

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

*1<sup>st</sup> Author*

**Prof. Dr. Bernardo Villarreal**

Departamento de Ingeniería, Universidad de Monterrey, I. Morones Prieto 4500 Pte., San Pedro Garza Garcia, NL 66238, Mexico  
E-mail: [bernardo.villarreal@udem.edu](mailto:bernardo.villarreal@udem.edu)

*2<sup>nd</sup> Author and Corresponding*

**Dr. Jose Arturo Garza-Reyes\***

Centre for Supply Chain Improvement  
The University of Derby  
Kedleston Road Campus, Derby, UK, DE22 1GB  
E-mail: [J.Reyes@derby.ac.uk](mailto:J.Reyes@derby.ac.uk)  
Tel. +44(0)1332593281

*3<sup>rd</sup> Author*

**Dr. Vikas Kumar**

Bristol Business School  
University of the West of England  
Coldharbour Ln, Bristol, UK, BS16 1QY  
E-mail: [Vikas.Kumar@uwe.ac.uk](mailto:Vikas.Kumar@uwe.ac.uk)  
Tel. +44(0)1173283466

**\* Corresponding Author**

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

## *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 Ayechev, 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.

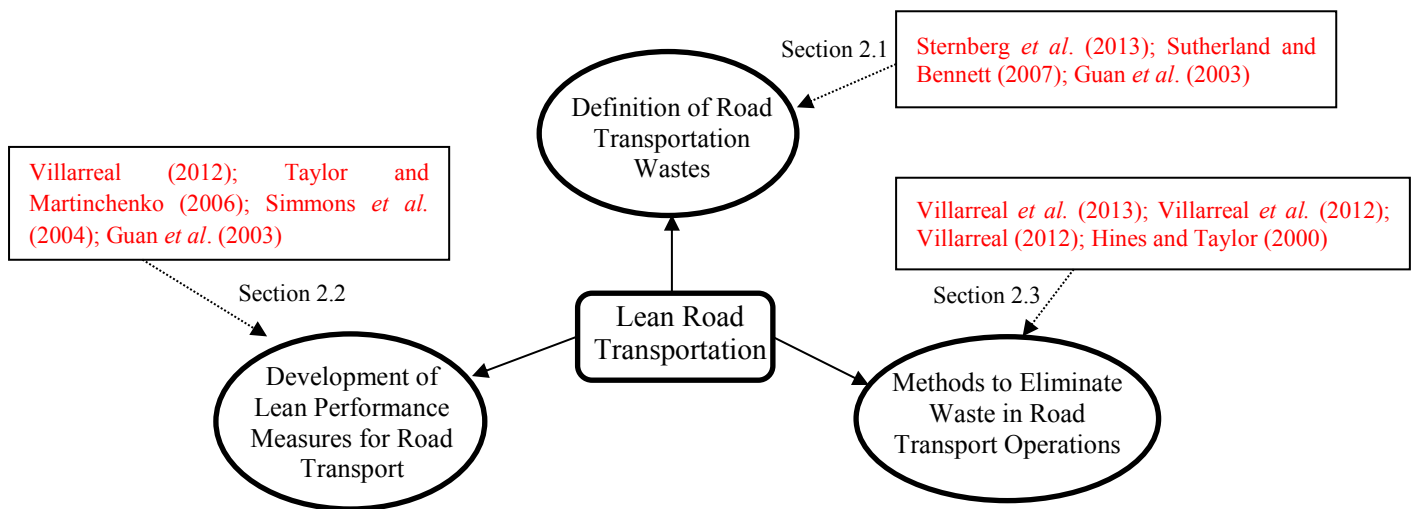


Figure 1. Concept map showing the different research streams of the lean road transportation area

### 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)

Waste	Description	Source
Overproduction	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	Definition by Tapping and Dunn (2006), confirmed in Sternberg's <i>et al.</i> (2013) study
Waiting	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	Definition from production (Liker, 2004), loading and unloading added as a common cause for waste of waiting noted from Sternberg's <i>et al.</i> (2013) empirical study
Incorrect processing	Consuming more resources for moving the goods than necessary due to inefficient routing or driving	Definition suggested based on Sternberg's <i>et al.</i> (2013) empirical study
Unnecessary movement	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	Definition by Tapping and Dunn (2006), movement due to sequencing errors added from the Sternberg's <i>et al.</i> (2013) empirical study
Defects	Waste caused by repairs, redelivery, scrapping, etc., due to damages on the transported goods or the equipment	Damages to the equipment added to the production definition, in alignment with the Sternberg's <i>et al.</i> (2013) empirical study
Resource utilisation (New)	Waste due to excessive equipment and bad resource planning	Definition suggested based on Sternberg's <i>et al.</i> (2013) empirical study
Uncovered assignments (New)	Carrying out unprofitable transport work due lack of information or planning	Definition suggested based on Sternberg's <i>et al.</i> (2013) empirical study
Excess inventory & Conveyance	Not applicable	Not reported in the empirical study

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.**

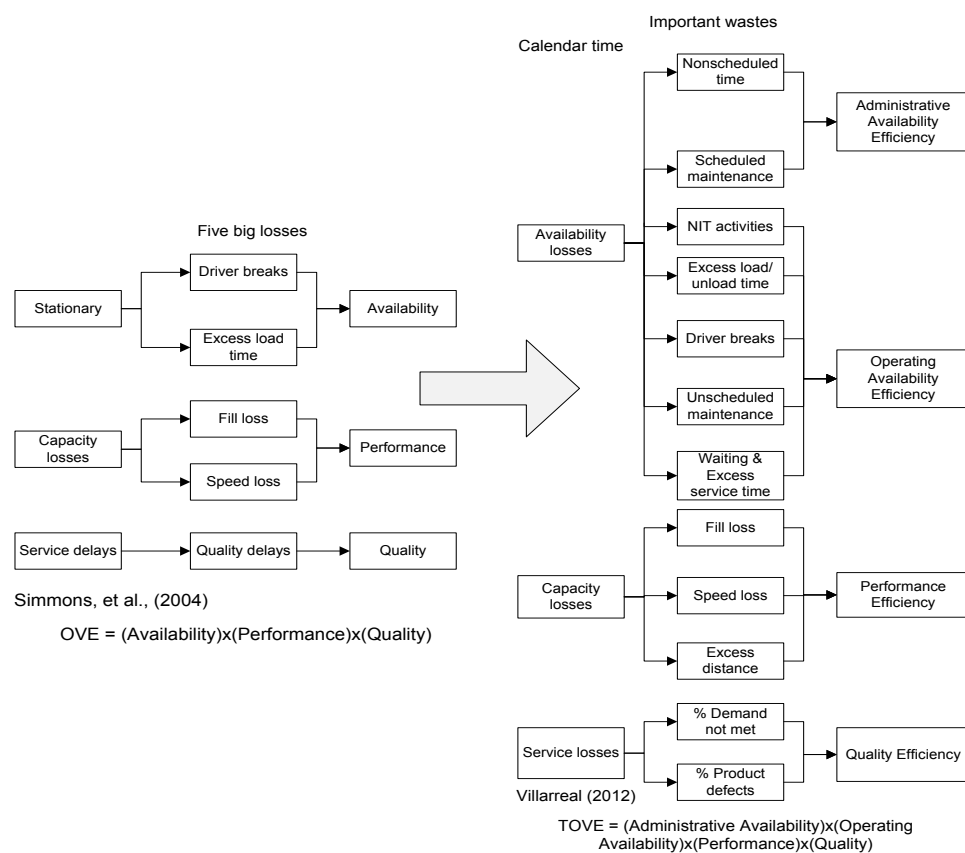


Figure 2. Description of OVE and TOVE structure and components

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.

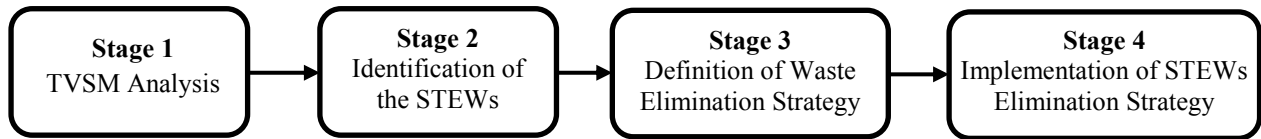
Villarreal *et al.* (2012) also proposed a comprehensive scheme to integrate the traditional operations research approach of developing algorithms to achieve an optimal solution to the vehicle routing problem with the Just-in-Time approach of milk runs to identify and reduce waste. Additionally, Villarreal (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.



**Figure 3.** Stages of the proposed systematic method to improve road transport operations

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.

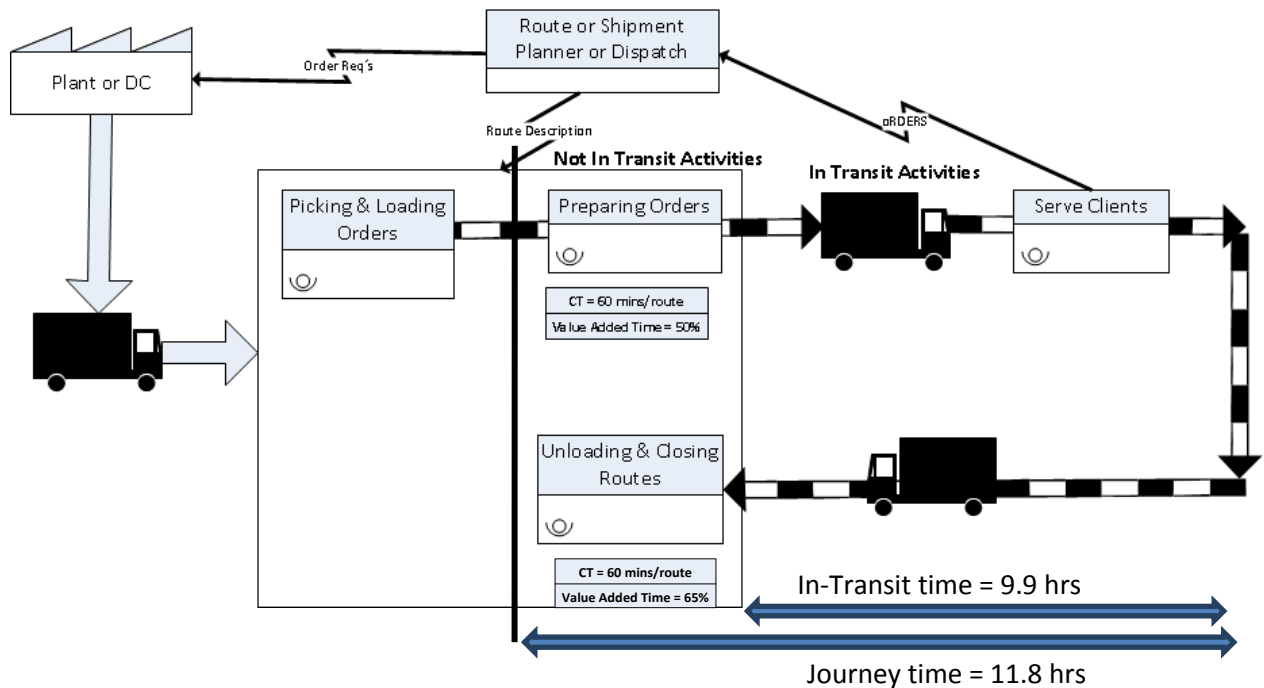


Figure 4. Macro level of TVSM for Escobedo routing operations

#### 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

Wastes	Process	Description	Impact on
<b>Incorrect processing and resource utilisation</b>	<ul style="list-style-type: none"> <li>• Transporting product to customers</li> </ul>	<ul style="list-style-type: none"> <li>• Sub-optimal routes defined by drivers</li> <li>• Sub-optimal client sequencing</li> <li>• Customers are visited several times per route.</li> <li>• Baskets for product larger than necessary</li> <li>• Truck capacity over-sized</li> </ul>	<ul style="list-style-type: none"> <li>• Truck capacity under-utilisation</li> <li>• Distance in excess per route</li> <li>• Long journey time of 11.8 hrs</li> <li>• Percentage of clients not visited per route</li> </ul>
<b>Uncovered assignments</b>	<ul style="list-style-type: none"> <li>• Transporting product to</li> </ul>	<ul style="list-style-type: none"> <li>• Customers not satisfied</li> </ul>	<ul style="list-style-type: none"> <li>• Percentage of clients not visited per route</li> </ul>

	customers		
<b>Unnecessary movements and waiting</b>	<ul style="list-style-type: none"> <li>• Serving customers</li> <li>• Returning spoiled products</li> <li>• Closing routes</li> </ul>	<ul style="list-style-type: none"> <li>• Procedures for serving customers, preparing and closing routes have non-value activities</li> </ul>	<ul style="list-style-type: none"> <li>• Serving time in excess</li> <li>• Waiting time to close routes</li> </ul>
<b>Defects</b>	<ul style="list-style-type: none"> <li>• Serving clients</li> </ul>	<ul style="list-style-type: none"> <li>• Product in customer premises gets spoiled</li> </ul>	<ul style="list-style-type: none"> <li>• Product returns</li> </ul>

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

Wastes	Non Value Added Time (hrs)
Incorrect processing and resource utilisation	6.30
Unnecessary movements and waiting	2.95
Uncovered assignments and defect waste	0.50
<b>Total</b>	<b>9.75</b>

#### 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.

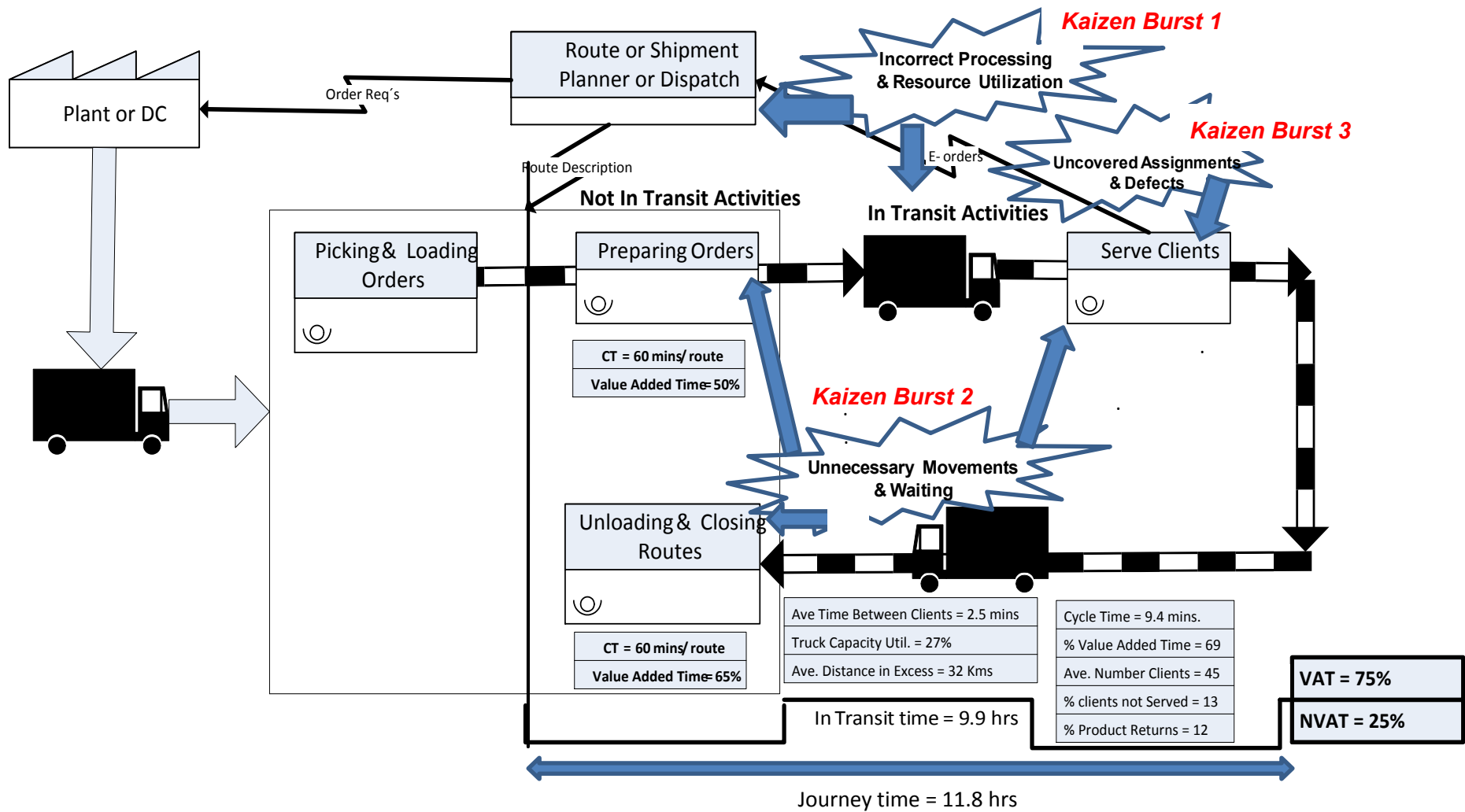


Figure 5. TVSM micro analysis for the routing operations from the Escobedo Distribution Centre

### 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

STEWS	Waste Description	Initiatives considered
<b>Incorrect processing and resource utilisation</b>	<ul style="list-style-type: none"> <li>• Sub-optimal routes defined by drivers</li> <li>• Sub-optimal client sequencing</li> <li>• Customers are visited several times per route</li> </ul>	<ul style="list-style-type: none"> <li>• Semi-dynamic route design</li> </ul>
<b>Unnecessary movements and waiting</b>	<ul style="list-style-type: none"> <li>• Procedures for serving customers, preparing and closing routes have non-value activities.</li> </ul>	<ul style="list-style-type: none"> <li>• Simplifying procedures</li> </ul>

#### 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 5.** Summary of the positive effect of optimising routes and NIT and serving activities

Concept	Current Status	Optimising Routes	Optimising NIT & Serving Activities
Number of routes	90	81	66
Clients per route	45	51	63
Total distance (km)	1770	1487	1203
Number of clients not served per route	6	0	0
Service time per client (min)	9.2	9.2	6.5
NIT activities time per route (min)	90	90	49

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 STEWs 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 (Adebajo *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 STEWs 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 Ayechev, 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.

## References

- Adebanjo, Tickle, M., Laosirihongthong, T., Mann, R. (2015), "A study of the use of business improvement initiatives: the association with company size and level of national development", *Production, Planning & Control*, Vol. 26, No. 7, pp. 507-524.
- Alagöz, A.Z., Kocasoy, G. (2008), "Improvement and modification of the routing system for the health-care waste collection and transportation in Istanbul", *Waste Management*, Vol. 28, pp. 1461-1471.
- Antony, J., Kumar, M., Madu, C.N. (2005), "Six sigma in small- and medium-sized UK manufacturing enterprises: Some empirical observations", *International Journal of Quality & Reliability Management*, Vol. 22, No. 8, pp. 860-874.
- Baker, B.M., Ayechev, M.A. (2003), "A genetic algorithm for the vehicle routing problem", *Computers & Operations Research*, Vol. 30, No. 5, pp. 787-800.

- Barber, S., Tietje, B.C. (2008), "A Research Agenda for Value Stream Mapping the Sales Process", *Journal of Personal Selling & Sales Management*, Vol. 28, No. 2, pp. 155-165.
- Belman, D., Lafontaine, F., Monaco, K.A. (2005), "Truck drivers in the age of information: transformation without gain", in Belman, D. and White, C.C. (Eds), *Trucking in the Age of Information*, Ashgate Publishing Company, Burlington, VT, pp. 183-212.
- Bevilacqua, M., Ciarapica, F. E., & Paciarotti, C. (2015), "Implementing lean information management: the case study of an automotive company", *Production Planning & Control*, Vol. 26, No. 10, pp. 1-16.
- Bicheno, J. (2004), *The New Lean Toolbox: Towards Fast, Flexible Flow*, 3rd ed., PICSIE Books, Buckingham.
- Bodin, L.D., Golden, B.L., Assad, A.A., Ball, M.O. (1983), "Routing and scheduling of vehicles and crews: The state of the art", *Computers & Operations Research*, Vol. 10, No. 2, pp. 69-211.
- Boudia, M., Louly, M.A.O, Prins, C. (2008), "Fast heuristics for a combined production planning and vehicle routing problem", *Production, Planning & Control*, Vol. 19, No. 2, pp. 85-96.
- Bouzon, M., Spricigo, R., Rodriguez, C. M., de Queiroz, A.A., Cauchick Miguel, P.A. (2015), "Reverse logistics drivers: empirical evidence from a case study in an emerging economy", *Production Planning & Control*, Vol. 26, No. 16, pp. 1-18.
- Burns, L.D., Hall, R.W., Blumenfeld, D.E., Daganzo, C.F. (1985), "Distribution strategies that minimize transportation and inventory costs", *Operations Research*, Vol. 33, No. 3, pp. 469- 490.
- Cabral, I., Grilo, A., Cruz-Machado, V. (2012), "A decision-making model for lean, agile, resilient and green supply chain management", *International Journal of Production Research*, Vol. 50, No. 17, pp. 4830-4845.
- Cameron, S., Price, D. (2009), *Business research methods: a practical approach*, Chartered Institute of Personal and Development, London.
- Chiu, H.N., Lee, Y.S., Chang, J.H. (2006), "Two approaches to solving the multi-depot vehicle routing problem with time windows in a time-based logistics environment", *Production, Planning & Control*, Vol. 17, No. 5, pp. 480-493.
- Cooper, C.M. (1983), "Freight consolidation and warehouse location strategies in physical distribution systems", *Journal of Business Logistics*, Vol. 4, No. 2, pp. 53-74.
- Deming, W.E. (1993), *The new economic for industry, government, education*, MIT Center for Advanced Engineering Studies, Cambridge, MA.
- Dennis, P. (2002), *Lean Production Simplified: A Plain Language Guide to the World's Most Powerful Production System*, Productivity Press, New York, NY.
- Dey, P. K., Cheffi, W. (2013), "Green supply chain performance measurement using the analytic hierarchy process: a comparative analysis of manufacturing organisations", *Production Planning & Control*, Vol. 24, No. 8-9, pp. 702-720.
- Eliiyi, D.T., Ornek, A., Karakütük, S.S. (2009), "A vehicle scheduling problem with fixed trips and time limitations", *International Journal of Production Economics*, Vol. 117, No.1, pp. 150-161.

- European Commission (2011), *Statistical pocketbook 2011*, Publications Office of the European Union, Luxembourg.
- Fugate, B.S., Davis-Sramek, B. and Goldsby, T.J. (2009), "Operational collaboration between shippers and carriers in the transportation industry", *International Journal of Logistics Management*, Vol. 20, No. 3, pp. 425-47.
- Garza-Reyes J.A., Flint, A., Kumar, V., Antony, J., Soriano-Meier, H. (2014), "A DMAIRC approach to lead time reduction in an aerospace engine assembly process", *Journal of Manufacturing Technology Management*, Vol. 25, No. 1, pp. 27-48.
- Gendreau, M., Laporte, G., Seguin, R. (1996), "Stochastic vehicle routing", *European Journal of Operational Research*, Vol. 88, No. 1, pp. 3-12.
- Ghiani, G., Guerriero, F., Laporte, G., Musmanno, R. (2003), "Real-time vehicle routing: Solution concepts, algorithms and parallel computing strategies", *European Journal of Operational Research*, Vol. 151, No. 1, pp. 1-11.
- Ghosh, S., Maiti, J. (2014), "Data mining driven DMAIC framework for improving foundry quality – a case study", *Production, Planning & Control*, Vol. 26, No. 6, pp. 478-493.
- Guan, T.S., Mason, K., Disney, S. (2003), "MOVE: Modified Overall Vehicle Effectiveness", *8<sup>th</sup> International Symposium on Logistics*, Seville, Spain, July 2003.
- Hill, A., Benton, W.C. (1992), "Modelling intra-city time-dependent travel speeds for vehicle scheduling problems", *The Journal of the Operational Research Society*, Vol. 43, No. 4, pp. 343-351.
- Hines, P., Rich, N., Esain, A., (1999), "Value stream mapping: A distribution industry application", *Benchmarking: An International Journal*, Vol. 6, No. 1, pp.60 - 77
- Hines, P., Taylor, D. (2000), *Going lean*, Lean Enterprise Research Centre, Cardiff Business School.
- Instituto Mexicano para la Competitividad (2004), *Elementos para mejorar la competitividad del transporte de carga*, Octubre.
- Jemai, Z., Rekik, Y., Kalaï, R. (2013), "Inventory routing problems in a context of vendor-managed inventory system with consignment stock and transshipment", *Production, Planning & Control*, Vol. 24, Nos. 8-9, pp. 671-683.
- Jones, D.T., Hines, P., Rich, N. (1997), "Lean logistics", *International Journal of Physical Distribution & Logistics Management*, Vol. 27, No. 3/4, pp.153-173.
- Kumar, M., Antony, J., Singh, R.K., Tiwari, M.K., Perry, D. (2006), "Implementing the Lean Sigma framework in an Indian SME: a case study", *Production Planning & Control*, Vol. 17, No. 4, pp. 407-423.
- Kumar, V.N.S.A., Kumar, V., Brady, M., Garza-Reyes, J.A., Soriano-Meier, H. (2012), "An AIS based approach to resolve forward-reverse logistics multi-period model with vehicle routing", *Proceedings of the 22nd International Conference on Flexible Automation & Intelligent Manufacturing (FAIM)*, Helsinki, Finland, 10-13 June.
- Kuo, Y. (2010), "Using simulated annealing to minimize fuel consumption for the time-dependent vehicle routing problem", *Computers & Industrial Engineering*, Vol. 59, No. 1, pp. 157-165.

- Kurdve, M., Hanarp, P., Chen, X., Qiu, X., Yan, Z., John, S., Jonas, L. (2011), "Use of environmental value stream mapping and environmental loss analysis in lean manufacturing work at Volvo", *Proceedings of the 4th Swedish Production Symposium (SPS11)*, Lund, Sweden, May 3-5.
- La Londe, B.J., Masters, J.M. (1994), "Emerging logistics strategies: blueprints for the next century", *International Journal of Physical Distribution & Logistics Management*, Vol. 24, No. 7, pp. 35-47.
- Laporte, G. (1992), "The vehicle routing problem: An overview of exact and approximate algorithms", *European Journal of Operational Research*, Vol. 59, No. 3, pp. 345-358.
- Lau, H.C.W., Chan, T.M., Tsui, W.T., Chan, F.T.S., Ho, G.T.S., Choy, K.L. (2009), "A fuzzy guided multi-objective evolutionary algorithm model for solving transportation problem", *Expert Systems with Applications*, Vol. 36, No. 4, pp. 8255-8268.
- Liker, J. (2004), *The Toyota Way: 14 Management Principles form the World's Greatest Manufacturer*, CWL Publishing Enterprises, New York, NY.
- Lummus, R.R., Vokurka, R.J., Rodeghiero, B. (2006), "Improving Quality through Value Stream Mapping: A Case Study of a Physician's Clinic", *Total Quality Management & Business Excellence*, Vol.17, No. 8, pp. 1063-1075.
- Lyons, A.C., Vidamour, K., Jain, R., Sutherland, M. (2013), "Developing an understanding of lean thinking in process industries", *Production Planning & Control*, Vol. 24, No.6, pp. 475-494.
- MapInfo Corporation (2015), available at: <http://www.mapinfo.com> (accessed on 7 April 2015).
- Mauri, F., Garetti, M., Gandelli, A. (2010), "A structured approach to process improvement in manufacturing systems", *Production, Planning & Control*, Vol. 21, No. 7, pp. 695-717.
- McKinnon, A., Campbell J., Leuchars, D. (1999), *Benchmarking vehicle utilisation and energy consumption measurement of key performance indicators*, Energy Consumption Guide 76 (DETR).
- McKinnon, A.C., Ge, Y., Leuchars, D. (2003), *Key performance indicators for the food supply chain, Transport Energy Benchmarking Guide 78*, Department for Transport, London.
- Monden, Y. (1998), *Toyota Production System: an integrated approach to just-in-time*, 2<sup>nd</sup> ed., Chapman & Hall, London.
- Nakajima, S. (1988), *An introduction to TPM*, Productivity Press, Portland, OR.
- Nousala, S., Ifandoudas, P., Terziovski, M., Chapman, R. (2008), "Process improvement and ICTs in Australian SMEs: a selection and implementation framework", *Production Planning & Control*, Vol. 19, No. 8, pp. 735-753.
- Ohno, T. (1988), *Toyota Production System: beyond large-scale production*, Productivity Press, Portland, OR.
- Osorio, C., Bierlaire, M. (2013), "A simulation-based optimization framework for urban transportation problems", *Operations Research*, Vol. 61, No. 6, pp. 1333-1345.

- Panwar, A., Nepal, B.P., Jain, R., Rathore, A.P.S. (2015), "On the adoption of lean manufacturing principles in process industries", *Production Planning & Control*, Vol. 26, No. 7, pp. 564-587.
- Pettersen, J. (2009), "Defining lean production: some conceptual and practical issues", *The TQM Journal*, Vol. 21, No. 2 pp. 127-142.
- Pisinger, D., Ropke, S. (2007), "A general heuristic for vehicle routing problems", *Computers & Operations Research*, Vol. 34, No. 8, pp. 2403-2435.
- Rother, M. and Shook, J. (2003), *Learning to see: value stream mapping to create value and eliminate muda*, Lean Enterprise Institute Inc., Cambridge, MA.
- Seth, D., Gupta, V. (2005), "Application of value stream mapping for lean operations and cycle time reduction: an Indian case study", *Production Planning & Control*, Vol. 16, No. 1, pp. 44-59
- Simmons, D., Mason, R., Gardner, B. (2004), "Overall vehicle effectiveness", *International Journal of Logistics: Research and Applications*, Vol. 7, No. 2, pp. 119-34.
- Singh, B., Sharma, S.K. (2009), "Value stream mapping as a versatile tool for lean implementation: an Indian case study of a manufacturing firm", *Measuring Business Excellence*, Vol. 13, No. 3, pp. 58 - 68
- Sternberg, H., Stefansson, G., Westernberg, E., Boije af Gennas, R., Allenstrom, E., Nauska, M.L. (2013), "Applying a lean approach to identify waste in motor carrier operations", *International Journal of Productivity and Performance Management*, Vol. 62 No. 1, pp. 47-65.
- Subsecretaría de Transporte (2013), *Estadística básica del autotransporte federal 2013*, Dirección General de Autotransporte Federal.
- Sutherland, J.L., Bennett, B., (2007), "The seven deadly wastes of logistics: applying Toyota Production System principles to create logistics value", *White Paper No. 701*, Center for Value Chain Research, Lehigh University, August.
- Swedish Association of Road Haulage Companies (2008), "Fakta om a°kerina°ringen", available at: [www.akeri.se/sveriges-akeriforetag/media/informations-material](http://www.akeri.se/sveriges-akeriforetag/media/informations-material) (accessed 22 June 2014).
- Taj, S. (2008), "Lean manufacturing performance in China: assessment of 65 manufacturing plants", *Journal of Manufacturing Technology Management*, Vol. 19, No. 2, pp. 217–234.
- Tapping, D. and Dunn, A. (2006), *Lean Office Demystified – Using the Power of the Toyota Production System in Your Administrative Areas* Chelsea, MCS Media Inc, Chelsea, MI.
- Taylor, L., Martichenko, R. (2006), "Lean Transportation- Fact or Fiction?", *Executive White Paper*, [www.fedex.com](http://www.fedex.com), September.
- Teichgräber, U.K., de Bucourt, M. (2012), "Applying value stream mapping techniques to eliminate non-value-added waste for the procurement of endovascular stents", *European Journal of Radiology*, Vol. 81, No. 1, pp. e47-e52.
- Tuli, P., Shankar, R. (2015), "Collaborative and lean new product development approach: a case study in the automotive product design", *International Journal of Production Research*, Vol. 53, No. 8, pp. 2457-2471.

- US Department of Transportation (2009), *The 2007 annual motor carrier efficiency study report to congress*, Federal Motor Carrier Safety Administration, Springfield, VA.
- US Department of Transportation (2011), *Freight facts and figures 2011*, Federal Highway Administration, Springfield, VA.
- UPS Logistic Group (2004), *Transportation suite routing and scheduling systems*, In: UPS Logistic Systems Presentation. Amnon Rasner Engineering Logistic System Ltd.
- Vanneste, S.G., Van Wassenhove, L.N. (1995), “An integrated and structured approach to improve maintenance”, *European Journal of Operational Research*, Vol. 82, No. 2, pp. 241–257
- Villarreal, B., Garcia, D., Rosas, I. (2009), “Eliminating transportation waste in food distribution: a case study”, *Transportation Journal*, Vol. 48, No. 4, pp. 72-77.
- Villarreal, B., Sañudo, M., Vega, A., Macias, S., Garza, E. (2012), “A lean scheme for improving vehicle routing operations”, *Proceedings of the 2012 International Conference on Industrial and Operations Management (IEOM)*, Istanbul, Turkey, July 3–6.
- Villarreal, B. (2012), “The Transportation Value Stream Map (TVSM)”, *European Journal of Industrial Engineering*, Vol. 6, No. 2, pp. 216-233.
- Villarreal, B., Macias-Sauza, S., Garza-Varela, E., (2013), “An efficiency improvement approach to reduce transportation cost: an application”, *Industrial and Systems Engineering Review*, Vol. 1, No. 2, pp. 153–161.
- Yin, R.K. (2012), *Applications of case study research*, 3<sup>rd</sup> ed., Sage Publications, Inc., London, UK.
- Yu, V.F., Hu, K.J., Chang, A.Y. (2015), “An interactive approach for the multi-objective transportation problem with interval parameters”, *International Journal of Production Research*, Vol. 53, No. 4, pp. 1051-1064.
- Woodside, A.G. (2010), *Case study research: theory, methods and practice*, Emerald Group Publishing Ltd., Bingley, UK.
- Womack, J.P. and Jones, D.T. (2003), *Lean Thinking – Banish Waste and Create Wealth in Your Corporation*, Free Press, Simon Schuster Inc, New York, NY.
- Zhang, J., Li, W., Qiu, F. (2014), “Optimizing single-depot vehicle scheduling problem: fixed-interval model and algorithm”, *Journal of Intelligent Transportation Systems: Technology, Planning, and Operations*, Vol. 19, No. 3, pp. 215-224.
- Zhong, H., Hall, R.W., Dessouky, M. (2007), “Territory planning and vehicle dispatching with driver learning”, *Transportation Science*, Vol. 41, No. 1, pp. 74-89.