Optimization of 'Milk Run' of JCB India Ltd. (Ballabhgarh Plant)

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***Abstract*—JCB India Ltd. is a construction equipment manufacturer. Every production day, required materials in manufacturing of equipments produced at their Ballabhgarh Plant are brought in by Milk Runs, or from warehouse inventory. This paper is an attempt to minimize cost of Milk Runs for JCB India Ltd. The system is mathematically modeled to minimize total time for milk runs, followed by formulation and solution of a 'Bin-packing problem' to fit requisite number of trips into minimum possible number of trucks.**

***Index Terms*—Milk runs, milk runs optimization, time minimization problem, bin packing problem.**

I. Introduction

Logistics forms a very important part of the Supply Chain. Timely and adequate availability of raw materials is essential for the production to run smoothly in any factory. As discussed by Chopra and Meindl [1], Milk Run is one of the common ways to facilitate material transport from suppliers to the plant. The routing of the Milk Run vehicles falls under the Vehicle Routing Problem (VRP). In the specific case of JCB India Ltd. (Ballabhgarh Plant), it comes under the scope of Vehicle Routing Problem with Time Windows (VRPTW) [2]. There has been significant work done in the area of Milk Runs already, as noted by Brar et al [3]. Sadjadi et al [4] have discussed minimizing the cost of the Milk Run based on simultaneously minimizing the transportation cost and the inventory costs, and have formulated the problem as a mixed integer problem. They have proposed a static solution to the problem of Milk Run route allocation, whereas Du et al [5] look at the dynamic solution, i.e real time dispatch of vehicles for optimized performance of the system. We develop a new approach for JCB's logistics since their transportation system is different from traditional Milk–Runs and cannot be modelled by any existing work.

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The components, parts and raw materials that are required in the manufacturing of the various machines produced at the Ballabhgarh Plant are brought in every production day. The space for inventory is very limited in the plant area; thus the shop floor inventory, on an average, is not more than an hour for each type of component. The demand of materials is catered to by Milk Runs, direct supply by the suppliers, or bringing the requisite amount from the warehouse, located 4 Km from the plant in Ballabhgarh. JCB India Ltd. has outsourced the daily working and managing of Milk Runs. The suppliers are classified on the basis of their distance from the JCB plant. The suppliers within 20 Km radius fall into the scope of Milk Runs. Suppliers farther away are covered under 3rd Party Logistics (3pl). Some suppliers supply the parts directly to the JCB plant i.e. they are not under 3pl or Milk Runs, they have chosen to supply the materials themselves. There are 18 suppliers that fall under the scope of the Milk Runs. The unloading of the materials is done in the logistics area of the plant. The JCB Ballabhgarh plant has 8 Docks which are used for unloading of the vehicles. The central purchase department decides what parts to buy from which supplier. JCB India passes on its production plans to the suppliers one month in advance (in the last week of the previous month). The logistics department coordinates with the Logistics Service Provider (LSP) team to plan out the routes of the trucks, and the schedule of Milk Runs.

Currently, the LSP runs 24 trucks in the Milk Runs every day to cater to the need of the materials by the plant. There are two types of trucks that are being used: TATA 709 and TATA 1516. The maximum capacity of a TATA 709 is 6 tonnes and the maximum capacity of a TATA 1516 is 9 tonnes. The LSP charges JCB India on the number of trucks it is plying every day, plus a certain fixed administrative cost per day it handles. One important condition imposed by JCB India is that each truck being used must make at least 3 trips every day. Further, by design the LSP trucks are required to follow a 'to and fro' movement pattern. Almost every truck collects material from the supplier, say supplier A,

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delivers it to JCB plant and makes at least 3 such trips every day. Given the constraints and peculiarities of the system, including the mindset of the management, it is not possible to switch over to a traditional Milk Run type movement pattern for the optimization of which there exists a variety of models and abundant prior work [6-8]. Therefore, JCB India Ltd formed a team to look at how their operations could be improved in the current framework. The team included a senior executive - a Vice President of JCB India Ltd - G. Sundararaman, and a two member team from the Indian Institute of Technology (IIT) Delhi. We tried several approaches including modelling the system as a weighted travelling salesman problem, but none could fit the requirements well. Eventually, we developed the model proposed in the paper, which to the best of our knowledge, is unique in the context of milk-runs. Our main contribution thus is to develop a mathematical model based on Mixed Integer Linear Programming (MILP) and Bin Packing to optimize the transportation costs within this framework.

Let C_1 be the cost per small truck (709) per day, C_2 the cost per large truck (1516) per day, and C_3 fixed administrative cost per day charged by the LSP to JCB. Let number of small trucks used everyday be n_1 and no of large trucks used everyday be n_2. Presently, n_1=14 and n_2= 10 (14 small and 10 large trucks). Then the total cost of Milk Runs per day (C) is given by:

$$C = n_1 C_1 + n_2 C_2 + C_3 \quad (1)$$

II. Daily Working

The LSP decides the window timings for the suppliers. This means allocating time slots for pick up of materials from their docks and times slots for unloading that truck in the docks of JCB India Ltd. The suppliers are expected to adhere to this schedule as they also sign on a contract agreeing to the window times, and other details. On the production volume, upto 115 machines can come off the assembly line. On every production day, the trucks are available for 12 hours, but the working hours are only 10 (breaks for lunch and tea take up the remaining 2 hours).The timings are from 8 am to 8 pm. There are over 300 different components that are brought in via Milk Runs, from the 18 suppliers.

Some suppliers have special requirements for the vehicles in which their material is to be carried. For example, two of the suppliers who supply the cabins for the backhoe machines, their supplies must come in trucks that have been modified in a specific way. So the trucks that bring material from them cannot be used to bring material from any other supplier. Thus, 5 small trucks have been dedicated to these two suppliers. They have been modified as per the requirement, and are used to ferry cabins from these suppliers to JCB, and cannot be used for any other supplier. Thus the remaining suppliers are catered to by 19 trucks (9 small, 10 large).

Some of the important things of this model are discussed in detail in the following section. A point to be noted is that henceforth, whenever the term supplier is used, it should be understood as one of the 16 suppliers coming under the umbrella of the Milk Run (excluding the two whose requirements are special and cannot be treated as a general case).

A. Window Timings

The time slot in which material is to be picked up from the supplier is called the window time. These are allocated to various suppliers keeping in mind a lot of factors. Almost all of the suppliers have only one loading dock, thus they can cater to only one truck at a time. As mentioned before, JCB's Ballabhgarh plant has 8 docks. The window times for the supplier should clearly be non – coincident.

B. Round Trip Times

The trucks start from the JCB compound, travel to the supplier, get loaded, travel back and are unloaded. The total time consumed is sum of all these times, and is called the total round trip time. It depends on the suppliers distance from JCB plant, the size of truck (larger truck takes longer to load as more material is to be loaded), the type of component in the truck (large parts like axles can be quickly loaded and unloaded, as compared to tiny components which come in small packaging, eg rubber hoses). Most of the trucks run to and fro between a particular supplier and JCB for the entire day.

C. Total Available Time and Capacity of Trucks

All the trucks are available effectively for 10 hours every day. So, total availability is the number of trucks times 10. The small trucks can bring maximum of 6 tonnes and large trucks can bring maximum of 9 tonnes in a trip. Underutilization of capacity is avoided as far as possible.

A couple of other noteworthy things are that sometimes, unplanned emergency trips are needed to cater to the required materials. Some of the suppliers require less than one trip in a day, when, for example, a single trip is enough to cater the needs from two supplier A and B i.e the truck can go to A first, then to B and then to JCB all in one trip. Then the total goods transported from both of these can fit into a single trip.

D. Mass to be Transported from a Particular Supplier

The mass to be brought from each supplier can be easily calculated based on the present schedule. Suppose a_i trips of the small trucks and b_i trips of the large truck are planned for the i^{th} supplier for every day, and m_i be the mass to be transported. Since the maximum capacity of the small truck is 6 tonnes and that of the large truck is 9 tonnes. Thus,

$$6a_i + 9b_i = m_i \quad (2)$$

III. Problem Definition

After analysing the current Milk Runs carried out by the LSP in cooperation with JCB India Ltd. the problem can be described as in Fig. 1:

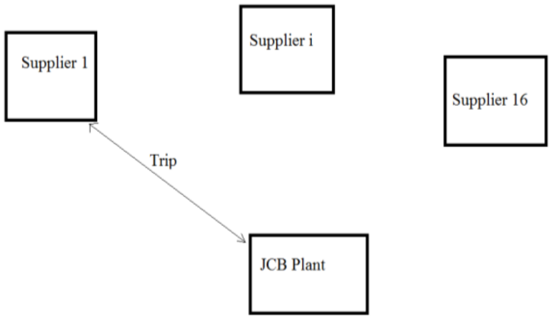

Figure 1. Problem Description

There are 16 suppliers, and the i^{th} supplier has to supply mass m_i in a day. Now, the problem is to figure out how to transport all that mass to JCB, adhering to the present window timings, and making sure that the capacities of the trucks are not exceeded, and all the material reaches on time, while minimizing the total cost function (Equation 1). In the next section, we describe the mathematical model to solve this problem.

IV. Mathematical Modelling

In this section, we develop a model for this system that takes into consideration the following:

1) *The objective of the model is to minimize the cost for JCB.*

2) *The following are the physical constrains :*

- All the required components of a day's production must reach JCB.
- Capacity of the truck must not be exceeded in any trip (in terms of mass and volume)
- Minimum of three trips per truck per day.

The pairing up of certain suppliers has been done together based on their proximity and the fact that all the material required from them can be brought into JCB in one trip itself. These are very special trips and extreme care has to be taken to plan them. Therefore, another constraint of the system is that neither can the pairing of such supplier be changed, nor the window timings. Thus, we leave them untouched in our optimization model for now are adjust them into the schedule at a later point in time. So, there are effectively 16 suppliers, with 19 trucks (10 large, 9 small) catering to their requirements. Out of the 16, 7 fall into the special category where the suppliers are paired up together.

Let s_i and t_i be the round trip times to the i^{th} supplier, for a small and large truck respectively, including the travel, loading and unloading times. Let T be the total time spent on the Milk Run in a day. Recall that a_i and b_i are the number of small and large truck trips respectively, to the i^{th} supplier. Then,

$$T = \sum_{i=1}^{9}(a_i s_i + b_i t_i) \quad (3)$$

This total time is catered to by 19 trucks, each of which can provide 10 working hours. If T is reduced, the total number of trucks in use is reduced, thus reducing the cost of Milk Run. All the aforementioned constraints need to be implemented. We do the optimization in two stages. In the first stage we optimize the total number of trips and in the second stage, we pack those trips to trucks, subject to the capacity constraints (in terms of time). In the following two subsections, we develop the Mixed Integer Linear Programme (MILP) and the bin-packing problem model.

A. Mixed Integer Linear Programme (MILP) Formulation

Let x_i be the number of small trips and y_i the number of large trips to the i^{th} supplier according to our model. Then the problem can be formulated as:

$$Objective\ Function:\ Minimize: T = \sum_{i=1}^{9}(x_i s_i + y_i t_i)$$

$$Subject\ to:$$

$$6a_i + 9b_i \geq m_i \qquad \forall\ i \in (1,2, \dots 16) \quad (4)$$

where the constraints allow the mass requirements to be met. In this model, the daily requirement is put in as direct constraints. The capacity of the trucks is exactly 6 tonnes for small and 9 tonnes for large trucks, thus ensuring capacities are not exceeded. All the required data (s_i, t_i, a_i, b_i) were tabulated and fed into this MILP, and then it was solved using CPLEX software. This gave a new profile of the number of trips of small and large trucks required at each of the suppliers, i.e. the solution set $\{x_i, y_i\}$.

B. Bin Packing Formulation

We thus have the optimum type and number of trips to reduce the total time of the Milk Runs. To get the number of trucks from the obtained solution, the number of trips has to be 'packed' into 'trucks'. Every truck is available for 10 hours every day. Each round trip is certain duration in minutes. Also, we know the different types (s_i) of the trips, and the number of those trips (x_i). This problem is solved separately for the large and small trucks. This is a standard Bin Packing Problem [9], which is formulated as follows:

$$Minimize: z = \sum_{i=0}^{n} k_i \quad (5)$$

Subject to:

$$\sum_{j=1}^{n} w_i p_{ij} \leq 600 k_i \quad i \in N = (1,2, \dots, n) \quad (6)$$

$$\sum_{i=0}^{n} p_{ij} = 1 \quad j \in N \quad (7)$$

$$k_i = 0\ or\ 1 \quad i \in N \quad (8)$$

$$p_{ij} = 0\ or\ 1 \quad i \in N, j \in N \quad (9)$$

where k_i = 1, if i^{th} truck is used and 0 otherwise; p_{ij} = 1, if j^{th} trip is assigned to i^{th} truck and 0 otherwise; w_j is the time duration of the j^{th} trip and n - the total number of trips - is given by:

$$n = \sum_{l=1}^{9} x_l \tag{10}$$

The solution of the bin packing problem gives us:

- The index i, which gives us the number of trucks, and
- The variable p_{ij} that represents the allocation of trucks to trips.

V. Results And Discussions

In this section, we compute the percentage improvement in logistics cost using our model. Presently, n_1=9, c_1=2659, n_2=10, c_2=3621, c_3=7104 and using (1), C= 67245. We solve the MILP and bin packing problem in CPLEX to get the following optimal solution:
n_1=3, c_1=2659, n_2=12, c_2=3621, c_3=7104, thus leading to C=58533 using (1). In other words, the reduction in total logistics cost expected from the implementation of this model is Rs. 8712 every day, or Rs. 2265120, i.e. Rs. 2.2 Million. In percentage terms, our model can reduce the Milk – Run costs of the JCB India Ltd. Ballabhgarh plant by 12.9%.

Thus, as expected, modeling and optimization can yield significant benefits to the logistics operations. In this case the operations cannot be modeled as a conventional milk-run where the delivery vehicle goes to multiple suppliers in a single trip and the objective is to find the optimal route. As mentioned earlier, the management at JCB is not yet ready to move to such a system, and hence the need to develop a different model to optimize the operations.

Our proposal is currently under consideration for implementation at the plant.

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