A Lean Scheme for Improving Vehicle Routing Operations

Bernardo Villarreal, Mayté Sañudo, Arminda Vega, Santiago Macias and Elsa Garza
Departamento de Ingeniería
Universidad de Monterrey, San Pedro Garza García, N.L., México 66238

Abstract

The Vehicle Routing Problem is well known in the Operations Research and Just in Time literature. From the O.R. point of view, the interest is concentrated on the development of algorithms to achieve an optimal solution to the problem with zero excess cost/distance/time. From the JIT literature, Vehicle routing is also known as a milk run and it is a fundamental element to enable JIT integration with suppliers. Under this approach, the routing operation should be as efficient or wasteless as possible. This work suggests to integrate both views; O.R. and JIT, into a comprehensive scheme that has the purpose of identifying and reducing waste. Examples of the application of the scheme are provided.

Keywords
Transportation waste elimination, lean transportation, value stream map, transportation efficiency

1. Introduction

The Vehicle Routing Problem is well known in the Operations Research and Just in Time literature. Its application is well suited to situations in which full truck loads are not possible, and the consolidation of orders or loads from several points are required to achieve higher capacity utilization levels for reducing transportation cost. From the O.R. point of view, the interest is concentrated on the development of algorithms to achieve an optimal solution to the problem. The aim is to achieve the minimum cost, distance or time solution.

From the JIT literature, Vehicle routing is also known as a milk run. It is a key aspect to enable frequent shipments of small lots from suppliers to customers, and therefore allowing for a Just in Time integration with them. Under the JIT approach, the goal would be to look for the most efficient operation by eliminating all kinds of waste, including even excess distance travelled or time taken to carry out a route.

This work provides a brief description of an approach to integrate both views; O.R. and JIT. The scheme suggested has the purpose of reducing waste related to the overall efficiency of the transportation vehicles. This has been discussed previously by [15,16]. This report consists of five sections. The next section deals with a brief review of the literature on the Vehicle Routing Problem (VRP) and lean transportation. Then, a description of the scheme utilized to decrease waste is described in section 3. The application of this scheme is undertaken in section 4, and section 5 presents a summary of conclusions.

2. Previous Research

The vehicle routing problem (VRP) is one of the most studied among the combinatorial optimization problems, due both to its practical relevance and to its considerable difficulty. The VRP is concerned with the determination of the optimal routes used by a fleet of vehicles, based at one or more depots, to serve a set of customers. The objective considered could be the minimization of distance, time or cost. In certain sense, the purpose would be to eliminate excess distances or time which are considered as wastes in the lean thinking arena. Several surveys of the different algorithms developed to solve the VRP problem with various characteristics and assumptions are provided by [1,3,5,6] and others. In classical VRP, the customers are known in advance. Moreover, the driving time between the customers and the service times at each customer are used to be known. The VRP consists of designing a set of least-cost (distance or time) vehicle routes in such a way that: (i) each customer is visited exactly once by exactly one vehicle; (ii) all vehicle routes start and end at the depot; (iii) some side constraints are satisfied. This basic problem has many variants. Among the most known are the Capacitated VRP (CVRP), VRP with time windows (VRPTW), and VRP with pick-up and deliveries (VRPPD).
It is well known that transportation is an activity classified by the lean movement as waste. However, in a world where markets are distant, it becomes a necessary activity to move goods to each customer. Therefore, if it cannot be eliminated, the goal is to make it as efficient as possible to reduce cost or distance/time. The activities involved in a routing operation are: shipment preparation, transporting goods and serving each customer assigned, going back to the origin and closing the route. This cycle could be repeated if required to satisfy market demand. It is then fair to consider all these activities when looking for the most efficient operation. However, the formulation of any of the VRP variants concentrates on improving the transporting activities. The rest are included in the formulations as "givens" ([9]). They are represented by fixed parameters, i.e., load/unload times and customer service time.

In summary, improving routing operations has been mainly sought by operations researchers through the development of algorithms that look for the achievement of “zero travelling distance or time wastes”. However, it has been found by [7,8,10 - 14] that this is not the only important concept of waste occurring in this activity. Thus, if the goal is to obtain an efficient routing operation, the current approach to improve it must be modified to consider all the activities.

Lean is the relentless elimination of waste in every area of operations. The origins of lean can be traced back to the 1930s when Henry Ford revolutionised car manufacturing with the introduction of mass production techniques. However, the biggest contribution to the development of lean manufacturing techniques over the last 50 years has come from Japanese automotive manufacturer, Toyota. Taiichi Ohno defined seven common forms of waste: production of goods not yet ordered; waiting; rectification of mistakes; excess processing; excess movement; excess transport; and excess stock. The Lean approach to enable waste elimination throughout the supply chain was extended in [17]. Transportation is one area where the application of lean techniques would yield important benefits.

The literature research on the development of concepts, methodologies and applications of lean thinking in the transportation sector is rather limited. A new measure called Overall Vehicle Effectiveness, OVE, to be used for improving the performance of truck transportation is provided in [10]. It is an extended version of the Overall Equipment Effectiveness indicator employed in lean manufacturing to improve equipment efficiency. A modified version of the OVE measure is suggested by [15]. This is called TOVE and considers total calendar time instead of loading time. This is due to the fact that waste identification and elimination is related to the transportation vehicles utilized to move product. Since vehicles represent a high investment, it is very important to keep them in operation at all time. As illustrated in Figure No. 1, four components for the new efficiency measure are suggested; Administrative or strategic availability, operating availability, performance and quality efficiencies. The new measure would be obtained from the product of administrative availability, operating availability, performance and quality. There are several waste concepts associated with each efficiency factor. For example, fill loss, speed loss and excess distance travelled are wastes that impact performance efficiency. Wastes related to quality efficiency are % of clients not serviced, % of demand not satisfied or product defects originated by mishandling during transportation. Driver breaks, breakdowns and corrective maintenance, and customer excess service time affect operating availability efficiency. The concept of vehicle administrative availability is important because it has a significant impact on the overall vehicle utilization and efficiency. It is mainly the result of administrative policies and strategies related to capacity or maintenance decisions. The main waste associated with this concept is nonscheduled time. A Value Stream Map suggested by [15] for transportation processes (TVSM) concentrates on identifying waste related to transport efficiency.

As illustrated in Figure 1, performance wastes are the ones related with the VRP problem solution. Applying VRP algorithms will eliminate excess distance and fill loss wastes. Availability and quality type of wastes could be reduced by improving routing activities through the application of IE and TQM tools.

3. A Lean Routing Scheme
According to [15], routing activities could be defined as In-Tansit (IT), that is, while the transportation service is in process, otherwise it would be Non-In-Transit (NIT); i.e. loading or unloading product at a distribution centre. Let us define as the transportation journey (TJ), the time specified for the transportation activity for the team of operators and the vehicle. This may be a fixed period such as a shift of eight hours, or variable depending on the distance required to travel to the customer. We will assume that there always be 24 hours per day available for the service, and so, several routing journeys (or services) are during a day. An activity is defined as Internal if it is carried out during the TJ by the team of operators with the vehicle. If it is carried out off the TJ or by another organizational entity, the activity is called External. The ideal would be that NIT activities are also external, and IT
activities are carried out internally.

A general procedure for reducing transportation waste that is adapted from the broad scheme suggested by [4] is provided by [13,14] to apply a lean improvement approach. The scheme suggested by [15] to reduce waste in transportation that is illustrated in Figure No. 2. The first step is the description of the transportation activities in detail complemented by the estimation of the TOVE index and the elaboration of the corresponding TVSM. The structure of the map can be divided into the macro context and the micro analysis phase.

![Diagram of TOVE structure and Transportation Wastes](image)

Figure 1 Description of TOVE structure and Transportation Wastes

The following stage consists of identifying waste at the macro level and particularly looking for opportunities to improve administrative availability. The macro context is directed to identify the macro characteristics of the route, namely; Average journey duration, the modified TOVE index and its components, vehicle administrative availability utilization based upon calendar time, availability wastes occurring off the route (such as vehicle nonscheduled time and scheduled maintenance time) and the proportion of internal and external activity time. This part of the map may serve to guide the improvement efforts according to the values of the TOVE factors; Availability, performance and quality. At the same time, if all the transport activities are internal there will be an important opportunity to improve vehicle efficiency.

The following stage focuses on identifying waste at the micro level. Especially, waste that impact on performance, operating availability and quality factors. The micro analysis phase completes the analysis of the wastes that drive vehicle operating availability, vehicle and route performance, and important route quality wastes. In this phase, the availability wastes considered are driver breaks, excess load/unload time and excess time taken by the operating team to carry out administrative activities with the customer. Performance wastes include speed and fill losses and excess distance required to fulfill customers demand. Quality wastes in transporting could refer to administrative errors, product defect generation and route customers not served on time and/or fully.

Given the most relevant waste concepts identified, a strategy for their elimination is devised and implemented in the final stage.
4. Applications of the Scheme

This section describes the application of the scheme in the distribution operations of two Mexican companies. The first application is on the distribution of bottled beverage to selling and consumption points located in the suburban area of Monterrey. The second application is on the routing operations of a leading retailing firm. In this case, the distribution centers located at Monterrey and Torreon supply goods to the firm’s retail network located at the Northeast of Mexico.

4.1 Waste identification for both companies

This section is devoted to describe the phases of waste identification for both firms of interest. The first company processes and distributes bottled beverage. It is an important company located in the north of México. A detailed description of the application is provided in [2]. In particular, we will focus on the distribution from regional distribution centers (DC’s) to retailing points such as convenience store chains, independent retailers, and supermarket chains. The company has several regional distribution centers, and for convenience, the one located in Monterrey will be described.

![Figure No. 2 General structure of transportation waste reduction scheme](image)

Given the most relevant waste concepts identified, a strategy for their elimination is devised and implemented in the final stage.

This regional DC counts with a fleet of about 90 trucks. The DC serves about 6000 customers that include selling points (convenience stores and the like) and consumption points such as pubs, restaurants and the like. The distribution of beverage is made daily through 76 fixed routes. The main strategic concern of the company in México refers to cost reduction. In order to handle this situation, the firm established a company wide strategy for reducing cost. Since routing cost became an important component of the total cost structure in recent years, mainly due to fuel increases above inflation rate, it was necessary to consider it for improvement.

Mapping the Transportation Process

The first step of the methodology is to map the transportation processes of interest which in this case correspond to the vehicle routing distribution from Monterrey DC to convenience stores. The TVSM for the routing operation is shown in Figure 2.

Identify relevant wastes at macro level

As previously stated in section 3, waste identification at this level emphasizes the overall context of the routing process chosen to study. The average journey time for the distribution of goods from the Monterrey DC to its corresponding retailing stores is 11.5 hrs increasing the cost associated to overtime labor very significantly. All the activities included in the process, from preparing the routes, serving the stores until closing every route are executed during the journey, i.e. all are internal. Internal NIT activities take 2.5 hrs on average about 22% of journey time. The average number of stores served by a route is 15.

TOVE index is estimated at 3%. The factors with greatest areas for improvement are operating and administrative availabilities with 19% and 31% respectively. Performance factor with 47% presents also a great area for improvement. The quality factor is estimated at 96% due mainly to product defects found at the customer premises.
**Identifying key wastes at micro level**

This stage is concerned with the analysis and identification of wastes and their causes in detail. The main area for improving in this case is to increase both the administrative and operating availability efficiencies.

The main waste that drives administrative availability efficiency down is the unplanned truck time of 13 hours. Thus, routing capacity utilization is less than 50%! The wastes that impact the most operating availability efficiency are internal NIT activities that account for 2.5 hrs and an excess customer service time of 65%. NIT activities include loading and unloading trucks, load inspection and closing the routes. These should be executed off the journey time by warehousing personnel. If this is done properly, the driving crew will utilize its working journey time in transit activities and will be able to serve more customers.

Customer service time includes the time taken to perform unloading product, inspecting and verifying with the store leader if the order is complete and getting and loading returns. The time taken to loading returns correctly is very important. Driver breaks were not scheduled and unscheduled maintenance was minimal.

The best option to increase performance efficiency is the reduction of excess distance travelled and fill loss wastes. Both wastes were impacted by the utilization of daily fixed routes with disregard of customer demand behavior. Daily demand from Monday to Wednesday was lower than the level shown during the period from Thursday to Sunday. Additionally, even though the firm owns a license of the UPS Roadnet suite, routes are not designed according to daily demand. Furthermore, route sequences are determined by the driver every day. Fill loss estimated in 55% was estimated from the loads carried by a significant sample of routes. Excess distance of 19% was estimated by comparing current route distances against the optimal determined by the UPS Roadnet for a significant sample of routes.

**Waste identification in the Retailing Company**

The discussion of this case is based on the work [16]. The firm is in the Mexican retailing sector and owns one of the largest convenience store network of the country. This consists of three echelons; Distribution centers (DC’s), cross docking points and the convenience stores. The network consists of ten DC’s, eleven cross docking points and about 7000 stores. The project has been divided into various phases of implementation and in this report, only the first phase is partially described. This describes only the application to the part of the network served by the DC’s located at Monterrey.

Given the actual fierce competition, the company launched a strategy for reducing operating cost throughout the supply chain. Transportation cost is the most important logistic cost of the firm. We will attack in the first phase 12% of this cost. Monterrey DC is located in Escobedo, Nuevo León, and serves directly 1174 stores that represent 18% of the total number of stores in México. These stores are assigned further to five operating zones; Monterrey, Tampico, Saltillo, Monclova and Allende.

**Mapping the Transportation Process**

The first step of the methodology is to map the transportation processes of interest which in this case correspond to the vehicle routing distribution from Monterrey DC to convenience stores (see Figure No. 2).

**Identify relevant wastes at macro level**

The average journey time for the distribution of goods from the Monterrey DC to its corresponding retailing stores is 9.85 hrs. All the activities included in the process, from preparing the routes, serving the stores until closing every route are executed during the journey, i.e. all are internal. Internal NIT activities take 2.17 hrs on average about 22% of journey time. The average number of stores served by a route is eight. TOVE index is estimated at 7%. The factors with greatest areas for improvement are operating and administrative availabilities with 39% and 41% respectively. Performance factor with 51% presents also a great area for improvement. The quality factor is estimated at 96.3% due mainly to customer unsatisfied demand.

**Identifying key wastes at micro level**

The best option to increase performance is the reduction of excess distance travelled estimated at 41%. This waste is originated mainly by two aspects. The first cause has to do with the elaboration of daily distribution routes. These were initially carried out manually by the route planner. Given the size of the operation, the variability of daily demand and the
rate of new store introduction, it was impossible to ask for good feasible routes. Route updating was nil. The second cause for deficient routing is due to the positioning of the Distribution Center (DC) utilized as the starting point for all routes. The current position has not been revised even though customer demand and new stores have changed in terms of location. The estimation of the level of waste was done by taking a sample of original routes and applying the UPS Roadnet software to determine optimal routes and several cross docking positions. The distance saved was of the order of 41%. In addition, there is also a fill loss of 15% that could be reduced through better route design.

The wastes that impact the most operating availability are internal NIT activities that account for 2.17 hrs and an excess customer service time of 50%. NIT activities include loading and unloading trucks and closing the routes. These should be executed off the journey time by warehousing personnel. If this is done, the driving crew will utilize its working journey time in transit activities and will be able to serve more customers.

Customer service time includes the time taken to perform unloading product, inspecting and verifying with the store leader if the order is complete and getting and loading returns. The excess time is also due to the establishment of very restrictive simultaneous time windows assigned to all suppliers originating additional waiting. Driver breaks were not scheduled and unscheduled maintenance was minimal (0.15 hrs).

The principal waste impacting the quality efficiency is the customer unsatisfied demand. This is estimated at 3.7% of sales. An analysis to determine the cause of this situation yielded that the picking and inspection operations were being executed poorly. Unsatisfied demand could have been covered because it was on stock, however it was not picked. Inspection procedures at the distribution center consist of manual sampling schemes that inspect 48% of the items required by orders from the stores. The previous situation has also a negative impact on the time required to serve each store. Store leaders asked for an intensive verification process of the shipments to make sure that they were received complete. Hence, the time taken to serve each store increased due to this situation.

4.2 Defining waste elimination strategy for both firms.

The definition of the strategies required for improving routing operations depends on the relevant wastes identified. As illustrated in Table 1, there is a great room for improvement in the availability efficiency factors, as well as in the performance efficiency factor.

<table>
<thead>
<tr>
<th>Efficiency factor</th>
<th>Bottled beverage case</th>
<th>Retailing case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative availability</td>
<td>31</td>
<td>41</td>
</tr>
<tr>
<td>Operating availability</td>
<td>19</td>
<td>39</td>
</tr>
<tr>
<td>Performance</td>
<td>47</td>
<td>51</td>
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<td>Quality</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td>TOVE</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>

The initiatives suggested for increasing the efficiency level of the routing operations are summarized in Table 2. An important project considered by the companies is the application of VRP solution algorithms to improve performance efficiency. Both firms have acquired the UPS Roadnet suite. An equally important set of initiatives is concerned with the implementation of IE initiatives necessary to increase the level of truck availability efficiencies.

Both firms decided to implement the initiatives in two phases. Initially, the idea was to improve significantly the availability efficiency factors. The goal of this stage was to have the highest level of truck availability for transporting products. As a result of this stage they expected the following:

- Each truck is scheduled for routing twice a day.
- Operating availability increased to a level greater than 90%.
- Increase the average number of customers served by route by at least 20%.
Figure 2 Transportation Value Stream Maps for Companies

Warehouse

Not-in-transit activities

In-Transit activities

Route preparation

Transport planning

Serving first client

Route closure

Serving last client

E-orders

Not-planned time = 13 hrs

Preventive maintenance = 30 min

Operating availability

Not-in-transit activities

In-Transit activities

50 min

Time between clients

= 40.6 min

Serving time per client

= 31.05 min

µ = 29 min

σ = 3.67 min

11.5 hrs

Performance Efficiency

Fill loss = 54.9%

Excess distance = 19.0%

Operational Availability

Excess serving time = 65.1%

NIT activities = 15.9%

Corrective maintenance = 2.08%

Transport planning

Warehouse

R e t u r n

Serve Last Customer

Route Preparation

Serve First Customer

4

Route Closing

Warehouse

Not-in-transit activities

In-Transit activities

Product

Demand

Operational Efficiency

Fill loss = 15%

Excess distance = 41%

Speed loss = 0%

Average clients/route = 8

Average travel time = 1.50 hrs

Return

Average return time = 0.88 hrs

Average transit time = 7.68 hrs

Average time = 9.85 hrs

Operational Availability

Fill loss = 13.9%

Excess serving time = 0.53 hrs

Corrective maintenance = 1.1 hrs

Return

Average travel time = 9.85 hrs

Operative Availability Efficiency

Not planned time = 13 hrs

Preventive maintenance = 30 min

All activities are Internal!

Performance Efficiency

Fill loss = 54.9%

Excess distance = 19.0%

TOVE Index = 3%

Adm Availability Effic = 31%

Operating Avail Effic = 39%

Performance Effic = 47%

Ave number clients = 15.25

Administrative Availability

Not planned time = 13 hrs

Preventive maintenance = 30 min

Journey time = 9.85 hrs

In-transit time = 7.68 hrs

Not-in-transit time = 2.17 hrs

387
<table>
<thead>
<tr>
<th>Initiative Description</th>
<th>Bottled Beverage</th>
<th>Retailing</th>
<th>Impact on</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Moving internal NIT activities to external by assigning them to warehousing operators</td>
<td>X</td>
<td>X</td>
<td>Availability Efficiency Factors</td>
</tr>
<tr>
<td>- Improving picking inspection, and return unloading procedures at the distribution center</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Eliminating inspection stages before routing</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Improving inspection procedures at the distribution center to reduce unsatisfied demand and excess time needed to verify products at stores</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>- Negotiating full time window flexibility with store leaders including night hours</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>- Redesigning procedures to serve customers with the use of technology</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>- Implementing UPS Roadnet software to design dynamic routes according to demand</td>
<td>X</td>
<td>X</td>
<td>Performance Efficiency Factor</td>
</tr>
</tbody>
</table>

The second stage consisted of applying VRP solution schemes. The projected objective includes the following.

- The elimination of excess distance travelled in each route.
- An increase of truck capacity utilization to levels greater than 90%.

The management of both companies estimated to achieve the following results, once both stages were fully implemented.

- A reduction of the number of weekly routes of at least 15%.
- A decrease of operating routing cost of at least 25%.
- A lower future investment requirement for trucks.

5. Conclusions

Vehicle routing operations has become an important issue for implementing JIT strategies in lean supply chains. Modeling these operations led researchers to develop an immense amount of publications and applications of the so-called Vehicle Routing Problem. The main objective of the VRP has been to minimize or eliminate excess distance/time/cost. This approach has overlooked the possibility of eliminating other type of (availability) wastes that could improve the efficiency of routing. This paper reviews the literature of lean methodology in the field of routing operations. It provides with the help of two real applications evidence of the potential benefits of applying a more comprehensive approach to the improvement of routing operations. The one suggested in this work looks for the identification and elimination of specific wastes associated with the transportation of goods to improve its efficiency. This is applied to the distribution networks of two Mexican companies.

As illustrated in Tables 1 and 2, the most significant improvement areas are related not only to the performance efficiency factor, emphasized by solving the VRP problem. There is a great area for improvement of routing operation in the availability factors. The particular wastes to be reduced are: Excess customer service and waiting times, excess route distance, truck fill loss capacity and the reassignment of NIT activities from internal to external status. The strategy devised to eliminate the identified wastes includes not only the application of UPS Roadnet software. Other projects based on IE and TQM techniques are also recommended. The application of the lean scheme proved to be very helpful to provide a more comprehensive guide to support management on the definition of an improvement strategy, and investment decision making.

The strategies for reducing waste are being implemented in both companies. The results obtained from the analysis and preliminary implementation actions give the responsible management high hopes and confidence that the overall initiative will be very successful.
References


