A Sequential Truck Transportation Waste Reduction Scheme

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Abstract — This work describes a proposed sequential scheme to identify and eliminate transportation waste. Current available schemes are based on eliminating transport efficiency wastes and do not consider this feature. The sequential nature of the scheme enables the possibility of handling multiple objectives, limited resource and goal setting situations. This new scheme considers also the elimination of the seven transportation extended wastes. The application of the improvement scheme is illustrated in the routing operations of a Mexican company.

Keywords-- Transportation waste elimination, lean routing, value stream map, transportation efficiency, sequential decision making.

I. INTRODUCTION

Freight transportation by truck has become an important element of international trade and supply chains performance. According to the [1], 68% of total tonnage moved in United States in 2010 was done by truck. Also, 29% of the tonnage of the trade with Mexico and Canada was done under this mode of transportation. The Mexican Transportation Secretary informed in [2] that about 75% of total ton-km was carried out by truck in year 2013. Finally, the European Commission reported in [3] that the European Union (27 members) moved 27% of its ton-km by truck.

Truck transportation has traditionally been stated as inefficient, both in European countries ([4, 5], North America ([6, 7]) and in México ([8]). Therefore, the potential of adapting and using a waste elimination framework to improve truck transport operations appears to be important.

The problem of concern in this paper is the improvement of transport operations performance. This problem has been treated exhaustively in the academic literature. Two approaches have been used to attain this goal; the mathematical modelling approach and the efficiency improvement approach. Under the first approach several classical problems have been utilized: The Vehicle Routing problem ([9, 10, 11]), the Transportation problem ([12, 13]) and others. These models have the objective of minimizing cost, time or distance. The efficiency improvement approach is based on the idea of eliminating waste. This scheme has the purpose of identifying and reducing waste in this activity and is discussed in detail in [14 – 19].

Our main contribution in this work is focused on proposing an approach of reducing waste in a sequential manner, and that can incorporate the two main streams of transportation waste classification known to date. This new approach is of interest in situations in which there are multiple objectives, budget constraints or performance goals are established. The paper is structured on five sections. The following section provides a brief review of the literature on lean transportation. The scheme utilized to decrease waste is described in section 3. The application to a Mexican firm is undertaken in section 4, and section 5 presents a summary of conclusions.

II. PREVIOUS RESEARCH

An alternate movement to improve transport operations has emerged in the last decade. It is an extension of the lean approach to the transportation operations. Under this movement, improvement is achieved by identifying and eliminating wastes relevant to transport operations. Traditionally, the focus of research within the Lean field has been on production activities related to quality improvements and the quest for increased efficiency. Transportation is often not regarded as a value-added activity and often is as waste that should be, if possible, eliminated ([20]).

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 [20]. The use of the Value
Stream Map ([20]) and the Supply Chain Mapping toolkit, described in [21] is fundamental to identify waste in this scheme. When mapping at the supply chain level, unnecessary inventories and transportation become important wastes to identify and eliminate. It is worth noticing that unnecessary transportation waste is related to location decisions that seek to optimize performance at individual points of the supply chain. Therefore, the solutions suggested for its elimination are concerned with the relocation and consolidation of facilities, a change of transportation mode or the implementation of milk runs.

A. Increasing Transport Efficiency

The first work dealing with transport efficiency improvement through waste elimination is due to [22]. According to these authors, eliminating unnecessary transportation can also be achieved increasing transport efficiency in addition to a change of transport mode or the relocation of facilities. Two main streams based on waste elimination have been suggested for increasing transport efficiency: The first scheme was initially proposed by [14]. This contribution recommends a new measure called Overall Vehicle Effectiveness, OVE, to be used for improving the performance of truck transportation. This 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 [18]. This is called TOVE and considers total calendar time instead of loading time (see Figure 1). In summary, four components for the new efficiency measure are suggested: Administrative or strategic availability, operating availability, performance and quality. The new measure would be obtained from the product of administrative availability, operating availability, performance and quality. 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. A value stream map for transportation processes (TVSM) that concentrates on identifying waste related to transport efficiency is suggested by [18]. It has been found that waste related to operating and administrative availabilities are very important. ([15, 16, 22]) and fill loss values ([23-26]).

The second scheme is provided by [27]. They propose the identification and elimination of transport wastes that are an extension of the seven wastes suggested by the Toyota Production System (TPS). Table 1 illustrates a description of these wastes in a transportation setting. A case study carried out through in-depth interviews with experts from the transportation and the Lean fields resulted in an adapted waste framework for motor carrier operations. The result of this study was that five out of the seven classical waste types can be applied in the motor carrier waste framework, but two do not fit, namely waste of excess inventory and conveyance. Instead, two new waste types are included: resource utilization and uncovered assignments. With these two additional new types, an adapted framework of seven wastes for motor carrier operations is developed. The new framework of 7 wastes in motor carrier operations was tested by studying operations at five different motor carrier operators in Sweden and Switzerland. The results from these studies validated the applicability of the new 7 waste framework for motor carrier operations and thereby confirmed the results of the interview study.

The framework was validated with a quantitative and qualitative multiple case study of three motor carrier operators in Sweden and two in Switzerland. The studies looked both in detail at the administrative and planning procedures in the office, as well as at the execution of the actual transport operations. The results indicated that 28.93 percent of the transport time is either partly or completely wasted. Driving between loading/unloading locations, loading and unloading were not considered waste, whereas extra driving, copying documents, controlling work of other people, walking around, phone calls (while standing still), extensive (≥50 percent) and/or non-registered (driver regulation) breaks and waiting were classified as waste.

III. PROPOSED METHODOLOGY

Transport waste elimination schemes available are limited. The broad scheme provided by [28] to implement lean improvement initiatives is modified in [16,17] to eliminate transportation waste. This is further modified by [18] to adapt it more specifically to transportation operations. The initial step is the description of the transportation activities in detail complemented by the estimation of the TOVE index. This is achieved by elaborating the Transportation Value Stream Map (TVSM). The structure of the map can be divided into two stages. The first stage is intended to gather information to explain the macro context of the transportation activities – i.e. general context of the operations and the values of all the efficiency factors described on the right of the TOVE measure in Figure 1. The second stage is used to facilitate the micro analysis phase in detail. Here, all the relevant wastes associated with the efficiency factors (described on the left of the TOVE measure in Figure 1) and their causes are identified. The previous scheme lack of a sequential mechanism to eliminate waste according to a certain criteria.
TABLE 1. DESCRIPTION OF SEVEN TRANSPORTATION EXTENDED WASTES (from [18])

<table>
<thead>
<tr>
<th>Waste</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overproduction</td>
<td>Producing reports no one reads or needs, making extra copies, emailing/faxing the same document/information multiple times, entering repetitive information on multiple documents and ineffective meetings</td>
<td>Definition by Tapping and Dunn (2006), confirmed in the empirical study</td>
</tr>
<tr>
<td>Waiting</td>
<td>Employees having to stand around waiting for the next process step, such as loading and unloading, or just having no work because of lack of orders, processing delays, equipment downtime and capacity bottlenecks</td>
<td>Definition from production (Likir, 2004), loading and unloading added as a common cause for waste of waiting noted from the empirical study</td>
</tr>
<tr>
<td>Incorrect processing</td>
<td>Consuming more resources for moving the goods than necessary due to inefficient routing or driving</td>
<td>Definition suggested based on the empirical study</td>
</tr>
<tr>
<td>Unnecessary movement</td>
<td>Any wasted motion employees have to perform during the course of their work, such as looking for information, reaching for, or stacking goods, equipment, papers, etc. Also, walking and extra movement created by sequencing errors is waste. This was found to be synonymous with conveyance</td>
<td>Definition by Tapping and Dunn (2006), movement due to sequencing errors added from the empirical study</td>
</tr>
<tr>
<td>Defects</td>
<td>Waste caused by repairs, redelivery, scrapping, etc., due to damages on the transported goods or the equipment</td>
<td>Damages to the equipment added to the production definition, in alignment with the empirical study</td>
</tr>
<tr>
<td>Resource utilization (new)</td>
<td>Waste due to excessive equipment and bad resource planning</td>
<td>Definition suggested based on the empirical study</td>
</tr>
<tr>
<td>Uncovered assignments (new)</td>
<td>Carrying out unprofitable transport work due lack of information or planning</td>
<td>Definition suggested based on the empirical study</td>
</tr>
<tr>
<td>Excess inventory &amp; Conveyance</td>
<td>Not applicable</td>
<td>Not reported in the empirical study</td>
</tr>
</tbody>
</table>
A. New Sequential Scheme

The scheme suggested by [18] is modified in this section to incorporate a dynamic and sequential feature. Figure 2 illustrates the main steps of the scheme. The initial step consists of the elaboration of the TVSM and the establishment of multiple objectives with priorities, an operational goal to achieve or an investment level that cannot be surpassed. Then, the following step consists of identifying waste at the macro level and particularly looking for opportunities to improve Administrative Availability. The macro context is required to identify the macro characteristics of the route, namely; average journey duration, the current TOVE index level and its components. It is very important to analyse vehicle Administrative Availability utilization based upon calendar time. Identify availability wastes occurring off the route (such as vehicle nonscheduled time and scheduled maintenance time) and the proportion of internal and external activity time. 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 to estimate each efficiency factor. Then, these are prioritized according to a certain criterion, e.g. contribution to increase TOVE index or an objective such as cost or customer service. One selects the factor with highest priority for further work. This process is carried out sequentially according to the priority assigned to each efficiency factor. After selecting the efficiency factor, it is suggested to identify the Seven Transportation Extended Wastes associated to enhance the process of defining initiatives to improve it. Improvement initiatives are generated and implemented. Next, results are compared with the goal or the budget and, if required, the previous process is continued.

![Fig. 2. General structure of transportation waste reduction scheme](image)

IV. IMPLEMENTATION AND RESULTS

The suggested scheme is illustrated by applying it to a Mexican company engaged in the production and distribution of refrigerated food in the Mexican market. The company is experiencing a high pressure to improve its customer service level. Initially, the routes were missing 12% of their clients because they arrived late. The firm was willing to have a perfect customer service level, and if possible, to reduce distribution cost. The company’s distribution network has a primary distribution network that sends product from plants to Central Distribution Centers (CDC’s), and from these to Regional
Distribution Centers (RDC’s). It also includes a secondary network that takes the goods from the RDC’s to the retailing points or stores.

The primary network includes thirteen plants, five CDC’s and seventy four RDC’s located across México. It is divided into five geographical regions. This paper is concerned with the application of the project on the Northeastern region. The firm started an effort to reduce distribution cost in 2009. Villarreal, et al., 2009 illustrate a summary of the initiative applied on the Northeastern part of the primary network with the objective of eliminating waste to diminish transportation cost. The purpose in this document is to describe the efforts to increase customer service level without increasing transportation cost in the secondary network. We will particularly focus on the application in routing operations of the Escobedo RDC.

A. 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 the Escobedo DC to convenience stores. The current TVSM for the routing operation is shown in Figure 3. As stated in the last section, the firm was willing to satisfy a perfect customer service level as the first priority objective. The second priority was assigned to the reduction of distribution cost.

B. 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 Escobedo DC to its corresponding retailing stores is 12 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 2.5 hrs on average about 21% of journey time. The average number of stores served by a route is 40.

   TOVE index is estimated at 6.5%. The factors with greatest areas for improvement are performance efficiency with 24% and administrative availability with 50%. Operating availability and quality efficiencies are estimated in 76% and 75% respectively. The first priority objective of the company is the improvement of the customer service level. This has been measured by the number of clients served per route. Initially, 13% of the scheduled clients per route are not visited. This concept has been identified as a Quality efficiency waste. Therefore, this factor is chosen for improvement.

C. Identifying key Wastes at Micro Level
   The number of clients not served per route is due to either missing time windows or not having the time to visit them. This level of customer service may be increased by re-assigning time spent on waste activities associated to the performance and operating availability factors. Also, for our case, the percentage of clients not visited is part of the STEW, uncovered assignments waste.

   Performance efficiency and associated STEW wastes
   Since the Performance factor is the one that can contribute the most to the TOVE Index value, it is selected first for improvement. The main efficiency wastes that drive this factor down are fill loss with 69% and a distance traveled in excess of 32 kms. The idea would be to decrease the time taken to satisfy customers per route. This will be done by redesigning them in an optimal manner.

   Originally, distance traveled in excess is a result of an inefficient route design. This process consists of assigning customers to a truck and defining the sequence of visiting them. This process is carried out by each driver. There is not an effort to look for cost reduction and customer time windows are disregarded. In summary, driver’s experience and criterion are used to design daily routes. The previous process description corresponds to that of an Incorrect Processing type of waste defined by [18]. Fill loss is a result of truck capacity under-utilization. Truck capacity cannot be fulfilled because the number of customers visited in each route is insufficient. This quantity is limited by the journey time. The only way to increase it is by reducing customer serving and transporting times. This will allow each route to increase the number of customers visited. Table 2 illustrates a summary of the initiatives suggested to improve performance efficiency (and its associated STEW).
TABLE 2. SUMMARY OF INITIATIVES TO IMPROVE PERFORMANCE EFFICIENCY

<table>
<thead>
<tr>
<th>STEW</th>
<th>Efficiency Wastes</th>
<th>Description</th>
<th>Initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect processing</td>
<td>- Truck fill loss</td>
<td>- Sub-optimal assignment of clients to routes.</td>
<td>- Semi-dynamic route optimization</td>
</tr>
<tr>
<td></td>
<td>- Distance in excess</td>
<td>- Sub-optimal client sequencing by drivers.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- % of clients not visited.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource utilization (new)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncovered assignments</td>
<td></td>
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</table>

Semi-dynamic routing design and implementation

This initiative started with the definition of a new route redesign review period. At the time of the development of the project there was not a review period determined. Four years had passed and the market had changed significantly in terms of the quantity, location and demand of the clients. After analyzing market demand growth, it was decided that the company would carry out a weekly route redesign when additional new clients appeared. The company had the option of using the UPS Roadnet suite, which they already owned, or to rent the online version of VIAMENTE.

A sample of 30% of the routes was redefined (see Figure 4 for an example of a redesigned route). This task was carried out by using the software VIAMENTE. Here, both the assignment of clients and the sequence of visiting them were modified. As an initial step, it was decided to do a pilot test with ten routes during two weeks. This had the purpose of building confidence, and making the necessary adjustments for a successful implementation. The results from the pilot run showed a significant reduction on the average number of clients not served per route from six to zero. Average Journey time did not changed significantly.
The final stage of implementation of the previously described strategy is under way. The initial step consisted of the pilot test already explained previously. The second step, which has already started, is the redesign of 30 routes. After applying the optimization software, this number of routes is reduced to 26 without compromising the customer service level. The average number of clients to be served by each route increases about 17% and the distance traveled per route decreases 32%. Distribution cost decreases an estimated 19%. It is estimated that this effort will be completely implemented and stable during the first quarter of year 2015. Finally, this initiative will be applied to the rest of the routing operations during the second quarter of 2015.

D. Minimization of Distribution Cost
At this point, the first objective of achieving a perfect customer service has been achieved. Now, the firm decided to look for a lower distribution cost taking care of not impacting negatively the customer service level. The efficiency factor with the next highest priority for further improvement is the Operating Availability efficiency.

Operating Availability efficiency and associated STEW wastes
The main efficiency wastes identified in this factor are: driving crew idle time during route preparation, waiting time while closing routes and serving time in excess. The STEW related with the efficiency wastes are waiting and unnecessary movements.

<table>
<thead>
<tr>
<th>STEW</th>
<th>Efficiency wastes</th>
<th>Description</th>
<th>Initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting and Unnecessary movement</td>
<td>- Driving crew idle time in route preparation.</td>
<td>- Procedures for serving customers, preparing and closing routes have non-value activities.</td>
<td>- Eliminating waste in procedures</td>
</tr>
<tr>
<td></td>
<td>- Serving customer time in excess.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Waiting time to close routes.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The previous efficiency wastes are found in the processes of serving customers, and the NIT activities. These occur due to inefficient procedures that contain many non-value activities. Customer service time includes the time taken to perform activities that do not add value or are not simplified such as inspecting product and verifying with the store leader if the order is complete and getting and loading product returns. There is also the need to consider the time taken to obtain the payment of the order from the customer. NIT activities must not be a responsibility of the driving crew in principle. However, if these have to be done, the idea would be to make them very efficiently, without waste. Currently, NIT activities take about 2 hrs.

Simplifying procedures
The simplification of procedures in three stages of the routing operations was undertaken: During route preparation before trucks leave for distribution, during serving clients, and at closing routes.

Route preparation before leaving to distribute product took too long. Driving crews were idle at least 50% of the time, doing nothing. So, they could have about 30 additional minutes for routing and distributing product. Serving clients consisted of
Implementing the actions previously described together with the redesign of the 30 routes provides an additional reduction of distribution cost. The required number of routes decreases to 22 with no impact on customer service level. The average number of clients served per route goes up to 23%. The level of distribution cost is reduced an additional 22%. Finally, these initiatives will be completely implemented together with the redesign of routes during the second quarter of 2015.

E. Further Iterations

At this point, the most important initiatives have been considered. Further iterations of the scheme would involve the implementation of lower capacity truck replacement and the increase of customer frequency visit. Since these initiatives required higher investment and a Marketing focus input, the management responsible of the project decided to postpone its implementation until a proper evaluation and additional information was available.

V. CONCLUSIONS

This paper deals with an application of lean methodology to the field of transportation, and in particular, to routing operations. Our main contribution in this work is focused on proposing an approach of reducing waste in a sequential manner, and that can incorporate the elimination of STEW in addition to efficiency wastes. Actual schemes are based on eliminating transport efficiency wastes and do not consider this feature. This new approach is of interest in situations in which there are multiple objectives, budget constraints or performance goals are established. The scheme is illustrated by applying it to a Mexican company engaged in the production and distribution of refrigerated food in the Mexican market. The company has the purpose of improving its customer service level. Initially, the routes were missing 13% of their clients because they arrived late. The firm was willing to have a perfect customer service level, and if possible, to reduce distribution cost as a secondary objective.

The first priority objective of the company is the improvement of the customer service level. This has been measured by the number of clients served per route. This concept has been identified as a Quality efficiency waste. Therefore, this factor is chosen for improvement. Since the Performance factor is the one that can contribute the most to the TOVE index value, it is selected first for improvement. The main efficiency wastes that drive this factor down are fill loss with 69% and a distance traveled in excess of 32 km per route. The idea would be to decrease the time taken to satisfy customers per route. This will be done by redesigning them in an optimal manner. After applying the optimization software, this number of routes is reduced to 26 without compromising the customer service level. The average number of clients to be served by each route increases about 17% and the distance traveled decreases 32%. It is estimated that this effort will be completely implemented and stable during the first quarter of 2015. At this point, the objective of achieving a perfect customer service has been achieved. Now, the firm decided to look for a lower distribution cost taking care of not impacting negatively the customer service level.

The efficiency factor with the next highest priority for further improvement is the Operating Availability efficiency. The main efficiency wastes identified in this factor are: driving crew idle time during route preparation, waiting time while closing routes and serving time in excess. The STEW related with the efficiency wastes are waiting and unnecessary movements. The previous efficiency wastes are found in the processes of serving customers, and the NIT activities. These occur due to inefficient procedures that contain many non-value activities. The simplification of procedures in three stages of the routing operations was undertaken: During route preparation before trucks leave for distribution, during serving clients, and at closing routes. Implementing the actions previously described together with the redesign of the 30 routes provides an additional reduction of distribution cost. The required number of routes decreases to 22 with no impact on customer service level. The average number of clients served per route goes up to 23%. Finally, these initiatives will be completely implemented together with the redesign of routes during the second quarter of 2015.

The application of the suggested scheme proved satisfactory. The company personnel involved with the application was convinced of the value added by the scheme. However, more results will be necessary to test the performance of the process and the quality of results obtained.
REFERENCES


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BIOGRAPHY

Bernardo Villarreal is a full professor of the Department of Engineering of the Universidad de Monterrey. He holds a PhD and an MSc of Industrial Engineering from SUNY at Buffalo. He has 20 years of professional experience in strategic planning in several Mexican companies. He has taught for 17 years courses on industrial engineering and logistics in the Universidad de Monterrey, ITESM and Universidad Autónoma de Nuevo León. He has made several publications in journals such as Mathematical Programming, JOTA, JMMA, European Journal of Industrial Engineering, International Journal of Industrial Engineering and the Transportation Journal. He is currently a member of the IIE, INFORMS, POMS, and the Council of Logistics Management.

Andrea López graduated with honors (Cum Laude) in Industrial Engineering with an emphasis in Logistics from the Universidad de Monterrey (UDEM). Andrea had started her MBA in 2011. Andrea’s main work and research interest is supply chain management. She has collaborated in various Supply Chain projects such as “Lean Transport Optimization project” at Sigma Alimentos. She is currently working as a Demand Program Coordinator for Sigma Alimentos.

María-Eugenia Rendón is a CUM LAUDE Industrial Engineer graduated from Universidad de Monterrey (UDEM). She is actually a graduate student of the Industrial Engineering MSc program at UDEM. Her specialty is the operations and logistics improvement. She has participated on several projects such as The Redesign of the Supply Process of Drugs on a Medical Center and the Improvement of the Transport System on a Paperboard Manufacturer. Nowadays, she works at this company on the Commercial Efficiency Department, developing strategies for Improving Productivity.

Sofía García is an industrial engineer graduated with honors from the Universidad de Monterrey (UDEM). She is currently a graduate student of the MSc program of Industrial Engineering at UDEM. Sofía’s main work and research interest is supply chain management. She has collaborated in Supply Chain projects for different enterprises such as “Lean Transport Optimization project” at Sigma Alimentos. At present, she is a senior Demand Planner for Oxxo, the largest convenience store chain in Mexico.