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].

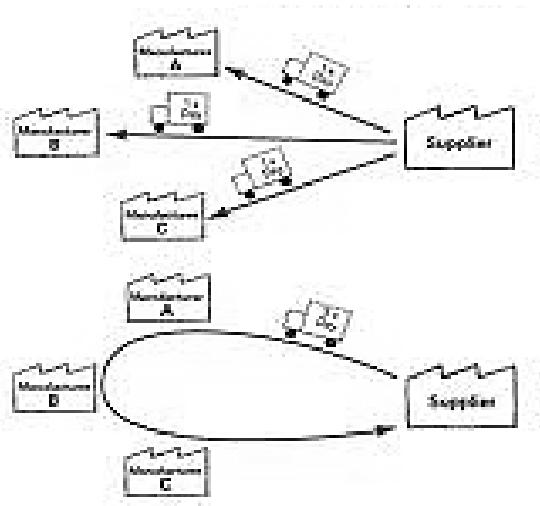

Fig. 1: Milk run material supply system

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

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 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 suppling a 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.

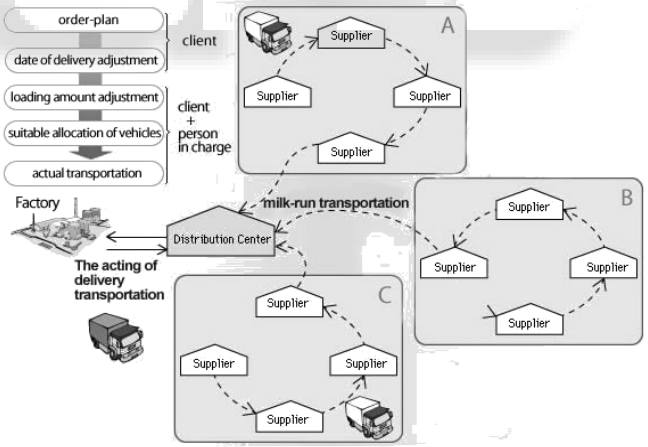

Fig. 2: Shows milk-run supply system for the manufacturing unit

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

$$= \sum_{r} (\text{route}_{r} + minc) + \sum_{k} Mc \times \frac{24}{Dperiod} \sum_{i,j=1}^{n} \text{Qij}$$

$$\sum_{i,j=1}^{n} Qij(Tij) \leq Dperiod$$

$$\sum_{i,j=1}^{n} QijDi \times Dperiod \leq C$$

$$\sum_{i,j=1}^{n} Qij = 1 \ \ (i = 1 \dots \dots n)$$

$$\sum_{i,j=1}^{n} Qij = 1 \ \ (j = 1 \dots \dots n)$$

$$\sum_{i,j=1}^{n} Qij = 1 \ \ (k = 1 \dots \dots n)$$

$$\sum_{i,j=1}^{n} Qij \ \leq Di$$

$$Dperiod \geq Minc$$

$$Qij \in (0,1)$$

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.

Variable	Conventional supply system	Milk-run supply system
Distance (Kms)	5756	4678
Travelling time (Hrs)	116	94

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.

Is 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.

Route	Total cost	
	Conventional supply system	Milk-run supply system
1	69072	56136
2	84025	72894
3	90354	86745
4	78034	64843
Total	321485	280618

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.

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