: Comparison of Conventional Supply System and Milk-Run Material Supply System**

(Travelling Time)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Conventional supply system (Time)</th>
<th>Milk-run supply system (Time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mehsana Zone</td>
<td>26.40 Hrs.</td>
<td>18.55 Hrs.</td>
</tr>
<tr>
<td>Ahmedabad Zone</td>
<td>49.10 Hrs.</td>
<td>40.10 Hrs.</td>
</tr>
<tr>
<td>Rajkot Zone</td>
<td>60.10 Hrs.</td>
<td>50.10 Hrs.</td>
</tr>
<tr>
<td>Vadodara Zone</td>
<td>28.20 Hrs.</td>
<td>19.05 Hrs.</td>
</tr>
<tr>
<td>Surat Zone</td>
<td>20.40 Hrs.</td>
<td>11.45 Hrs.</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>184.20 Hrs.</strong></td>
<td><strong>139.25 Hrs.</strong></td>
</tr>
</tbody>
</table>

**9.2 Vehicle Routing Database**

The android application has been developed to track the vehicle throughout the route. This application will be installed and run in to each stations of respective route for supervision and inspection purpose. It will be also installed into the mobile handset of driver to make sure data input is authentic and correct. It will indicates the detail schedule and weight distribution (Both pick-up and deliver) of entire route. The analysis was made through the available database, which will help to conclude the traffic and weight consideration. Fig. 20 shows the input page of the application, through which data entry can be done.
This android application is run as a trial testing to obtain the database for a one week. The prepared database will be used for the future reference to forecast the demand and supply, which will support to determine the number of vehicle and scheduling of vehicle required in each routes. Based on the trial testing the database is prepared and analyzed in matlab by using the graphical user interface to determine the weight distribution in entire Gujarat state, which is shown in fig. 21. It will also indicate the travelling time require between two stations and

**FIGURE 20: Vehicle Routing Android Application**

**FIGURE 21: Vehicle Routing Weight Analysis**

Red: Above 750 kg.  Orange: Between 350 kg to 750 kg.  Yellow: Between 175 kg to 350 kg.  Green: Below 175 kg.
driver detail of the delivery taken place in the past. The above Fig. 21 shows the amount of weight carried between each stations. The red line indicates the weight distribution taken place above 750 kg. between two stations. Likewise orange line, yellow line and green line represent the weight distribution between 350 kg. to 750 kg., 175 kg. to 350 kg. and below 175 kg. respectively. It has been observed from the fig. 5.26 that the weight distribution is higher between major cities and regional offices, while the small cities and isolated places have lower weight distribution.

10. Conclusions and Future scope
As per the study of vehicle routing problem in supply chain management the Gujarat state is considered to implement the milk run material supply system in courier industries, as courier industries has a major involvement in logistic industry. GA is employed in matlab to solve the current travelling salesman problem. Total 17 routes are constructed according to the concept of milk-run material supply system, which cover 110 cities across the Gujarat states. It has been observed from the result, that the reduction of the overall cost, time and distance will be have a major impact in supply chain industry.

Conclusion
Following conclusion can be drawn from this research work;

- In this study, the mathematical formulation and genetic algorithm is proposed for the solution of homogeneous and heterogeneous fleets for VRPSPDTW encountered in real life situations, where routes are constructed, service and delivery period are determined and schedule is obtained. Hence overcoming the limitation of current literature that usually employ for one or few products. Computational results and proposed procedure represents an excellent performance.
- The overall supply chain cost has been minimized by using milk-run system in transportation instead of direct shipment.
- The result shows reduction in the carbon dioxide emission from the transportation system by improving the vehicle utilization.
- Hence implementation of the milk-run efficiently can compress cycle time, minimize distance, decrease total cost, reduce carbon emission, increase vehicle utilization and improve profitability.
- It has been seen form the result that decreased of vehicle’s travelling distance is 1880 kms or by 25.28 % in a day.
- With the linear connection between vehicle’s travelled distance and travelled time, the reduction of vehicle’s travelled time is 44.95 hrs. or by 24.40 %.
The optimized model has achieved reduction of the overall cost at an extent level, that is Rs. 10750 or by 18.07 % in a day.

The overall reduction of CO2 emission is by 24.94 % in the environment.

**Future Scope**

Future research will be mainly addressed towards extending the application of the algorithm to various manufacturing environments to test its suitability and foster the necessary improvements.

There are many uncertainties existing in practical environment, such as delivery reliability, stochastic customer demand, dynamic environment etc. These uncertainties influence much on vehicle scheduling and transportation cost. Further research will be focus on modification of genetic algorithm in vehicle routing problem with uncertain environment.

11. **Publications**


12. **References**

23. Yong Wang, Xiaolei Ma, Yunteng Lao, Yinhai Wang, Haijun Mao (2012) Vehicle routing problem: simultaneous deliveries and pickups with split loads and time windows. 92nd Annual meeting of the transportation research board.
Annexure: I
Optimization Approach of Vehicle Routing By a Milk-Run Material Supply System

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Abstract— Material handling is one of the most crucial issues that should be taken into account for eliminating waste and reducing the cost. The purpose of this research is to develop a mathematical model, which will be helpful to construct the routes and determine the service period for the design of milk-run material supply system. The material supply by this system occurs on a just-in-time basis from a central warehouse to several stations. Milk-run material supply system is the round trips are either goods collected from several suppliers and transported to one customer, or goods collected from one supplier and transported to several customers. Besides, it’s intends to construct routes based on an initial service period value and attempts to improve the solution by considering different period values. The most suitable solution is decided on the basis of the least total material handling and inventory holding cost. The objective of the mathematical model is the minimization of the total material handling and inventory holding cost. These saving could be either use for reduction of the product cost, which will boost up the sales or to lift the company profit margin.

I. INTRODUCTION

Milk-run supply system can be classified into external milk-run system and internal milk-run system. Internal milk-run systems are those that deliver parts to the customers inside of the plant. Application of milk-run distribution systems in plants is to standardize the material handling system and eliminates the waste. If a good material handling system design is accomplished, it is claimed that the cost will decrease between 10% and 30% [2]. In a typical industry, material handling composes the 25% of the workers, 55% of the factory area, and 87% of the production time [3].

The objectives of the lean logistics are the delivery of the right mix of products at the right time to the right place, and carry out these activities, effectively [1]. Assembly lines must satisfy the customer demand neither late nor early, because early production incurs inventory holding cost and late production causes either lost sales or backlog. Therefore, parts supply to the point of use in the assembly line must be also achieved just-in-time (JIT). Otherwise, either time losses may occur due to disorganized and insufficient material supply to the assembly line, or excess inventory accumulates. JIT material delivery to the internal customers is usually achieved by means of the pull production control that employs Kanban. Pull production control mechanism is based on replacement of a predefined level of buffer stock of parts needed for an operation. Whenever a workstation starts consuming parts from a container, it detaches the Kanban attached to it and posts it into a Kanban post or puts into the order box, which is an order of a container of parts. The Kanban are collected frequently by the material handling staff, and the material requirements are satisfied by the supplier of each station of the line. The exact number of parts must be delivered to prevent inventory holding.

Today, assembly lines usually require many types of components at different stages of assembly operations simultaneously. The need to move small quantities of large number of items within the plant with short and predictable lead times without increasing transportation costs resulted in development of milk-run material delivery systems [1]. Milk-run delivery system picks up and delivers containers of parts along the fixed routes each comprised of a predetermined set of stock points of the stations of an assembly line, based on a schedule. Therefore, integration of pull production control with the milk-run part supply system for the assembly lines is beneficial.

II. LITERATURE REVIEW

During the review of JIT parts supply of materials studies, papers of two inter-related topics were reviewed: Kanban or pull production control papers and milk-run material supply papers. Kumar and Panneerselvam [6] made a critical review of Kanban papers and examined the papers about single-card and two-card Kanban systems, blocking mechanisms coupled with the buffer capacities, and measure of performance. In addition, Junior and Filho [7] focused on special cases or variations of the Kanban systems developed to overcome the problems occurring due to the unfavourable conditions of use. The authors reported that most of the proposed systems follow the original Kanban logic. In addition, Hao and Shen [8] reviewed the studies considering Kanban systems and concluded that these relevant papers did not consider the material handling issues at the shop.

Fig. 1: Milk run material supply system
floor level, though it affects the system performance considerably [8].

In contrast to the Kanban literature, there exists a limited literature on milk-run material supply system, based on the pull philosophy. This type of papers about milk-run material supply systems can be divided into two groups: internal and external milk-run. Internal milk-run systems are those that deliver parts to the customers inside of the plant. Vaidyanathan et al. [4] analysed the JITVRP (just-in-time vehicle routing problem) and emphasized the unique characteristic of this problem. JITVRP requires that the quantity to be delivered at each of the demand nodes is a function of the route taken by the vehicle assigned to serve that node. The authors developed a non-linear mathematical model for this problem, relaxed it by making some assumptions and proposed a linear model that attempts to determine the lower bound for the number of vehicles required [4]. Moreover, a two-stage heuristic algorithm was proposed in this paper, for the solution of the problem.

Satoglu et al. [15] explained JIT material supply system for assembly line. They approached heuristic and mathematical method for routing. However, the researchers did not attempt scheduling of the vehicles in their research. Domingo et al. [9] explained a real implementation of milk-run material supply system that serves a lean assembly line. They followed a practical approach. First, the stock points where pickups and deliveries were determined. Then, the sequence of operations was defined and alternative routings were determined. The stock points with high demand rates and those with lower demand rates were included in two separate routings. Then, the pickup and delivery schedule were developed. However, the researchers did not attempt to make an optimal milk-run delivery system design.

Alvarez et al. [10] presented a case study of the redesign of an assembly line by using lean production tools. To reduce lead time and excessive stocks and improve material flow within the manufacturing system, Kanban-based production control and a milk-run material handling system were implemented. The authors realized that the design of Kanban production control system is insufficient without implementing an appropriate material handling vehicle [10]. Boysen and Bock [11] considered scheduling JIT part supply to a mixed-model assembly line where assembly line and the warehouse are at different factory floors. The authors used dynamic programming and then simulated annealing for the solution of the problem. Hao and Shen [8] developed a prototype software system that integrates discrete event simulation with agent-based simulation technique to evaluate the performance of a Kanban-based milk-run system serving an assembly line. In addition, Costa et al. [12] analysed the milk-run material delivery system of an electronics company using the simulation technique. In addition, Nemoto et al. [16] explained JIT external milk-run applications of the Toyota automobile assembly factories located in Thailand. Some studies considered time windows and VRPSPD (vehicle routing problem simultaneous pick-up and delivery). Angelelli and Mansini [13] formulated a mixed-integer non-linear model of the VRP (vehicle routing problem) with time windows and simultaneous pickup and delivery. The term of “time windows” means that the material handling vehicle's pickup and delivery service at a supplier must be started and completed between the predefined time points. Ohlman, Fry, and Thomas [14] considered the VRP with time windows and split deliveries, where orders are picked up from a network of suppliers and delivered to the depot of a lean (JIT) production system. The authors divided the problem into two phases: the routing phase and the scheduling phase. Similarly, Chuah and Yingling [5] developed a non-linear mathematical model of the VRP with time windows and considered high-frequency and small-quantity deliveries from suppliers to a JIT assembly plant.

Based on this review, it can be also deduced that there are only a few internal milk-run system studies in the literature. It has been observed that many manufacturing companies around the world aim to implement milk-run approach inside their production systems. Thus, there is a considerable requirement of studies that intend to design milk-run supply systems. Therefore, the contribution of this research will be significant to both the industry and the literature.

III. PROBLEM DEFINITION

The conventional deliveries occur on the bases of First in First out (FIFO) from supplier to customer. As it has been discussed earlier that if warehouse (D) are supplying goods to supplier A, B, and C, then deliveries occurs according to the necessity or requirement of suppliers. For example if supplier A wants goods the warehouse D will send the delivery then after the deliveries occurs to supplier B and supplier C according to their necessity. Milk-run material supply system is the round trips are goods collected from warehouse and transported to all suppliers at one trip.

![Fig. 2: Shows milk-run supply system for the manufacturing unit](image)

That will not only reduce the transportation cost but also time as well. There is also other problem connected with conventional supply system like rigid traffic condition, air pollution etc. So by implementing the milk run material supply system lots of problem could be overcome. Ultimately by using this supply system the material handling cost and inventory holding cost could be reduced to an extent level. The period of delivery time, routing of vehicle and pick up serviced need to be determined for the design of milk run material supply system. The mathematical model of the milk run design is explained in further section.
IV. FORMULATION OF MODEL

The mathematical model of the milk run supply system has been formulated in this section. Before the model explained, it is important to go through the assumptions and notations. They are given as below

1. The buffer stock at warehouse should be predetermined.
2. According to the route, the truck assigned for delivery must visit each supplier.
3. There should be only one dock at warehouse, which delivers the materials to all suppliers.
4. The service period should be known.
5. There should be continuous delivery of materials to all suppliers.
6. The demand rate of all suppliers should be predetermined.

The subscripts, parameters and decision variable are given below.

Subscripts
i, j: Stations point
a: Warehouse or Central depot
r: Routes index
t: Time periods
k: vehicle index

Parameters
N: Number of suppliers
Di: Demand rate of stock points per unit
Pi: Production rate of item x for suppliers i, j, k
C: Truck capacity
Tij: Transportation time to station i and k
S: Buffer stock held in warehouse
Hc: Inventory holding cost
Mc: Material handling cost
Tr: Transportation cost

Variables
Dperiod: Delivery time of truck from warehouse to each station
Qij: vehicle k assigned to route r (1 or 0)
Minc: Cost of delivery per vehicle
Router: 1, if vehicle travel in between or 0

A. Mathematical model

Minimize total cost

\[ = \sum_{r} (\text{route}_r + m\text{inc}) + \sum_{k} M\text{c} \times \frac{24}{D\text{period}} \sum_{i,j=1}^{n} Qij \]

\[ \sum_{i,j=1}^{n} Qij(Tij) \leq D\text{period} \]

\[ \sum_{i,j=1}^{n} QijD_i \times D\text{period} \leq C \]

\[ \sum_{i,j=1}^{n} Qij = 1 \quad (i = 1 \ldots n) \]

\[ \sum_{i,j=1}^{n} Qij = 1 \quad (j = 1 \ldots n) \]

The main objective of this model is to minimize the total material handling cost. According to milk-run material supply system the route is constructed, which certainly reduce the transportation cost at an extent level. In this model, there are two parts are explained. In the first part, minimum transportation cost of delivery per vehicle per route is obtained. In the second part total material handling cost per day is obtained, if the delivery occurs from warehouse to each station.

V. RESULT AND DISCUSSION

In order to analyse the performance of the model, the model is solved through integer software package. The parameters are used through mathematical model and the result is explained in various forms. The results are given in below tables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conventional supply system</th>
<th>Milk-run supply system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (Kms)</td>
<td>5756</td>
<td>4678</td>
</tr>
<tr>
<td>Travelling time (Hrs)</td>
<td>116</td>
<td>94</td>
</tr>
</tbody>
</table>

Table 1: Comparison between conventional and Milk-run supply system

As, it has been observed from the above table that the implementation of milk run material supply system affects the routing of vehicle significantly. It has been seen that the total distance has been reduce to 4678 kms from 5756 kms by just introducing the routes by the help of milk-run model. So as the total travelling time is also gone down to 94 hrs from 116, if the warehouse is making a delivery to 20 lines continuously in a day with various products.

It has not only save the total travelling time and cost but that will reduce the total inventory holding cost as well. As the continuous supply of material through milk-run supply system that will make the production line healthier and reduce the waiting period and buffer stock.

It is also observed if the minimal groups are made than the total travelling time is reducing to an extent level as well. Because the distance between each lines are very far, so if we make a group of 5 for each route/vehicle that will make a 4 routes to feed 20 lines , which can be feed by single vehicle using milk-run material supply system that will reduce the transportation cost.

<table>
<thead>
<tr>
<th>Route</th>
<th>Conventional supply system</th>
<th>Milk-run supply system</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>69072</td>
<td>56136</td>
</tr>
<tr>
<td>2</td>
<td>84025</td>
<td>72894</td>
</tr>
<tr>
<td>3</td>
<td>90354</td>
<td>86745</td>
</tr>
<tr>
<td>4</td>
<td>78034</td>
<td>64843</td>
</tr>
<tr>
<td>Total</td>
<td>321485</td>
<td>280618</td>
</tr>
</tbody>
</table>

Table 2: Comparison of operating cost between conventional and Milk-run supply system
The table shows the comparison of the total operating cost of conventional supply system and milk-run supply system. Four routes are developed on the appropriation of the supply chain. As, it has been observed from the above table that the total operating cost is reduced at a significant level by introducing routing of supply line by milk-run material supply system. If we supply to all 20 line by conventional supply system the transportation cost is 321485, which will reduced to 280618 by introducing milk-run material supply system.

VI. CONCLUSION

In this paper, the vehicle routing problem was investigated for the multi- buyers from single warehouse supply chain with milk-run material supply system. On the basis of all analysis the mathematical model is proposed for the design of milk-run material supply system. In which single warehouse serves the 20 various buyers from different areas. According to this supply system vehicle leave from the depot and serves all the suppliers on predetermined path and return to depot periodically. The objectives of this model are to reduce the total inventory holding and material handling cost. Is has been observed form the above section that the total transportation cost and waiting time is reduced significantly, which will took down the inventory and material handling cost.

The mathematical model is used to calculate the requirement of number of vehicles and period of the routes. Although the mathematical model is non-linear due to continuous demand of each station and it is not precise for the large scale problem. Therefore it will be inevitable to use heuristic approach and compare them to reach at an optimal solution. During the design of a milk-run material supply system the routing of vehicle, period of the delivery and pick up service is determined. In future studies scheduling of vehicles and calculation of service period can be done that ultimately considers the total material handling and inventory holding cost.

REFERENCE


Annexure: II
Design and development of an internal milk-run material supply system in automotive industry.

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Abstract

Material handling is one of the most crucial issues that should be taken into account for eliminating waste and reducing the cost. The purpose of this paper is to develop a mathematical model and a heuristic approach, which will be helpful to construct the routes and determine the service period for the design of an internal milk-run material supply system. The material supply by this system occurs on a just-in-time basis from a central warehouse to several stations of an assembly line. Milk-run material supply system is the round trips are either goods collected from several suppliers and transported to one customer, or goods collected from one supplier and transported to several customers. Besides, the heuristic approach intends to construct routes based on an initial service period value and attempts to improve the solution by considering different period values. Furthermore the scheduling of the vehicles will be calculated based on necessity of the raw materials and routes. The most suitable solution will be decided on the basis of the least total material handling and inventory holding cost. The objective of the mathematical model is the minimization of the total material handling and inventory holding cost. These saving could be either use for reduction of the product cost, which will boost up the sales or to lift the company profit margin.

Keywords: Milk run material supply, JIT

1. Introduction

Milk-run supply system can be classified into external milk-run system and internal milk-run system. Internal milk-run systems are those that deliver parts to the customers inside of the plant. Application of milk-run distribution systems in plants is to standardize the material handling system and eliminates the waste. If a good material handling system design is accomplished, it is claimed that the cost will decrease between 10% and 30% [2]. In a typical industry, material handling composes the 25% of the workers, 55% of the factory area, and 87% of the production time [3]. The objectives of the lean logistics are the delivery of the right mix of products at the right time to the right place, and carry out these activities, effectively [1]. Assembly lines must satisfy the customer demand neither late nor early, because early production incurs inventory holding cost and late production causes either lost sales or backlog. Therefore, parts supply to the point of use in the assembly line must be also achieved just-in-time (JIT). Otherwise, either time losses may occur due to disorganized and insufficient material supply to the assembly line, or excess inventory accumulates. JIT material delivery to the internal customers is usually achieved by means of the pull production control that employs Kanban. Pull production control mechanism is based on replacement of a predefined level of buffer stock of parts needed for an operation. Whenever a workstation starts consuming parts from a container, it detaches the Kanban attached to it and posts it into a Kanban post or puts into the order box, which is an order of a container of parts. The Kanban are collected frequently by the material handling staff, and the material requirements are satisfied by the supplier of each station of the line. The exact number of parts must be delivered to prevent inventory holding.

Today, assembly lines usually require many types of components at different stages of assembly operations simultaneously. The need to move small quantities of large number of items within the plant with short and predictable lead times without increasing transportation costs resulted in development of milk-run material delivery systems [1]. Milk-run delivery system picks up and delivers containers of parts along the fixed routes which comprised of a predetermined set of stock points of the stations of an assembly line, based on a schedule. Therefore, integration of pull production control with the milk-run part supply system for the assembly lines is beneficial. The contribution of this research will be development of a mathematical model and a heuristic approach where the routes are constructed and the service period is determined for the design of an internal milk-run material supply system that works on just-in-time basis. Both of the techniques consider the total material handling and inventory holding cost. Especially, in cases of large real-life problems, the route construction algorithm (heuristic approach) is beneficial.

2. Literature review

During the review of JIT parts supply of materials studies, papers of two inter-related topics were reviewed: Kanban or pull production control papers and milk-run material supply papers. Kumar and Panneerselvam [6] made a critical review of Kanban papers and examined the papers about single-card and two-card Kanban systems, blocking mechanisms coupled with the buffer capacities, and measure of performance. In addition, Junior and Filho [7] focused on special cases or variations of the Kanban systems developed to overcome the problems occurring due to the unfavourable conditions of
The authors reported that most of the proposed systems follow the original Kanban logic. In addition, Hao and Shen [8] reviewed the studies considering Kanban systems and concluded that these relevant papers did not consider the material handling issues at the shop floor level, though it affects the system performance considerably [8]. In contrast to the Kanban literature, there exists a limited literature on milk-run material supply system, based on the pull philosophy. This type of papers about milk-run material supply systems can be divided into two groups: internal and external milk-run. Internal milk-run systems are those that deliver parts to the customers inside of the plant. Vaidyanathan et al. [4] analysed the JITVRP (just-in-time vehicle routing problem) and emphasized the unique characteristic of this problem. JITVRP requires that the quantity to be delivered at each of the demand nodes is a function of the route taken by the vehicle assigned to serve that node. The authors developed a non-linear mathematical model for this problem, relaxed it by making some assumptions and proposed a linear model that attempts to determine the lower bound for the number of vehicles required [4]. Moreover, a two-stage heuristic algorithm was proposed in this paper, for the solution of the problem. Satoglu et al. [15] explained JIT periodic material supply system for assembly line. They approached heuristic and mathematical method for routing. However, the researchers did not attempt scheduling of the vehicles in their research.

Domingo et al. [9] explained a real implementation of milk-run material supply system that serves a lean assembly line. They followed a practical approach. First, the stock points where pickups and deliveries were determined. Then, the sequence of operations was defined and alternative routings were determined. The stock points with high demand rates and those with lower demand rates were included in separate routings. Then, the pickup and delivery schedule were developed. However, the researchers did not attempt to make an optimal milk-run delivery system design. Alvarez et al. [10] presented a case study of the redesign of an assembly line by using lean production tools. To reduce lead time and excessive stocks and improve material flow within the manufacturing system, Kanban-based production control and a milk-run material handling system were implemented. The authors realized that the design of Kanban production control system is insufficient without implementing an appropriate material handling vehicle [10]. Boysen and Bock [11] considered scheduling JIT part supply to a mixed-model assembly line where assembly line and the warehouse are at different factory floors. The authors used dynamic programming and then simulated annealing for the solution of the problem. Hao and Shen [8] developed a prototype software system that integrates discrete event simulation with agent-based simulation technique to evaluate the performance of a Kanban-based milk-run system serving an assembly line. In addition, Costa et al. [12] analysed the milk-run material delivery system of an electronics company using the simulation technique. In addition, Nemoto et al. [16] explained JIT external milk-run applications of the Toyota automobile assembly factories located in Thailand.

Some studies considered time windows and VRPSPD (vehicle routing problem simultaneous pick-up and delivery). Angelelli and Mansini [13] formulated a mixed-integer non-linear model of the VRP (vehicle routing problem) with time windows and simultaneous pick-up and delivery. The term of “time windows” means that the material handling vehicle's pickup and delivery service at a supplier must be started and completed between the predefined time points. Ohlman, Fry, and Thomas [14] considered the VRP with time windows and split deliveries, where orders are picked up from a network of suppliers and delivered to the depot of a lean (JIT) production system. The authors divided the problem into two phases: the routing phase and the scheduling phase. Similarly, Chuah and Yingling [5] developed a non-linear mathematical model of the VRP with time windows and considered high-frequency and small-quantity deliveries from suppliers to a JIT assembly plant. Based on this review, it can be also deduced that there are only a few internal milk-run system studies in the literature. It has been observed that many manufacturing companies around the world aim to implement milk-run approach inside their production systems. Thus, there is a considerable requirement of studies that intend to design internal milk-run systems. Therefore, the contribution of this research will be significant to both the industry and the literature.

3. Conclusion
The research can be carried out by two different methods called mathematical model and heuristic approach. The delivery of the parts to the station of assembly line will be based on JIT. Considering a central warehouse, where vehicle will pick up the full containers of components and deliver them to the buffer stock area. Once assembly line will start to consume these components from a container, it will issue a Kanban card, in other word indication of the requirement of another container. The vehicle will collect the requirement from the unit specified by Kanban and deliver the full container to the buffer stock area. The vehicles delivery will be on JIT basis, neither late nor early. The mathematical model will be used to calculate the requirement of number of vehicles and period of the routes. Although the mathematical model is non-linear due to continuous demand of each station [4] and it is not precise for the large scale problem. Therefore it will be inevitable to use heuristic approach and compare them to reach at an optimal solution. In this method an algorithm (Route construction algorithm) will be developed. It will be helpful to calculate the feasible route and scheduling of vehicles.
During the design of a milk-run material supply system the routing of vehicle, period of the delivery and pick up service will be determined. The objective of this model is to construct the route, scheduling of vehicles and to determine the service period that ultimately minimizes the total material handling and inventory holding cost.

Reference

Annexure: III
Implementation of milk run material supply system in vehicle routing problem with simultaneous pickup and delivery

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ABSTRACT

The vehicle routing problem is a common central problem in operations research arise in various fields, required to optimally route a fleet of vehicle to several set of consumers with simultaneous pickup and delivery. Material handling is one of the most critical problem that should be considered importantly for eliminating waste and reducing the cost. In large scale industries various transportation systems are considered in order to material requirement of the system. However, it is very complicated especially dealing with large scale industries with enormous number of material need to be delivered at various locations. This paper reviews the most efficient methods (nonlinear method and heuristic approach) to solve related issues. The optimal method enhances the truck utilisation, cargo loading efficiency, inventory holding cost and total transportation cost. It helps to use operation research techniques to develop a mathematical model to solve a vehicle routing problem considering simultaneous pick-up and deliveries with time constraints. This optimal method reduces the number of trucks on road as well, which leads to decrease a traffic problem, so ultimately the burning of fossil fuel can be decreased and carbon dioxide emission in environment will be decreased. During the design of milk run new routes will be developed and ultimately overall flexibility can be increased based on the demand of customer or suppliers.

Keywords: Vehicle routing, Material handling, Kanban, Milk-run

1. INTRODUCTION

The material handling system required provision of large and medium scale production system for proper planning. It is not only focus on the production, but mostly effects on the supply chain and management of material. The prime aim of this paper is to review a technique, which leads to reduce transportation cost, reduced inventory holding cost and delivery of the materials to customers in right amount at right time and on right place. Milk run supply system is also known as the cyclic goods supplying system, where goods are either collected from the several supplier and deliver to the certain customer or goods are collected form the certain supplier and deliver to the several customer in cyclic manner. In this method good collection take place to different supplier in one truck following predefined route to collect parts or product to deliver them to the factory[1]. The aim of this paper to review the most efficient technique to develop a mathematical model and a heuristic approach, where the construction of routes and determination of the service period will be take place for vehicle routing problem by milk-run material supply system that works on just-in-time basis with simultaneous pickup and delivery considering time frame. The primary purpose of establishing a supply chain is to minimize the flow of row material at every point in order to improve the productivity and achieve a cost saving[9]. Assembly lines must satisfy the customer demand neither late nor early, because early production incurs inventory holding cost and late production causes either lost sales or backlog. Therefore, parts supply to the point of use in the assembly line must be also achieved within just-in-time (JIT)[10]. Otherwise, either time losses may occur due to disorganized and insufficient material supply to the assembly line, or excess inventory accumulates. It has review that when dealing with major scale industries especially continuously changing the demand nonlinear mathematical model need to be formulate, which has to compare with the heuristic algorithm to get the optimal solution.

2. LITERATURE REVIEW

The vehicle routing problem (VRP) has been extensively studied in operations research since last five decades. Ben Peterson and Willem Hoeve presented that it is absolutely challenging to design a fixed set of truck routes depend on the various demand of the customer[4]. The concept of milk run logistics is a cover of transportation network, where all input and output material requirement of several station and according to several predefined schedules [1]. Gurinder
and Gagan Saini analysed milk run logistics and give a directions of the trucks, which create a route of the materials. During the review of JIT parts supply of materials studies, papers of two inter-related topics were reviewed: Kanban or pull production control papers and milk-run material supply papers [5]. David Gyulai [2] consider layout of shopfloor define a set of routes and station in this point defines a “route node”, which helps to find an amount of transported goods and required to cycle time of transportation [2]. Theeratham and Manoj [3] made a critical review on the auto manufacturing industry milk run operation, pickup truck and supply auto parts to suppliers. It creates a column generation technique exploits an important characteristics of most large scale linear program to solve branch and bound algorithm. One of the most benefit is that author can design a simple algorithm which generate column outside the branch and bound tree also reduced size problem. Swee Li Chee [5] studied the method on the production planning and control than the present a push system, which is analysed on the simulation model. This process created a number of Kanban card, which help to create a hybrid Kanban system to handle urgent order, Toshinori Nemoto [6] made a critical review of milk run logistics on the Japanese automobile manufactures in Thailand is perform to maintain a small lot frequency delivery to assembly, which reduce a gap between transport frequency and production. Second JIT concept is also involve in paper [6]. Toshinori Nnemeto [6] reviewed the JIT concept on the assembly line, although create a nonlinear mathematical model to help in demand of the each stations. It will issue a Kanban card and help on the buffer stock area and create a mathematical single warehouse serve the 20 various buyers from different area. The model reduced transportation cost and inventory cost. Padmanabha Raju n [7] reviewed the supply chain system win - win process. It increases strong relationship between customers and supplier, satisfaction of the customer, reduce inventory, improve time to market, decrease cost and improve profitability. In addition, Junior and Filho [7] focused on special cases or variations of the Kanban systems developed to overcome the problems occurring due to the unfavourable conditions of use. The authors reported that most of the proposed systems follow the original Kanban logic. In addition, Hao and Shen [8] reviewed the studies considering Kanban systems and concluded that these relevant papers did not consider the material handling issues at the shop floor level, though it affects the system performance considerably [8]. Macro Dewitz and Stefan Galka [9] research on the drive through concept in milk run or tugger train is an efficient way to supply the production area at higher frequencies. In this process it is fully automated storage system. It can also analysed on outputpoint of ASRS concept cost effective. Zhenlai You and Yang Jiao [10] reviewed that milk run scheme can help to find shortest distance and lowest cost. Milk run model can improve the load factor, advance time efficiency fulfill transport demand. In this studied environment issue and time constraints also studied. Swee Li Chee [5] analysed the milk-run material delivery system of an electronics company using the simulation technique. In addition, Nemoto et al. [6] explained JIT external milk-run applications of the Toyota automobile assembly factories located in Thailand. Some studies considered time windows and VRPSD (vehicle routing problem simultaneous pick-up and delivery). Zhenlai You and Yang Jiao [10] formulated a mixed-integer nonlinear model of the VRP (vehicle routing problem) with time windows and simultaneous pickup and delivery. The term of “time windows” means that the material handling vehicle’s pickup and delivery service at a supplier must be started and completed between the predefined time points. Based on this review, milk run logistic utilise the trucks efficiently in terms of the truck space utilisation becomes very high. Its result in less environment impacts, including carbon dioxide emission. It can also deliver parts to supply line at the right time on the demand of the customer.

3. FEATURES OF MILK RUN MATERIAL SUPPLY SYSTEM

Milk run supply system can be further divided into the two categories, the one of that is called as external milk run logistic and the other one is called as internal milk run logistic. Internal milk run logistic for the delivering the goods within the plant or specified are like an assembly line. On the other hand external milk run logistic run between the warehouse to the distribution centres. Now a days the business environment is becoming increasingly competitive as supply-chain business customers expectations ratchet ever upwards and the capability of competing companies to deliver consistent quality at low prices continues to develop. The major organisation spend lot of capital towards the transportation cost. Therefore it is inevitable to implement a proper transportation system to cut the total cost of product to sustain in the competitive globe. Milk run material supply system is not only being used by automobile industries but also many other industries has accepted the cost cutting material supply system. Milk run has been accepted and implemented by the small scale industries as a frequent part procurement supply system, especially in developing countries. Milk run material supply system is secure logistics system which means it reduces transportation related concerns at an extent level. Standard material handling system can minimize the total material handling and inventory holding cost to the extent level. It is will mainly focus on quality and speed of the transportation with below mentioned features.

- Design of a milk-run material supply system, that will enable to determine routing and scheduling of vehicle, period of the delivery and pick up service.
- The objective of this model is to construct the routes, scheduling of vehicle and determine the service period.
- Milk run material supply system can minimize the total material handling and inventory holding cost.
• Reduction of exhaust gas emission of pollutant in environment by constructing cyclic routes and efficient utilisation of no. of vehicle.

4. CONCLUSION

In this paper, we mainly concentrate on the milk run vehicle routing problem with simultaneous pick-ups and deliveries with time frame for determining the effective milk run plan for minimum transportation cost in minimum time duration. Milkrunk method either delivers materials from suppliers to the factory or factory to the customers. Implementation of milk run material supply system successfully will improve loading rates and reduce number of trucks utilities and travel distance. Vehicle routing problem can be solved by mainly two method first one is algorithm and second method with the help of the operation research techniques (nonlinear methods). As a result it can find a minimum transportation cost and exhaust gases emission can be reduced due to less vehicle utilisation. To address the problem of having route construction algorithm for milk-run supply system, we need to develop a mathematical model and heuristic approach that constructs the routes and determines the service period on just-in-time basis to minimize material handling and total inventory holding cost. As in real world large scale problem, due to continuous demand of material non-linear model may not go through the high accuracy. It is inevitable to implement the heuristic approach. Milk run process will decrease transportation cost, reduce inventory and decrease global warming problem in environment.

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