Lean Road Transportation – A Systematic Method for the Improvement of Road Transport Operations

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Abstract

Road transportation has become an important factor in international trade and the management of supply chains. However, this form of product logistics has generally been considered inefficient. Traditionally, practical inefficiencies of road transportation have been addressed through mathematical modelling, operations research-based methods, and simulation. This paper presents an alternative systematic approach to improve road transport operations based on lean thinking and the reduction of the seven transportation extended wastes (STEWs). To do this, the paper reviews the extant literature in the area of lean road transportation, providing a structured research definition of the application of lean thinking in road transport operations and hence guidance on the limited research conducted in this field. The systematic lean transportation method is then presented and empirically tested through a case study in a Mexican firm. The results obtained from the case study indicate that the proposed systematic lean method is an effective alternative for the improvement of road transport operations, with the number of distribution routes and distance travelled being reduced by 27% and 32% respectively. The proposed method can be used by organisations as a guide to help them improve their road transport operations. In addition, the paper’s aim is to contribute by stimulating scholars to further study the application of lean thinking and waste reduction in road transport operations.

Keywords: Lean, road transportation, transportation efficiency, value stream mapping, waste elimination.
1. Introduction

Freight transportation by road has become an important element of international trade and supply chain performance. For example, according to the US Department of Transportation (2011), 68% of the total tonnage moved in the United States in 2010 was done by truck, whereas 29% of the ton-km of this country’s trade with Mexico and Canada was also moved under this mode of transportation. Similarly, the Mexican Transportation Secretary informed that in 2013 about 75% of total ton-km was carried out by trucks (Subsecretaría de Transporte, 2013). The European Commission reported in 2008 (European Commission, 2011) that the European Union moved 27% of its ton-km by truck. However, despite its importance, road transportation has traditionally been stated as inefficient in Europe (McKinnon et al., 1999; Swedish Association of Road Haulage Companies, 2008), US (Belman et al. 2005; US Department of Transportation, 2009) and Mexico (Instituto Mexicano para la Competitividad, 2004). To address the practical inefficiencies of road transportation, Sternberg et al. (2013) suggest that researchers have traditionally approached the improvement of road transport operations through mathematical modelling (e.g. Ghiani et al., 2003; Laporte, 1992; Hill and Benton, 1992; Bodin et al., 1983), operations research-based methods that include stochastic programming (e.g. Gendreau et al., 1996), genetic algorithms (e.g. Baker and Ayechew, 2003), heuristics approaches (e.g. Boudia et al., 2008; Pisinger and Ropke, 2007), among others, and simulation (e.g. Osorio and Bierlaire, 2013; Kuo, 2010). Under these approaches, various classical problems have been addressed. For example, the vehicle routing (e.g. Jemai et al., 2013; Kumar et al., 2012; Boudia et al., 2008; Chiu et al., 2006; Zhong et al., 2007), vehicle scheduling (e.g. Zhang et al., 2014; Eliiyi et al., 2009), and transportation problems (e.g. Yu et al., 2015; Lau et al., 2009), among others. These works have been mainly focused on optimising resource utilisation (e.g. Chiu et al., 2006; Zhong et al., 2007; Eliiyi et al., 2009), routes (e.g. Lau et al., 2009; Jemai et al., 2013), cost (e.g. Boudia et al., 2008; Eliiyi et al., 2009; Yu et al., 2015), time (e.g. Chiu et al., 2006; Zhong et al., 2007; Zhang et al., 2014; Yu et al., 2015) and distance (e.g. Zhang et al., 2014). However, the improvement of the actual road transportation operations to gain efficiency has rarely been studied (Fugate et al., 2009).

In the last decade, however, an alternative movement to improve road transport operations has emerged. This movement represents an extension of the lean production approach that advocates the application of its principles and tools to road transport operations. Since unnecessary costs and significant waste exist in most transportation networks (McKinnon et al., 2003), the “lean road transportation” movement is based on improving road transport operations by identifying and eliminating relevant wastes, also known as “non-value added activities” within the lean terminology. However, research on the application of lean thinking in the road transportation sector is scarce (Villarreal et al., 2009). It has been mainly limited to the definition of road transportation wastes (Sutherland and Bennett, 2007; Guan et al., 2003; Sternberg et al., 2013) as well as the development of lean performance measures (Guan et al., 2003; Simmons et al., 2004; Villarreal, 2012; Taylor and Martinchenko, 2006) and methods (Hines and Taylor, 2000; Villarreal et al., 2012; Villarreal, 2012; Villarreal et al., 2013) to assess performance and eliminate waste. Therefore, to complement and support the very narrow body of knowledge on lean road transportation, this paper presents a systematic method for improving road transport operations based on the elimination of the Seven Transportation Extended Wastes (STEW) proposed by Sternberg et al. (2013). This study also reports the implementation of the proposed method in the distribution network of a large Mexican organisation.
The rest of the paper is organised as follows: Section 2 provides a brief review of the main streams of research on lean road transportation; a description of the method proposed in this paper to improve road transport operations is outlined in Section 3, whereas its application is undertaken in Section 4; Section 5 discusses the results of the case study; and Section 6 presents the conclusions, limitations and future research opportunities derived from this research.

2. Literature Review

The lean philosophy considers transportation as waste (Womack and Jones, 2003). However, in the current globalised market, transportation is a necessary activity to deliver goods to customers. In fact, transportation can nowadays be considered as a differentiating factor that adds service value to customers (Villarreal et al., 2009). Thus, a line of academic research has been devoted to transfer the application of lean principles and tools to improve road transportation, particularly, through the elimination of waste. This research line has been conducted through three main streams as illustrated in the concept map in Figure 1.

2.1 Definition of road transportation wastes

Waste elimination is an important aspect of the lean concept (Pettersen, 2009) to increase value for customers (e.g. Bicheno, 2004; Dennis, 2002) and reduce costs (e.g. Monden, 1998; Ohno, 1988). Hence, researchers such as Guan et al. (2003), Sutherland and Bennett (2007), and Sternberg et al. (2013), realised the potential of adapting and using a classification of waste, departing from the seven wastes as defined by Toyota (Ohno, 1988), for the specific application to road transport operations. Villarreal et al. (2009) suggested this as one of the main research streams in the area of lean road transportation, see Figure 1. In particular, Sutherland and Bennett (2007) defined what they called the “Seven Deadly Wastes of Logistics” (i.e. overproduction, delay/wait, excess transport/conveyance, motion, inventory, space and errors). According to their study, these wastes keep supply chain management away from achieving its full business potential. Similarly, Sternberg et al. (2013) developed a waste framework, for motor carrier operations, which intends to provide a structured framework to identify, classify and understand inefficiencies in road operations. Sternberg et al. (2013) concluded that five, out of the seven Toyota wastes (Ohno, 1988), apply to motor...
carrier operations, but two do not, namely: waste due to excess inventory and conveyance. Instead, two new waste types were included: resource utilisation and uncovered assignments. Table 1 presents a brief description of the waste framework.

Table 1. Description of seven wastes extended to transport operations (adapted from Sternberg et al., 2013)

<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, e-mailing/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 Sternberg’s et al. (2013) 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 (Liker, 2004), loading and unloading added as a common cause for waste of waiting noted from Sternberg’s et al. (2013) 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 Sternberg’s et al. (2013) 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 Sternberg’s et al. (2013) 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 Sternberg’s et al. (2013) empirical study</td>
</tr>
<tr>
<td>Resource utilisation</td>
<td>Waste due to excessive equipment and bad resource planning</td>
<td>Definition suggested based on Sternberg’s et al. (2013) empirical study</td>
</tr>
<tr>
<td>(New)</td>
<td></td>
<td></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 Sternberg’s et al. (2013) 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>

Furthermore, based on an extended version of Overall Equipment Effectiveness (OEE) (Nakajima, 1988) termed as Overall Vehicle Effectiveness (OVE) (Simmons et al., 2004), Guan et al. (2003) identified five transport losses, or wastes; driver breaks, excess load time, fill losses, speed losses, and quality delays. These studies show that although the identification of road transportation wastes has gained the attention of researchers, it is an area which still requires further investigation.
2.2 Development of lean performance measures for road transportation

Measurement on a continuous basis is crucial to improve operations and supply chains (Cabral et al., 2012; Dey and Cheffi, 2013). In this situation, the application of lean practices to road transportation requires adequate metrics to measure the system’s performance as a basis for continuous improvement. Simmons et al. (2004) proposed OVE for monitoring and improving the performance of truck transportation. OVE is an extended version of the OEE indicator employed by lean to improve equipment effectiveness. A modified version of the OVE measure was then suggested by Villarreal (2012). This is known as Transportation Overall Vehicle Effectiveness (TOVE), which considers total calendar time, instead of loading time, as waste identification and elimination is related to the transportation vehicles utilised to move products. Since vehicles represent a high investment, it is important to keep them in operation at all times (Villarreal, 2012). Figure 2 compares and illustrates the elements of OVE and TOVE, and their related wastes.

![Diagram of OVE and TOVE structure and components](image)

Simmons, et al., (2004) OVE = (Availability x Performance x Quality)

Villarreal (2012) TOVE = (Administrative Availability x Operating Availability x Performance x Quality)

Figure 2. Description of OVE and TOVE structure and components

Under this approach, waste elimination is concentrated on achieving the highest truck efficiency, similar to what OEE seeks in production equipment. Thus, operations mapping and waste identification are carried out following the truck. In summary, TOVE consists of four components: administrative availability, operating availability, performance and quality. In this way, TOVE is obtained from the product of these mutually exclusive components. The concept of vehicle administrative availability is important because it has a significant impact on the overall vehicle utilisation and efficiency. It is mainly the result of administrative policies and strategies related to capacity or maintenance decisions.
2.3 Methods to eliminate waste in road transport operations

Unnecessary transportation waste, in many cases, is related to location decisions that seek to optimise performance at individual points of the supply chain. Thus, the solutions suggested for its elimination are normally concerned with the relocation and consolidation of facilities, a change of transportation mode, or the implementation of milk runs. However, according to McKinnon et al. (1999) and Fugate et al. (2009), eliminating unnecessary transportation can also be achieved by increasing transport efficiency. In this case, Hines and Taylor (2000) developed a four stage methodology to eliminate waste in transportation processes. Villarreal et al. (2009) applied this methodology to the distribution of frozen goods of a Mexican company leader in the production and distribution of frozen and refrigerated products. This resulted in an improved capacity utilisation and availability of vehicles, which helped this company to save about 12.3 million pesos (approximately £0.55 million) in future budgeted investment.

Villarreal et al. (2012) also proposed a comprehensive scheme to integrate the traditional operations research approach of developing algorithms to achieve an optimal solution to the vehicle routing problem with the Just-in-Time approach of milk runs to identify and reduce waste. Additionally, Villarreal (2012) adapted Value Stream Mapping (VSM), which he called Transportation Value Stream Mapping (TVSM), to support efficiency improvement programmes in transport operations. Later, Villarreal et al. (2013) developed a scheme around a modified version of the OEE metric. This index was adapted to be used as the main performance measure in transport operations to eliminate availability, performance and quality related wastes.

Despite the three research streams and amount of work identified and discussed in this section, research on the development of concepts, methodologies, and applications of lean thinking in the transportation sector, specially road transportation, can still be considered rather limited (Villarreal et al., 2009). Especially when compared with the vast amount of research on lean’s application to other industries such as manufacturing (Taj, 2008), processes (Panwar et al., 2015; Lyons et al., 2013) and services (Sternberg et al., 2013). This paper therefore complements and enhances the lean road research area by proposing a systematic method for improving road transport operations.

3. Systematic Method for the Improvement of Road Transport Operations

The method proposed to improve road transport operations consists of the systematic conduction of the four general stages illustrated in Figure 3. The initial/first stage comprises the analysis of a road vehicle’s flow as well as the activities associated with its transport operations. To achieve this, the proposed method suggests conducting an analysis of the value stream of the road transportation operations through a TVSM study (Villarreal, 2012). The study of the value stream of manufacturing (e.g. Seth and Gupta, 2005; Singh and Sharma, 2009), service (e.g. Barber and Tietje, 2008), healthcare (e.g. Teichgräber and de Bucourt, 2012; Lumus et al., 2006) and environmental (Kurdve et al., 2011) operations supported by the traditional VSM (Rother and Shook, 2003) has been widely documented in the academic literature. However, evidence of the use of VSM to support the analysis of the value stream of logistics and transport operations is almost non-existent in the academic literature, with only a handful of articles considering it (Villarreal et al., 2013; Villarreal, 2012; Villarreal et al., 2012; Hines et al., 1999; Jones et al., 1997). Thus, besides proposing an alternative systematic method to improve road transport operations, this article also contributes to the current limited body of knowledge on the application of VSM in the logistics and transport sector. In this case, the TVSM will concentrate on identifying waste
related to transport efficiency (Villarreal et al., 2012). The TVSM should consider the complete distribution cycle from picking and loading product orders to the transportation vehicles, to unloading product returns from the market and closing administratively the route or shipment.

The TVSM analysis can be structured in two parts; one that includes activities pre and post transport and serving clients; and another that considers the physical distribution of the product. The first set of activities is called Not-In-Transit (NIT) activities, whereas the second is known as In-Transit (IT) activities. NIT activities should be executed by warehouse operators while vehicle drivers should focus on performing IT activities only. The information included in the TVSM for NIT activities is the same as that of a traditional VSM as established by Rother and Shook (2003), namely; cycle time, value added time, uptime and setup time. NIT activities should align to the takt time required to load customer orders to trucks and deliver them on time. In the case of IT activities, the TVSM analysis requires specific data that include; average time between clients, truck capacity utilisation level, average distance travelled per client, distance travelled in excess per route, and the percentage of waiting time in transit. On the other hand, for serving clients; cycle time, value added time, the average number of clients per route, the percentage of clients not served, and the percentage of product returns are the main data that should be gathered for the TVSM analysis.

The TVSM analysis will enrich and contribute to the identification of the relevant STEWs (Sternberg et al., 2013) in the second stage of the proposed method. The third stage has the objective of formulating strategies and initiatives to eliminate the STEWs (Sternberg et al., 2013) identified in the previous stage. Improvement initiatives and strategies may include lot splitting, the application of order consolidation, and sequencing initiatives that would impact the utilisation of the transportation capacity and/or reduce the distance travelled to satisfy customers (Villarreal et al., 2009; La Londe and Masters 1994; Burns et al., 1985; Cooper, 1983). Finally, the last phase concerns the implementation of the initiatives and a follow-up of results.

The systematic method proposed can support wider road transportation improvement programmes (i.e. kaizen programmes), for example, those conducted under the umbrella of the Deming’s continuous learning and improvement model PDCA (Deming, 1993). This model has been used as a continuous feedback loop for the improvement of products and processes based on four steps: Plan (P), Do (D), Check (C) and Act (A). The “Plan” step covers activities related to the definition of the problem and the desired state, data collection, identification of root causes, the definition, evaluation and selection of the best solution alternatives, and finally, the scheduling and planning of the required resources for the implementation. The “Do” phase concerns the implementation of the selected initiatives. The last two steps of the PDCA model (i.e. Control and Act) are oriented to determine if the expected results were achieved and to ensure that these are maintained.

In a road transportation improvement programme, the proposed method would support and be aligned to the first two phases of the PDCA model; Plan and Do. In this case, stages 1
to 3 of the proposed method would be part of the “Plan” phase, whereas the last stage would be included in the “Do” phase. Therefore, if one would decide to apply the PDCA cycle for improving road transport operations, the recommended method may be used during the initial two stages of the model.

4. Case Study Implementation and Results

This section presents a case study where the proposed systematic lean method to improve transport operations has been deployed, in the distribution operations of a large Mexican organisation, to explore its effectiveness. Woodside (2010) and Cameron and Price (2009) consider a single detailed case study as a valid research methodology, particularly when the study is applicable and suitable for the organisation where the research occurs. The use of a single case study has been well accepted, in recent times, in the academic literature as a valid research method. This is evident from the high volume of recent researches published using a single case study research method (e.g. Bouzon et al., 2015; Bevilacqua et al., 2015; Tuli and Shankar, 2015; among others). Even though a single case study might be considered as a limited approach to prove the effectiveness of the proposed systematic method, if it is replicated again in this and/or different industrial context, a generalisation and validation of findings can be achieved (Garza-Reyes et al., 2014; Yin, 2012). Thus, it would fall in the future research agenda to test the proposed systematic lean transportation method through the use of multiple cases study in different settings.

The Mexican organisation has a primary distribution network which transports frozen and refrigerated products from plants to Central Distribution Centres (CDCs), and from these to Regional Distribution Centres (RDCs). It also includes a secondary network that takes the goods from the RDCs to retailing points or stores. The primary network includes thirteen plants, five CDCs and seventy four RDCs located across México. It is divided into five geographical regions. This paper is concerned with the application of the proposed systematic method on the North-eastern region. This zone accounts for 15% of the total national demand with sixteen RDCs. The firm started an effort to reduce distribution cost in its primary distribution network in 2009. A summary of this initiative is described in Villarreal et al. (2009). To further reduce distribution cost and increase customer service in the secondary distribution network, the studied organisation decided to undertake an improvement project adopting the systematic lean transportation method proposed in this paper. In particular, the improvement project focused on the routing operations from the Escobedo Distribution Centre (DC) to its customers.

4.1. Stage 1. TVSM Analysis

The first step of the proposed systematic lean method consists of conducting a TVSM analysis to map the transportation processes of interest. The current macro level TVSM for the routing operations is shown in Figure 4. It was constructed with information gathered from an administrative information system supported by the truck’s GPS and drivers’ handhelds. Additionally, a team of researchers collected detailed field data by accompanying the truck driving crews. This was done by sampling 30% of the routes. The transportation operations mapped consisted of the following activities:

- Preparation of routes: This step included the inspection of the orders and truck’s load as well as reviewing the route;
- Distribution of products (i.e. transporting products, serving customers and collecting spoiled products);
- Returning back to the DC;
• Closing routes: This stage included settling payments from customers with the cashiers and returning spoiled product and the truck.

The TVSM study indicated that the average journey time for the distribution of goods from the Escobedo DC to its corresponding retailing stores was 11.8 hrs, see Figure 4. All the activities included in the process, from preparing the routes and serving the stores until closing every route, were executed during the journey. The TVSM analysis also indicated that the average IT time was 9.9 hrs (83.8%), leaving only 2 hrs, on average, for the truck and driving crew to spend on NIT activities executed in the DC.

Figure 4. Macro level of TVSM for Escobedo routing operations

4.2. Stage 2. Identification of STEWs

The second stage in the systematic lean transportation method proposed consists of the identification of the relevant STEWs (Sternberg et al., 2013). Table 2 presents a summary of the most important STEWs identified through the TVSM analysis as well as the processes where they were associated to and how they affected the transport operation.

Table 2. Summary of relevant STEWs

<table>
<thead>
<tr>
<th>Wastes</th>
<th>Process</th>
<th>Description</th>
<th>Impact on</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect processing and resource utilisation</td>
<td>Transporting product to customers</td>
<td>• Sub-optimal routes defined by drivers</td>
<td>• Truck capacity under-utilisation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sub-optimal client sequencing</td>
<td>• Distance in excess per route</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Customers are visited several times per route.</td>
<td>• Long journey time of 11.8 hrs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Baskets for product larger than necessary</td>
<td>• Percentage of clients not visited per route</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Truck capacity over-sized</td>
<td></td>
</tr>
<tr>
<td>Uncovered assignments</td>
<td>Transporting product to</td>
<td>• Customers not satisfied</td>
<td></td>
</tr>
<tr>
<td></td>
<td>customers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unnecessary movements and waiting</td>
<td>Procedures for serving customers, preparing and closing routes have non-value activities</td>
<td>Serving time in excess</td>
<td>Waiting time to close routes</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>----------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>• Serving customers</td>
<td>• Procedures for serving customers, preparing and closing routes have non-value activities</td>
<td>• Serving time in excess</td>
<td>• Waiting time to close routes</td>
</tr>
<tr>
<td>• Returning spoiled products</td>
<td>• Procedures for serving customers, preparing and closing routes have non-value activities</td>
<td>• Serving time in excess</td>
<td>• Waiting time to close routes</td>
</tr>
<tr>
<td>• Closing routes</td>
<td>• Procedures for serving customers, preparing and closing routes have non-value activities</td>
<td>• Serving time in excess</td>
<td>• Waiting time to close routes</td>
</tr>
</tbody>
</table>

Figure 5 illustrates the micro context of the TVSM previously presented in Figure 4. The most relevant information is also summarised in Table 2. The average number of stores served by a route was 45. Therefore, the organisation studied utilised its fleet only about 49% of the available daytime. Additionally, 17% of this time, both truck and its driving crew were in the DC performing NIT activities.

Before trucks left the DC, the driving crew had to prepare the route. This included activities such as loading and truck inspection, a quick meeting, and route sequence definition. As shown in the Figure 5, the crew was idle 50% of the average time taken for route preparation. After distributing the product to customers, the driving crew had to participate in closing their routes. This NIT activity consisted of settling the payments collected from customers with the cashiers, returning both spoiled product and the truck. In particular, the original procedure carried out by the cashiers was manual, sequential, and with different cycle times, which resulted in an important total queueing time per route of 17 minutes. Total waste identified in the activity of closing routes was estimated to be 21 minutes (35%).

IT activities consisted of transporting product and serving customers. Average transport time between clients was estimated to be 2.5 minutes. It was identified that on average, only 27% of truck capacity was utilised per route. In addition, each route travelled 32 kilometres in excess. Serving customers took an average of 9.4 minutes per stop, of which 31% was identified as non-value added.

4.2.1 Incorrect processing and resource utilisation

As indicated in Table 2 and Kaizen burst 1 in Figure 5, incorrect processing and resource utilisation wastes were found, in this case, mainly during the transportation of products to customers. These occurred because of inefficiencies in the design of routes (i.e. customer assignment to trucks and visit sequencing). Route design was a shared responsibility between the route dispatcher and the truck drivers. All the routes were fixed and established four years ago. Assigning additional customers and customer sequencing was determined based on the experience of each driver. Customer time windows were not considered, resulting in several visits to customers per route. As a consequence, 73% of transport capacity was under-utilised and 32 kilometres of distance per route were travelled in excess. In addition, these wastes caused longer journey durations and hence an important number of programmed customers were not visited because of the lack of time. On average, a route did not visit 13% of the programmed customers.

4.2.2 Unnecessary movements and waiting

Unnecessary movements and waiting time were found in the processes of serving customers and NIT activities as indicated in Table 2 and Kaizen burst 2 in Figure 5. These occurred due to inefficient procedures that contained non-value added activities. Customer service time included the time taken to perform activities that did not add value or were not
simplified, for example, inspecting products, verifying with the store leader whether the order was complete, and getting and loading product returns. Serving clients was an activity with 31% of its time categorised as waste. There was also the need to consider the time taken to obtain the payment of the order from the customer. In principle, NIT activities must not be the responsibility of the driving crew. However, if these have to be done, the objective would be to perform them efficiently. In this case, NIT activities took about 2 hrs. This accounted for 17% of total journey’s time. Even though there were no bottlenecks present in the warehousing activities, 50% of the time for preparing routes was found to be waste. Also, 35% of the time taken to unload and close routes was found to be non-value added.

4.2.3 Uncovered assignments and defect waste

Defect waste in this case included the percentage of spoiled product that was returned to the company. This waste occurred during serving customers. For this case, it was estimated that 12% of the product demand was returned because it became spoiled. The main cause of this waste was the low product distribution frequency, for example, each customer was visited twice per week.

Uncovered assignment waste consisted of the percentage of customers not visited per route. The cause of this waste was the amount of time misused on inefficient procedures, waiting and unnecessary movements. Thus, any initiative directed to reduce this wasted time would positively impact on decreasing the number of customers missed per route.

4.2.4 Analysis of value added time

Additional relevant information about the routing operations concerns the level of value added time (VAT) per route. As shown in Figure 5, about 75% of the total journey time was VAT. This was equivalent to 3 hrs. After considering driver breaks, the remaining 8.3 hrs associated with VAT was used for transporting and serving customers. However, it yet remains to be seen if this time is used properly. That is, trucks should be loaded at full capacity without travelling distance in excess. It also assumes that all customers are served satisfying 100% of their demand.

However, as shown in Figure 5, there was a truck capacity utilisation of 73% and a distance travelled in excess of 32 kms per route. This was equivalent to 6.3 hrs of non-value added time (NVAT). Finally, there was also 13% of customers not visited and 12% of the product was returned. This would result in an additional equivalent time waste of 0.5 hrs. Thus, in total, an additional equivalent time of 6.8 hrs of NVAT was identified. Therefore, for this case, only 1.5 equivalent hrs the truck would be moving fully loaded travelling zero distance in excess, and satisfying 100% of customer demand. Table 3 illustrates the impact of each STEW on NVAT. The incorrect processing and resource utilisation wastes were considered the most relevant.
### Table 3. Summary of impact of STEWs on NVAT

<table>
<thead>
<tr>
<th>Wastes</th>
<th>Non Value Added Time (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect processing and resource utilisation</td>
<td>6.30</td>
</tr>
<tr>
<td>Unnecessary movements and waiting</td>
<td>2.95</td>
</tr>
<tr>
<td>Uncovered assignments and defect waste</td>
<td>0.50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9.75</strong></td>
</tr>
</tbody>
</table>

#### 4.2.5 Impact of STEWs on efficiency factors

As previously described in Section 2.2, the determination of the TOVE index metric requires the identification of several wastes associated with its different components: administrative and operating availability efficiencies, performance efficiency and quality efficiency, see Figure 1. It would be of interest to determine the inter-relationships between both waste classification streams: STEW’s and efficiency wastes. Considering Figure 1 and Table 1 as a basis, the following points can be concluded:

- STEW’s waiting is similar to the efficiency waste of waiting;
- STEW’s resource (i.e. truck, operator, etc.) utilisation includes the efficiency waste (truck) fill loss;
- STEW’s overproduction, waiting and unnecessary movements can cause efficiency wastes related to activities performed with time in excess (e.g. loading, unloading, inspection and customer serving);
- STEW’s defect includes efficiency wastes product defective and corrective maintenance;
- STEW’s incorrect processing, uncovered assignments and resource utilisation can cause efficiency wastes (truck) fill loss and/or distance travelled in excess;
- STEW’s resource utilisation can cause efficiency wastes time not planned for trucks and/or internal NIT activities;
- STEW uncovered assignments can cause efficiency waste demand not satisfied.

In general, there is a strong relationship between both waste schemes. It seems that the identification of certain STEWs increases the probability of occurrence of certain efficiency wastes. This aspect can be used to delineate an overall waste identification scheme. Two basic types of inter-relationships are identified in this case, namely: the STEW causes an efficiency waste (cause & effect), and an efficiency waste is included, or is a component, of a STEW.

The previous findings can be used to design more effective transportation waste elimination schemes. A new hybrid scheme could use performance measures (TOVE, availability efficiency, etc.) as references for goal setting improvement purposes. The identification of wastes would be enriched by the consideration of the two waste streams: STEWs and efficiency wastes. Further discussion on this potential scheme is left for future works.
Figure 5. TVSM micro analysis for the routing operations from the Escobedo Distribution Centre

Route or Shipment
Planner or Dispatch

Route Description

Picking & Loading Orders

Preparing Orders
CT = 60 mins/ route
Value Added Time = 50%

Unloading & Closing Routes
CT = 60 mins/ route
Value Added Time = 65%

Serve Clients

In Transit Activities
In Transit time = 9.9 hrs
Journey time = 11.8 hrs

Not In Transit Activities

Incorrect Processing & Resource Utilization

Uncovered Assignments & Defects

Unnecessary Movements & Waiting

E- orders

Order Req’s

Cycle Time = 9.4 mins.
% Value Added Time = 69
Ave. Number Clients = 45
% clients not Served = 13
% Product Returns = 12

VAT = 75%
NVAT = 25%

Ave Distance in Excess = 32 Kms

 incorrect processing & resource utilization

Kaizen Burst 1

Kaizen Burst 2

Kaizen Burst 3

Journey time = 11.8 hrs
4.3 Stage 3. Definition of waste elimination strategy

As previously discussed, different strategies have been proposed by, for example, Villarreal et al. (2009), La Londe and Masters (1994), Burns et al. (1985), Cooper (1983), among others, to improve transport operations. In this case, the strategy established to decrease the main STEWs (Sternberg et al., 2013) identified was originally aimed at eliminating two sets of wastes. The first set consisted of the elimination of incorrect processing and resource utilisation. The second set included unnecessary movements and waiting time. Both sets of wastes had an important impact on the level of uncovered assignments waste (see Table 2). The waste elimination strategy formulated to tackle the STEWs is briefly described in Table 4. Particularly, this project was focused on the deployment of improvement strategies based on the design of semi-dynamic routes and the improvement of procedures. Hence, other improvement strategies such as increasing the frequency of customers’ visits, redesigning the basket size of transport vehicles, and using smaller trucks could be considered as part of a second wave of future improvement strategies.

Table 4. Description of improvement strategies

<table>
<thead>
<tr>
<th>STEWs</th>
<th>Waste Description</th>
<th>Initiatives considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect processing and resource</td>
<td>• Sub-optimal routes defined by drivers</td>
<td>• Semi-dynamic route design</td>
</tr>
<tr>
<td>utilisation</td>
<td>• Sub-optimal client sequencing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Customers are visited several times per route</td>
<td></td>
</tr>
<tr>
<td>Unnecessary movements and waiting</td>
<td>• Procedures for serving customers, preparing and closing routes have non-value</td>
<td>• Simplifying procedures</td>
</tr>
<tr>
<td></td>
<td>activities</td>
<td></td>
</tr>
</tbody>
</table>

4.3.1 Semi-dynamic routing design

This initiative started with the definition of a new route redesign review period. At the time of the development of the project, there was no determined review period. Four years had passed and the market dynamics had changed significantly in terms of the quantity, location and demand of the clients. After analysing the market demand growth and considering that each customer was visited twice per week, it was decided that the company would carry out a weekly route redesign when additional new clients appeared. The weekly customer growth rate per route was a maximum of two new customers. The solution used before the redesign consisted in including the new customers to the closest route and sequenced between the two closest customers. The company had the option of using specialised software programmes such as Roadnet Transportation Suite Routing and Scheduling Systems (UPS Logistic Group, 2004), which they already owned, and Map-Info (MapInfo Corporation, 2015). In particular, MapInfo software could be used to perform a map and geocode analysis while Roadnet Transportation Suite would enable the company to create optimised routes and load plans (Alagöz and Kocasoy, 2008).

4.3.2 Simplifying procedures

The simplification of procedures in three stages of the routing operations was undertaken, namely: (1) during route preparation before trucks left for distribution, (2) during serving clients, and (3) at closing routes. Route preparation before leaving to distribute products was
a lengthy activity. Driving crews were idle at least 50% of the time. So, they could have about 30 additional minutes for routing and distributing products.

Serving clients consisted of unloading and inspecting each customer order. Then, they would put the product in the customer’s receiving area and obtain their payment. Finally, product returns were identified, counted, and packed to be transported back to the company’s DC. The last stage requiring procedure simplification was closing routes at the DC. This stage included the activities of settling customer payments and product returns. Hence, long queues occurred because of the inefficient work of two cashiers. Each cashier performed different activities in series, and were idle 36% of the time. A new procedure in which both cashiers performed all the tasks in parallel to each other was designed. This reduced idle time to 15% and decreased total time required for this activity by about 22%.

It is estimated that the benefits that can be derived from implementing the semi-dynamic route design and simplification of procedures improvement strategies are significant. Table 5 illustrates a summary of these benefits. For instance, if the semi-dynamic route optimisation strategy is implemented, the impact would be limited to the elimination of incorrect processing and resource utilisation wastes. It is estimated that customer service level would be fully satisfied with this implementation. Also, total distance travelled by all the routes would decrease by 16% and the number of routes would be reduced by 10%.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Current Status</th>
<th>Optimising Routes</th>
<th>Optimising NIT &amp; Serving Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of routes</td>
<td>90</td>
<td>81</td>
<td>66</td>
</tr>
<tr>
<td>Clients per route</td>
<td>45</td>
<td>51</td>
<td>63</td>
</tr>
<tr>
<td>Total distance (km)</td>
<td>1770</td>
<td>1487</td>
<td>1203</td>
</tr>
<tr>
<td>Number of clients not served per route</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Service time per client (min)</td>
<td>9.2</td>
<td>9.2</td>
<td>6.5</td>
</tr>
<tr>
<td>NIT activities time per route (min)</td>
<td>90</td>
<td>90</td>
<td>49</td>
</tr>
</tbody>
</table>

Implementing the improvements and standardising projects of NIT and customer serving activities would also yield important benefits. For instance, total distance would decrease another 19%, and the number of routes would be reduced by 18%, see Table 5. This further improvement effort would have a significant positive impact on distribution costs. In this context, it is estimated that a minimum cost reduction of 27% will be achieved when all the initiatives are implemented. Hence the importance of not only proposing the improvement strategies but also deploying them as indicated by the proposed systematic lean method.

### 4.4 Stage 4. Implementation of STEW's elimination strategy

The implementation of improvement strategies is more effective when they are first supported by a pilot test to validate their effectiveness (Nousala et al., 2008). Thus, the implementation of the strategy to eliminate the STEWs included an initial pilot test. The two initiatives that required careful attention were the semi-dynamic route redesign and simplification of procedures.
4.4.1 Redesign of routes

A sample of 30% of the routes was redefined. This task was carried out with the support of the specialised software programs Roadnet Transportation Suite Routing and Scheduling Systems (UPS Logistic Group, 2004) and Map-Info (MapInfo Corporation, 2015). Here, both the assignment of clients and the visiting sequence were optimised. 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 reduction on the average number of clients not served per route from six to zero. However, average journey time did not changed significantly.

4.4.2 Final implementation of initiatives

The implementation of the previously described strategy is currently under way. This has been divided into two fronts: the first front is concentrated on improving warehousing (NIT) and the procedure for serving clients. The main initiative for NIT activities consists of improving the tasks performed by the cashiers. In particular, the original procedure to settle cash payments from the customers was modified and automated. Now, both cashiers perform the full job from start to end. These projects have already been fully implemented.

The second front is concerned with route design. The initial step in this front consisted of the pilot test explained earlier. The second step, which has already started, is the redesigning of all 90 routes. After applying the optimisation software, the number of routes has been reduced to 66 (see Table 5), without compromising the customer service level. The average number of clients to be served by each route has increased by about 40%, and the distance travelled reduced by 32%. It is estimated that this effort will be completely implemented and stabilized during the first quarter of 2016. Finally, this initiative will be applied to the rest of the routing operations during the second quarter of 2016.

5. Discussion

The systematic lean thinking-based method proposed in this paper contributes to expand the very limited application of lean principles and tools in the logistics and transport sector as highlighted by Villarreal et al. (2009). First, unlike other approaches such as mathematical modelling, operations research-based methods and simulation, which have been traditionally used to improve road transport operations through the optimisation of resource utilisation (e.g. Chiu et al., 2006; Zhong et al., 2007; Eliiyi et al., 2009), routes (e.g. Lau et al., 2009; Jemai et al., 2013), cost (e.g. Boudia et al., 2008; Eliiyi et al., 2009; Yu et al., 2015), time (e.g. Chiu et al., 2006; Zhong et al., 2007; Zhang et al., 2014; Yu et al., 2015) and distance (e.g. Zhang et al., 2014), the proposed approach is based on the improvement of transport operations by the elimination of waste (i.e. non-value added activities), and hence improving the efficiency of the actual road transportation operations. This presents an opportunity for logistics and transport companies to reduce operational costs (Monden, 1998; Ohno, 1988) and increase value for their customers (Bicheno, 2004; Dennis, 2002) similar to companies in other sectors such as manufacturing (Taj, 2008), processes (Lyons et al., 2013) and services (Sternberg et al., 2013). The method proposed in this paper thus provides companies in the logistics and transport industry with the opportunity to also benefit from the lean philosophy.

The outcome of its application in the studied company echoes the positive results that organisations from other sectors have already experienced with the application of lean thinking. The results also supports earlier findings by researchers such as Villarreal et al. (2009), Sternberg et al. (2013), and Villarreal et al. (2013), and thus emphasise that lean
thinking can be an effective approach that both researchers and industrialists can further explore to improve road transport operations.

Second, the results of the case study suggest that VSM, a lean tool that has successfully been applied to study the value streams of manufacturing (e.g. Seth and Gupta, 2005; Singh and Sharma, 2009), service (e.g. Barber and Tietje, 2008), healthcare (e.g. Teichgräber and de Bucourt, 2012; Lumus et al., 2006) and environmental (Kurdve et al., 2011) processes, can also be effective in identifying wastes in logistic and transport operations. Due to the limited evidence in the academic literature in this respect (Villarreal et al., 2013; Villarreal, 2012; Villarreal et al., 2012; Hines et al., 1999; Jones et al., 1997), the present paper adds to the existing scant literature by providing further evidence of the application of VSM in the logistics and transport sector.

Third, although improvements in road transport operations can be conducted in an ad hoc basis, a systematic improvement approach underpinned by lean principles and tools provides a more effective and efficient approach. This is evidenced by the effectiveness of other systematic approaches to problem solving and improvement such as PDCA (Adebanjo et al., 2015; Deming, 1993) and DMAIC (Ghosh and Maiti, 2014; Garza-Reyes et al., 2014). The importance of following a structured and integrated approach to operations improvement has been widely discussed in the academic literature (e.g. Garza-Reyes et al., 2014; Mauri et al., 2010; Vanneste and Van Wassenhove, 1995). In this research, the proposed systematic method helped the studied organisation to establish a standardised routine to improve its transport operations. Therefore, its application provides organisations with a platform to achieve this.

6. Conclusions, limitations and future research opportunities

This paper presents an alternative systematic method to improve transport operations based on lean thinking and the reduction of the STEW$s proposed by Sternberg et al. (2013). The paper thus offers road logistics and transport organisations with an approach that they can employ to improve their operations. This is considered the main practical contribution of this paper.

The theoretical contribution of this paper is also significant. Besides the proposal of the method and its reported application, the paper also contributes to the lean and logistics theory by providing a structured research definition of the application of lean thinking in road transport operations. In this case, the paper identifies and classifies three streams of research, which have been directed to: (1) define wastes specific to road transportation, (2) develop lean performance measures for road transportation, and (3) propose methods to eliminate waste in road transport operations. A clearly defined research structure, such as the one provided in this paper, will not only facilitate the understanding and further research in this promising field, but also stimulate scholars to further study the application of lean thinking and waste reduction in road transport operations. Through a better understanding of this area, logistics and transport organisations will also be able to formulate more effective strategies for the improvement of their operations using lean thinking.

In terms of the implementation of the systematic method proposed, various constraints were encountered, with complex confounding factors that are important to be highlighted in order to also consider its deployment. Kumar et al. (2006) comment that it is important to discuss the difficulties encountered when implementing improvement programmes in order to provide valuable learning lessons, and in this way facilitate their future deployment. In the case of the implementation of the proposed systematic method, convincing top management for taking a broader view of the process instead of only considering route design through
software optimisation was an arduous task. This may be considered a natural phenomenon in the logistics and transport industry, as previously indicated by the literature review most inefficiencies in road transport operations are addressed through mathematical modelling (e.g. Ghiani et al., 2003; Laporte, 1992; Hill and Benton, 1992; Bodin et al., 1983), operations research-based methods (e.g. Gendreau et al., 1996; Baker and Ayechew, 2003; Boudia et al., 2008; Pisinger and Ropke, 2007), and simulation (e.g. Osorio and Bierlaire, 2013; Kuo, 2010). In addition, the limited use of lean thinking in the logistics and transport sector may also suggest that there is no clear understanding of the benefits on how lean thinking can support the improvement of operations in this sector. This study provides a basis for this clarification. Top management teams were convinced by citing examples of some successful organisations, in other industries (Taj, 2008; Lyons et al., 2013; Sternberg et al., 2013), that had improved the efficiency of their processes and enhanced their bottom-line results using the application of lean thinking principles.

Moreover, finding employees’ resistance when introducing a new business strategy is a normal phenomenon (Kumar et al., 2006; Antony et al., 2005). The employees of the studied organisation earlier believed that the use of lean thinking and resulting implementation of new and fewer routes could considerably change their working patterns, affect their performance, and ultimately endanger their job opportunities. This negative attitude was overcome with the support of top management, who convinced their employees of the opportunities and benefits that the adoption of lean would bring to the organisation and its employees. The management encouraged their employees by rewarding them for their effort in improving performance following the adoption of lean principles. This also contributed in convincing them that their jobs would not be in danger and efforts on improving performance will be adequately rewarded. This progressively increased confidence among employees, and eventually they were prepared to embrace the proposed method in their operations.

Finally, although the method proposed yielded positive results in the studied organisation, the use of a single case study research approach employed in this paper suggests that further research must be conducted to test the method in different industrial settings and organisations. This will further validate the effectiveness and applicability of the method in different industrial situations. Therefore, the collection of further evidence through a multiple case study approach is part of the future research agenda of the authors. The limited use of lean thinking to improve lean road transport operation as highlighted in the paper suggests that there is no clear understanding on the benefits of lean, and how to use its principles and tools to improve this type of operations. This article has provided some evidence of this, and can serve as a motivation to undertake further research in this area.

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