

A Proposed Hybrid Scheme for Eliminating Road Transportation Waste

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Abstract - Evidence suggests that road transportation has become an important factor of international trade and supply chains performance and that it is generally considered an inefficient operational activity. In the last decade, a new 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. Previous works related to transportation waste have focused on the elimination of efficiency wastes. These types of waste are related to the improvement of the Operational Vehicle Effectiveness (OVE) and Total Operational Vehicle Effectiveness (TOVE). Lately, a systematic method for improving road transport operations based on the elimination of the *Seven Transportation Extended Wastes* (STEW) has also been suggested. It will be of interest to conduct a preliminary exploration about the possible inter-relationships between the efficiency waste schemes with the STEWs and explore the possibility of using them for building more effective improvement procedures. This paper is intended to carry out such study and provide a potential scheme that considers the identification and elimination of both type of wastes.

Keywords - *Lean transportation, efficiency wastes, truck utilization, transport waste elimination*

I. INTRODUCTION

Freight transportation by truck has become an important element of international trade and supply chains performance. Truck transportation has traditionally been stated as inefficient, both in European countries ([1,2]), North America ([3,4]) and in México ([5]). Therefore, the potential of adapting and using a waste elimination framework to improve truck transport operations appears to be high.

In the last decade, an emerging 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. Previous works related to transportation waste have focused on the elimination of efficiency wastes ([6,7,8,9]). An alternate waste elimination scheme for improving road transport was suggested by [10] based on the *Seven Transportation Extended Wastes* (STEW). It will be of interest to conduct a preliminary exploration about the possible inter-relationships between the efficiency waste schemes with the STEWs and explore the possibility of using them for building more effective improvement procedures.

This paper is intended to carry out such study and provide a potential scheme that considers the identification and elimination of both types of waste. The paper is organized into five sections. The following section provides a brief review of the literature on lean transportation. The scheme utilized to decrease waste is described in section 3. The application to a Mexican firm is undertaken in section 4, and section 5 presents a summary of conclusions.

II. PREVIOUS RESEARCH

Waste elimination is a fundamental aspect in Lean literature ([11,12]). A process can be separated into value adding and non-value adding steps, also called waste, according to market's needs. Toyota was the first to contribute in the waste identification process. Toyota defined seven major types of waste in manufacturing and business processes ([12, 13]). These include overproduction, waiting, unnecessary transport, incorrect processing, excess inventory, unnecessary movement and defects. References [14,15] show us that a great deal of waste has yet to be identified and eliminated in the administrative processes that support shop floor operations. In order to facilitate it, they adapt the seven wastes previously described for manufacturing operations to administrative processes, adding a new waste of underutilized people. As the focus of the value stream includes the complete value adding (and non-value adding) process, from conception of customer requirements to the consumer's receipt of product, there is a clear need to extend this internal waste removal to the complete supply chain. The seven wastes previously mentioned required an adaptation to the supply

chain environment. Reference [16] developed a process mapping tool called Value Stream Map (VSM) for the extended enterprise, looking to identify waste between facilities and installations in a supply chain.

A. Waste Elimination in Transport Operations

Transportation is an inherent element of a distribution strategy. The structure of a strategy differs depending upon the supply chain network design, the market geographic distribution, and the orders size and frequency, as described in [17]. According to [18], eliminating unnecessary transportation can be achieved increasing transport efficiency. Original work on lean transportation was developed by [19]. The authors suggest four lean transportation laws that can explain how the application of lean in transportation can positively impact overall organizational performance. Reference [20] developed a methodology for waste elimination in the area of railroad transportation. In this work, waste is defined as any activity or event that results in the ideal product not being provided. Finally, the Lean methodology has also been applied successfully to airline operations by [21].

Two main approaches based on waste elimination have been suggested for improving transport operations: The first scheme was initially proposed by [6]. This contribution recommends a new measure called Overall Vehicle Effectiveness, OVE, to be used for improving the efficiency of truck transportation. This is an extended version of the Overall Equipment Effectiveness indicator employed in lean manufacturing to improve single equipment efficiency ([22]). A modified version of the OVE measure is suggested by [7]. This is called TOVE and considers total calendar time instead of loading time and includes additional waste concepts as shown in Fig. 1.

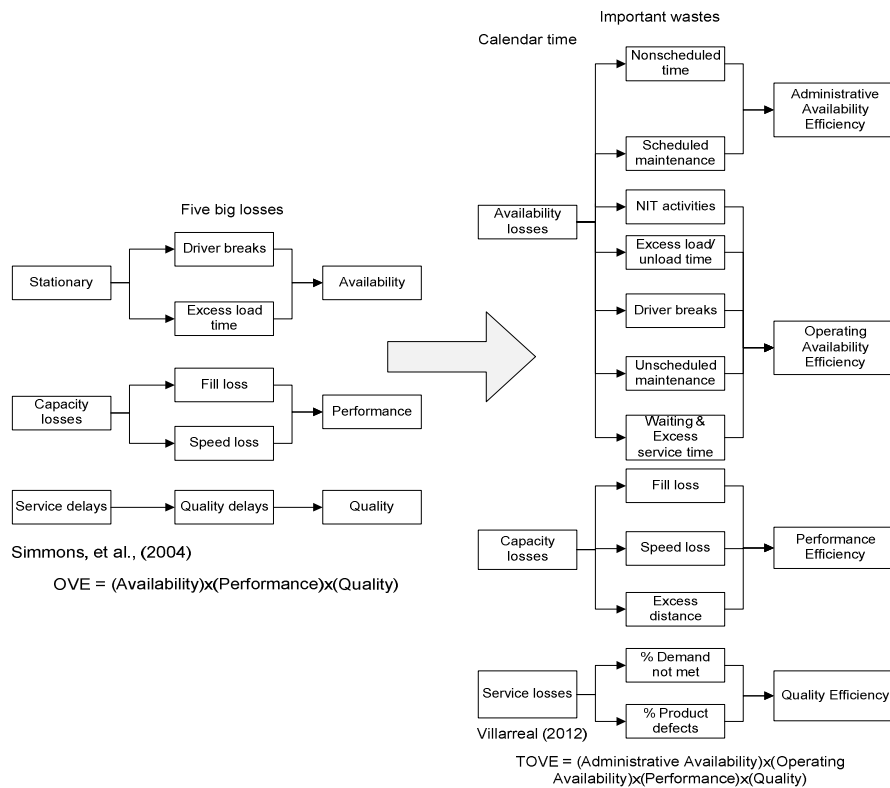


Fig. 1. Description of OVE and TOVE structure and components

Under this approach, waste elimination is concentrated on achieving the highest truck efficiency, similar to what the OEE looks for in a manufacturing machine. Thus, operations mapping and waste identification is carried out following the truck. In summary, four components for the new efficiency measure are suggested; Administrative or strategic availability, operating availability, performance and quality. The new measure would be obtained from the product of administrative availability, operating availability, performance and quality. The concept of vehicle administrative availability is important because it has a significant impact on the overall vehicle utilization and efficiency. It is mainly the result of administrative policies and strategies related to capacity or maintenance decisions. Reference [7] suggests a value stream map for transportation

processes (TVSM) that concentrates on identifying waste related to transport efficiency. It has been found that waste related to operating and administrative availabilities are very important. ([1,23,24]) and fill loss values ([25,26,27,28]).

The second scheme is provided by [10]. They propose the identification and elimination of transport wastes that are an extension of the seven wastes suggested by the Toyota Production System (TPS). Table 1 (from [10]) illustrates a description of these wastes in a transportation setting. A case study carried out through in-depth interviews with experts from the transportation and the lean fields resulted in this adapted waste framework. The result of this study was that five out of the seven classical waste types can be applied in this waste framework, but two do not fit, namely waste of excess inventory and conveyance. Instead, two new waste types are included: resource utilization and uncovered assignments.

TABLE 1 DESCRIPTION OF SEVEN WASTES EXTENDED TO TRANSPORT OPERATIONS

Waste Description	Source
1. 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 [14] confirmed in the empirical study
2. 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 the empirical study.
3. Incorrect processing.- Consuming more resources for moving the goods than necessary due to inefficient routing or driving	Definition suggested based on the empirical study.
4. Unnecessary movements.- 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 [14], movement due to sequencing errors added from the empirical study.
5. 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 empirical study.
6. Resource utilization (new).- Waste due to excessive equipment and bad resource planning	Definition suggested based on the empirical study.
7. Uncovered assignments.- Carrying out unprofitable transport work due lack of information or planning	Definition suggested based on the empirical study.

As it is the case for manufacturing operations, under this approach, operations mapping and waste identification is centered in the operations process following the product, instead of the manufacturing machine or truck. The framework was validated with case studies of three motor carrier operators in Sweden and two in Switzerland. The results showed that 28.93 percent of the transport time is either partly or completely wasted. Resource utilization and unnecessary movement with 11.45 and 7.21 % were the most important wastes identified. Waste of unprofitable assignments estimated at 39.19% of the percentage of transport assignments, was calculated separately.

B. Interaction Between both Approaches

It would be of interest to determine the interactions and relationship between both waste classification streams: STEW's and efficiency wastes. Considering Figure 1 and Table 1 as a basis, we can conclude the following points.

- STEW waiting is similar to the efficiency waste of waiting.
- STEW resource (truck, operator, etc.) utilization 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 defect includes efficiency wastes product defective and corrective maintenance.
- STEW's incorrect processing, uncovered assignments and resource utilization can cause efficiency wastes (truck) fill loss and/or distance traveled in excess.
- STEW resource utilization 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 transportation extended seven wastes increases the probability of occurrence of certain efficiency wastes. This aspect can be used to delineate an overall waste identification scheme. Two 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 use of performance measures (TOVE, availability efficiency, etc.), suggested by the efficiency approach is important because these can be used for reference and goal setting improvement purposes.

III. WASTE ELIMINATION SCHEMES

Several transport waste elimination schemes have been reported. Most of the available schemes designed are based on increasing vehicle effectiveness. The first one considered is the broad scheme provided by [29] to implement lean improvement initiatives. This is modified in [24] to eliminate transportation waste. This is further modified by [7] to adapt it to a specific environment of transport operations, considering efficiency wastes in the procedure. All the previous schemes have the purpose of eliminating efficiency wastes. Reference [30] provide another alternative scheme that is based on the identification and elimination of STEW. All these schemes are focused on eliminating efficiency waste or STEW's. There has not been an effort to discuss the possibility of defining a scheme that integrates both streams of waste.

The general scheme recommended considers that truck efficiency determines the transportation operations performance. That is, improving truck efficiency will decrease transportation cost and/or improve transportation time delivery. This scheme includes the following steps.

- Elaborate a Transportation Value Stream Map (TVSM) ([7]), and identify efficiency wastes.
- Estimate TOVE and efficiency factors.
- Prioritize efficiency factors (performance, availability, quality) to improve.
- Select the highest priority factor for improving.
 - o Identify transportation extended seven wastes related to the efficiency factor of interest.
 - o Define and implement waste elimination initiatives associated to the previously selected factor.
- If desired, go to step of selecting efficiency factor.
- If not, stop.

IV. APPLICATION OF THE SCHEME

This section presents a case study where the systematic lean scheme proposed to improve transport operations has been deployed, in the distribution operations of a large Mexican organisation, to explore its effectiveness. The Mexican organisation has a primary distribution network which conveys 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 percent

of the total national demand with sixteen RDCs. To further reduce distribution cost and to increase customer service in the secondary distribution network, the studied organisation decided to undertake an improvement project adopting the systematic scheme proposed in this paper. In particular, the improvement project focused on the routing operations from the Escobedo Distribution Centre (DC) to its customers.

A. Elaborate TVSM and Compute TOVE and Efficiency Factors

The first step of the systematic lean method proposed consists in conducting a TVSM analysis to map the transportation processes of interest, which in this case corresponded to the vehicle routing distribution from the Escobedo DC to convenience stores. The current TVSM for the routing operations is shown in Fig. 2. This map was constructed with information gathered from an administrative information system supported by the truck's GPS and the drivers' handhelds. Additionally, a team of students obtained detailed field data by accompanying the truck driving crews of a sample of 30% of the routes enabling the process of identification of wastes. The transport operations mapped include the following activities.

- Preparation of routes. This step includes the inspection of the orders' load, the truck and reviewing the route.
- Distribution of products (transporting products, serving customers and collecting spoiled product).
- Returning back to the DC.
- Closing routes. This stage includes settling payments from customers with the cashiers and returning spoiled product and the truck.

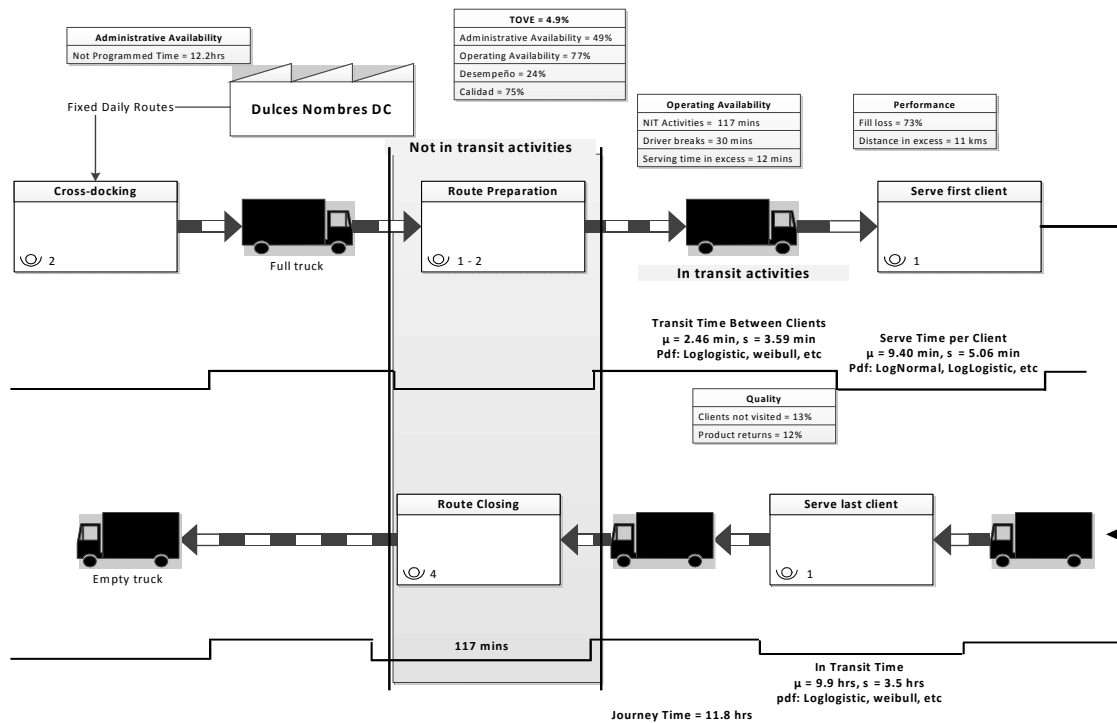


Fig. 2. TVSM for Escobedo routing operations

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 3. All the activities included in the process, from preparing the routes, serving the stores until closing every route were executed during the journey, i.e. all are internal. The TVSM analysis also indicated that the average In-Transit time was 9.9 hrs, whereas the average number of stores served by a route was 45. Therefore, the company was utilizing its fleet only about 49% of the daytime available. Additionally 17% of the time, both truck and its driving crew were in the DC performing Not in Transit activities. TOVE index is estimated at 4.9%. The factors with greatest areas for improvement are performance efficiency with 24% and administrative availability with 49%. Operating availability and quality efficiencies are estimated in 78% and 75% respectively. Figure 4 presents this information.

B. Select Efficiency Factors and Identify Associated STEWs

The second stage in the systematic lean transportation method proposed consists of the prioritization and selection of the efficiency factor with best opportunity area for improvement. In our case, the performance factor with 24% is selected. As given in the TVSM, the relevant detailed efficiency wastes that determine the level of this factor correspond to truck fill loss and distance traveled in excess.

The identification of the relevant STEWs ([10]) associated to the detailed efficiency wastes is the following step. Table 2 presents a summary of the most important STEWs identified associated with the Fill Loss and Distance in Excess wastes. In general, the main STEWs identified were related to: incorrect processing and resource utilisation.

TABLE 2. RELEVANT STEWs ASSOCIATED TO PERFORMANCE DETAILED WASTES

STEWS	Process	Description	Impact on
Incorrect processing and resource utilisation	<ul style="list-style-type: none"> Transporting product to customers 	<ul style="list-style-type: none"> Sub-optimal routes defined by drivers. Sub-optimal client sequencing. Customers are visited several times per route. Baskets for product larger than necessary Truck capacity over-sized 	<ul style="list-style-type: none"> Truck capacity under-utilization Distance in excess per route.

As illustrated in Table 2 incorrect processing and resource utilisation wastes were found, in this case, mainly in 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.

C. Definition of Waste Elimination Strategy for Performance Factor

In this case, the strategy established to decrease the main STEWs ([10]) identified was originally aimed at eliminating incorrect processing and resource utilisation. The waste elimination strategy formulated to tackle the STEWs is focused on the deployment of improvement strategies based on the design of semi-dynamic routes. Hence, other improvement strategies such as increasing the frequency of customers' visits, redesigning the basket size of transport vehicles, and using smaller trucks would be considered as part of a second wave of future improvement strategies.

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, it was decided that the company would carry out a weekly route redesign when additional new clients appeared. The company had the option of using specialised software programmes such as Roadnet Transportation Suite Routing and Scheduling Systems ([31]), which they already owned, and Map-Info ([32]). 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 ([33]).

D. Implementation of Strategy for Improving Performance Factor

It is estimated that the benefits that can be achieved by implementing this improvement strategy are significant. Table 3 illustrates a summary of these benefits. For instance, if the semi-dynamic route optimisation project 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 3. SUMMARY OF THE POSITIVE EFFECT OF OPTIMIZING ROUTES AND NIT AND SERVING ACTIVITIES

Concept	Current Status	Optimising Routes
Number of routes	90	81
Clients per route	45	51
Total distance (km)	1770	1487
Number of clients not served per route	6	0
Service time per client (min)	9.2	N/A
NIT activities time per route (min)	90	90

The implementation of improvement strategies is more effective when they are first supported by a pilot test to validate their effectiveness ([34]). Thus, the implementation of the strategy to eliminate the STEWs included an initial pilot test.

A sample of 30% of the routes was redefined. This task was carried out with the support of the specialised software programmes Roadnet Transportation Suite Routing and Scheduling Systems ([31]) and Map-Info ([32]). 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 change significantly. The second step, which has already started, is the redesigning of all 90 routes. It is estimated that this effort will be completely implemented and stabilized during the first quarter of 2015. Finally, this initiative will be applied to the rest of the routing operations during the second quarter of 2015.

E. Determine if Improvement Efforts are Continued

Finally, after the first efficiency factor has been improved, the management of the firm decided to continue the improvement effort. Thus, the following step of the scheme would be the selection of the efficiency factor. However, it is now necessary to re-compute the values of the efficiency factors given that the route redesign strategy has been implemented.

As expected, the performance efficiency factor will become close to 100% after the final implementation of the previously described initiative. The quality factor is improved to 88% because the percentage of clients not visited per route is eliminated. Finally, both, the administrative and the operating availability factors remain to be selected. Improving the administrative availability factor would require the utilization of the truck fleet a second journey per day. The management of the company did not consider this option feasible because of existent current security issues in México. Thus, the next factor to consider is the operating availability factor.

F. Identify Relevant STEW's Associated with the Factor

The detailed efficiency wastes that determine the level of the operating availability factor are NIT activities and the serving time in excess. 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 as waste. Also, 35% of the time taken to unload and close routes was found as non-value added.

The relevant STEW's associated are unnecessary movements and waiting. The initiatives delineated to eliminate these wastes consist of simplifying procedures for serving customers and closing routes.

G. Definition of Waste elimination Strategy for Operating Availability Factor

The simplification of procedures in three stages of the routing operations was undertaken, namely: (1) during route preparation before trucks leave 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 obtaining 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 is closing routes at the DC. This stage includes 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 achieved by implementing this improvement strategy are significant. Table 3 illustrates a summary of these benefits. However, implementing the improvements and standardising projects of NIT and customer serving activities would yield important benefits. For instance, total distance would decrease another 19%, and the number of routes would be reduced by 18%, see Table 4. 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.

TABLE 4. SUMMARY OF THE POSITIVE EFFECT OF OPTIMIZING 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	N/A	N/A
NIT activities time per route (min)	90	90	49

H. Implementation of Strategy for Improving Operating Availability Factor

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 job completely. These projects have already been fully implemented.

I. Determine if Improvement Efforts are Continued

At this point, no further improvement efforts were considered by the Management of the firm. Therefore, the scheme for improvement is stopped.

J. CONCLUSIONS

Road transportation has become an important factor of international trade and supply chains performance ([35,36,37]). It is also generally considered an inefficient operational activity ([1,2,3,4,5]). This paper presented a systematic approach to improve transport operations based on lean thinking and the reduction of

the efficiency ([6,7]) and seven transportation extended wastes (STEWs) proposed by [10]. Thus, the paper proposes an alternative hybrid approach that follows a limitedly explored improvement stream for road transport operations, “lean road transportation”.

The deployment of the systematic lean approach proposed is reported with its application in a Mexican firm. The first stage of the systematic lean method consisted of performing a TVSM analysis to study the road vehicle’ flow, the activities associated with its transport operations as well as supporting the following stages two of the method. The scheme is sequential in nature and based upon the idea that truck efficiency improvement originates higher levels of transport operations performance. Therefore, the estimation of the TOVE index and the efficiency factors are a key feature of the scheme.

The following stages of the scheme are determined by the priority given to each efficiency factor. For instance, in the application case the first factor analyzed and improved is the performance efficiency factor. The level estimated for this factor was determined by the identified wastes distance traveled in excess and truck fill loss. Given this result, we proceed to identifying the STEW’s that cause the previous wastes. These were incorrect processing and resource utilization. The strategy defined to eliminate them is based on the improvement of route design. After implementing the improvement strategy, there was another round of improvement. In this new iteration, it was determined to increase the level of the operating availability factor. The detailed efficiency wastes identified were customer serving time in excess and internal NIT activities. The strategy delineated consisted of simplifying the procedures for serving customers and closing routes. Finally, after implementing the new procedures, the Management of the firm decided to stop the application of the scheme.

After implementing all the initiatives, the company was confident that the number of routes could be reduced by 27% without compromising the customer service level, whereas distance travelled per route would decrease by 32%. This is an interesting finding that provides potential learning for other organisations aiming to reduce their road transportation waste. The findings suggest that following the STEWs approach of waste reduction can help organisations to significantly improve the efficacy of their road transport operations.

This paper also aimed at contributing by stimulating scholars to further study the application of lean thinking and waste reduction in road transport operations. Finally, a preliminary discussion about the inter-relationship between STEW and efficiency wastes was undertaken. It will be of interest to obtain further evidence of these and additional inter-relationship results to explore the possibility of using them for building more effective improvement procedures as part of the future research agenda derived from this paper.

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