

# An Efficiency Improvement Approach to Reduce Transportation Costs: An Application

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**Abstract.** The reduction of transportation costs is an important issue for many companies that need to stay competitive. This work describes the application of a scheme for increasing transportation efficiency to achieve this purpose. This scheme is developed around a modified version of the Operational Equipment Effectiveness (OEE) index used in Total Productive Management (TPM). This is adapted to be used as the main performance measure in transport operations. Availability, performance and quality wastes are identified using Value Stream Mapping of the operation. The implementation is carried out in the routing operation of a Mexican firm. The improvement initiatives are still in progress but the projected and available results are provided.

**Keywords:** Transportation waste elimination, lean routing, value stream map, transportation efficiency, Vehicle Routing Problem

## 1. Introduction

According to Christopher (1992), a key feature of present-day business is the idea that it is supply chains that compete, not companies, and that the success or failure of supply chains is ultimately determined in the market-place by the end consumer. It is extremely important that firms undertake the right strategies to successfully compete. Fisher (1997) point out that supply chains must acquire capabilities to become efficient or agile in accordance with the type of products they market. In particular, an efficient supply chain is suitable for selling functional products. As suggested by Hill (1997) the order winner factor in this market is cost, having quality, lead time and service level as order qualifiers. The main supply chain strategy recommended in Towill & Christopher (1992) to become efficient is waste elimination.

The problem of concern in this paper is the reduction of transportation cost in routing operations. The problem of reducing routing costs has been treated exhaustively in the academic literature. The Vehicle Routing Problem (VRP) is well known in the Operations Research and Just in Time literature. Its application is well suited to situations in which full truck loads are not possible, and the consolidation of orders or loads from several points are required to achieve higher capacity utilization levels for reducing transportation cost. From the O.R. point of view, the interest is concentrated on the development of algorithms to achieve an optimal or near-optimal solution to the problem. From the JIT literature, vehicle routing is also known as a milk run. It is a key aspect to enable frequent shipments of small lots from suppliers to customers, and therefore allowing for a Just in Time integration with them. This work provides a brief description of the application of an approach that integrates both views; O.R. and JIT. This scheme has the purpose of identifying and reducing waste in this activity and is discussed in detail by Villarreal, et al., (2010) and Villarreal (2012).

This report consists of five sections. The next section deals with a brief review of the literature on the Vehicle Routing Problem (VRP) and lean transportation. Then, a description of the scheme utilized to decrease waste is described in Section 3. The application of this scheme is undertaken in Section 4, and Section 5 presents a summary of conclusions.

## 2. Previous Research

The VRP is one of the most studied among the combinatorial optimization problems, due both to its practical relevance and to its considerable difficulty. The VRP is concerned with the determination of the optimal routes used by a fleet of vehicles, based at one or more depots, to serve a set of customers. The objective considered could be the minimization of distance, time or cost. In a certain sense, the purpose would be to eliminate excess distance in excess, which is considered as waste in the lean thinking arena. Several surveys of the different algorithms developed to solve the VRP problem with various characteristics and assumptions are available in the literature (Golden & Assad, 1988; Laporte, et al., 2000; Laporte & Osman, 1995; Toth & Vigo, 2002). An important aspect in vehicle routing that affects operational performance is that of driver familiarity with service territories. This is more so when the number of clients is very large and vary significantly. Driver performance improves with his degree of familiarity with addresses and locations. This can be a valuable asset when confronted with an environment with stochastic demand because it provides the company with high levels of flexibility to redefine daily routes. A two step vehicle dispatching procedure that balances the trade-offs of route optimality and driver familiarity is provided in Zhong, et al., (2007). This research is the basis upon which was developed the UPS Roadnet transportation suite software. This tool will assign customers to trucks according to their location and demand, and design daily route sequences to minimize distance.

Lean is the relentless elimination of waste in every area of operations. The origins of lean can be traced back to the 1930s when Henry Ford revolutionised car manufacturing with the introduction of mass production techniques. However, the biggest contribution to the development of lean manufacturing techniques over the last 50 years has come from the Japanese automotive manufacturer, Toyota. Taiichi Ohno defined seven common forms of waste: production of goods not yet ordered; waiting; rectification of mistakes; excess processing; excess movement; excess transport; and excess stock.

The lean approach to enable waste elimination throughout the supply chain was extended in Womack & Jones (1994). Transportation is one area where the application of lean techniques would yield important benefits. It is well known that transportation is an activity classified by the lean movement as waste. However, in a world where markets are distant, it becomes a necessary activity to move goods to each customer.

The literature research on the development of concepts, methodologies and applications of lean thinking in the transportation sector is rather limited. Most of the existing work concentrates on the definition of wastes specific to this process (McKinnon, et al., 2003; McKinnon, et al., 1999; Simmons, et al., 2004; Taylor & Martinchenko, 2006, Treviño, et al., 2008; Villarreal, et al., 2009). A methodology for waste elimination in the area of railroad transportation suggested by Dirnberger (2003) is one of the earliest contributions in this area. In this work, waste is defined as any activity or event that results in the ideal product not being provided. Four lean transportation laws proposed by Taylor & Martinchenko (2006) explain where and how transportation processes may be suboptimal and how the application of lean in transportation can positively impact overall organizational performance. These are: The Law of Transportation Waste, The Law of Transportation Strategy, The Law of Daily Event Management, and The Law of Transportation Performance.

The scheme described in this paper includes the definition of several types of waste specific to transportation with the goal of improving efficiency as the relevant performance measure in transport operations. In particular, it is defined for enterprises that own a fleet of vehicles to distribute its products. The use of the Overall Vehicle Effectiveness (OVE) measure for improving transport efficiency is recommended by Simmons, et al., (2004). This measure is attained by translating the principles of the OEE index used in TPM. OVE is to be used to measure the effective utilization of the road haulage vehicle in the freight transport industry. As illustrated in Figure 1, the components of the measure are basically the same.

The availability, performance and quality efficiency factors were calculated and multiplied together to produce a total OVE percentage rate and the method converted the OEE losses (breakdowns, changeovers, speed, minor stoppages, defects, yield loss) from manufacturing to transport. The result is the definition of five transport losses or wastes, which are:

- Driver breaks: Statutory breaks taken during a journey are considered a loss. If the statutory break is taken at the end of a journey or when somebody else is loading/unloading then it is not a loss.
- Excess load time: A standard time is allowed to load and unload a vehicle. When loading/unloading exceeds the standard time, for reasons outside the control of the vehicle driver, then excess load time occurs.
- Fill loss: Ideally the vehicle will be full; either by weight or volume, whichever is the lower constraint. Fill loss occurs when the vehicle is not fully loaded.
- Speed loss: The difference between maximum attainable speed and the average speed is the speed loss.
- Quality delays: Goods damaged in transit or poor/invalid paperwork would both be examples of quality issues that impact adversely on the OVE measure.

The OVE measure is modified in Guan, et al., (2003) by dividing the performance factor into two components; Route and time efficiencies. With this change, the measure will be able to reflect the efficiency of a route. An additional version of the OVE measure is suggested by Villarreal (2012). This is called Total Overall Vehicle Effectiveness (TOVE) and considers total calendar time instead of loading time. This is due to the fact that waste identification and elimination is related to the transportation vehicles utilized to move product. Since vehicles represent a high investment, it is very important to keep them in operation at all times.

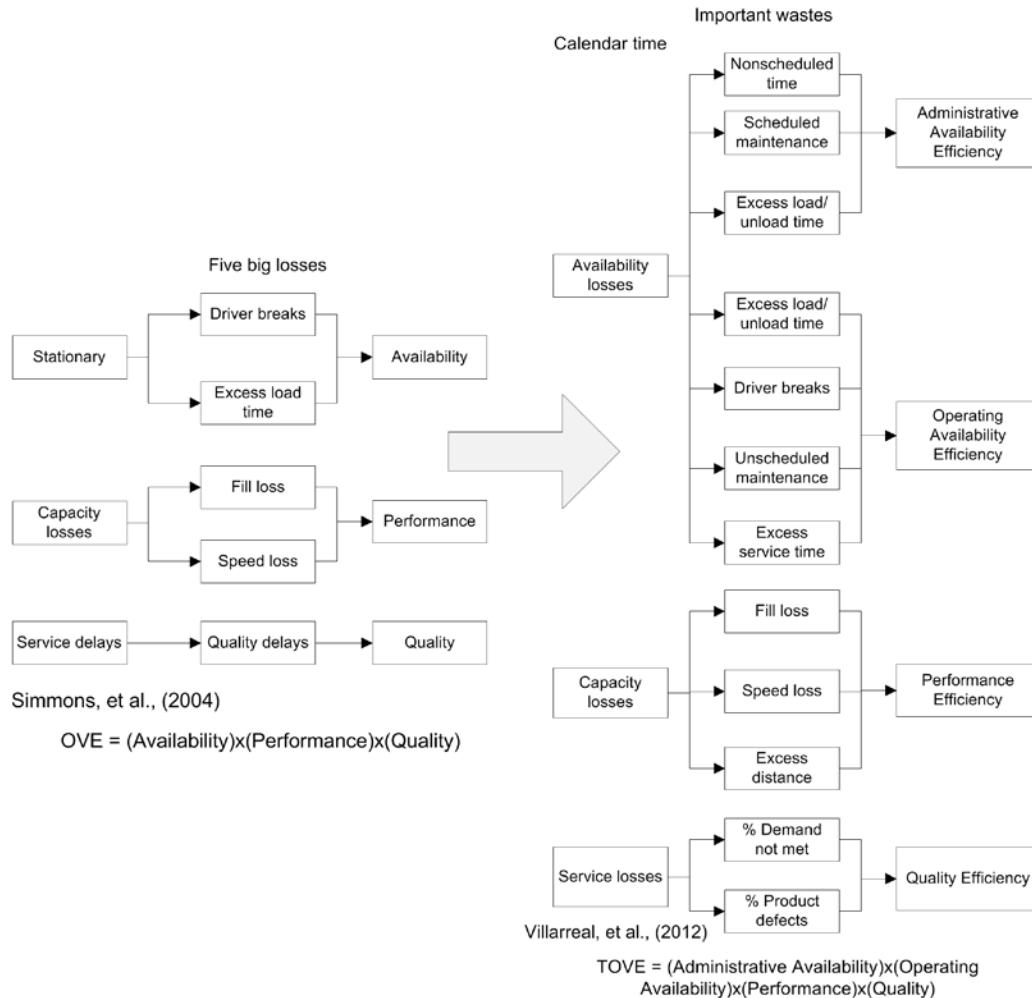


Figure 1. Structure of OVE and TOVE Measures

As illustrated in Figure 1, four components for the new efficiency measure are suggested: Administrative availability, operating availability, performance and quality. The new measure would be obtained from the product of administrative availability, operating availability, performance and quality. There are several waste concepts associated with each efficiency factor. For example, fill loss, speed loss and excess distance travelled are wastes that impact performance efficiency. Wastes related to quality efficiency are the percentage of demand not satisfied and product defects originated by mishandling during transportation. Driver breaks, breakdowns and corrective maintenance, and customer excess service time affect operating availability efficiency. Hence, in addition to the wastes given by Simmons, et al., (2004), we suggest the consideration of the following wastes shown in Figure 1:

- Non-scheduled time. It relates to partially using the time of the day for the job, i.e., only one eight-hour shift per day.
- Vehicle scheduled maintenance time. Time required for preventive maintenance
- Excess customer service time

- Vehicle breakdowns and non-scheduled or corrective maintenance
- Vehicle waiting time at DC.
- product defects originated by handling and routing
- The percentage of demand not satisfied in a route.

Additionally, excess distance travelled per route over the minimum required would be related to vehicle performance efficiency index. The concept of vehicle administrative availability is important because it has a significant impact on the overall vehicle utilization and efficiency. It is mainly the result of administrative policies and strategies related to capacity or maintenance decisions. The main waste associated with this concept is nonscheduled time.

In summary, improving routing performance has been mainly sought by operations researchers through the development of algorithms that look for the achievement of “zero travelling distance or time wastes”. However, it has been found that this is not the only important concept of waste occurring in this activity. Waste related to low availability factor values has been found to be very significant by McKinnon, et al., (2003), McKinnon, et al., (1999), Simmons, et al., (2004), Treviño, et al., (2008), Villarreal, et al., (2009) and Villarreal, et al., (2009). Table 1 illustrates a summary of the efficiency factor values found in two additional applications. A detailed description for each case is provided in Molina, et al., (2012) and Villarreal, et al., (2010) for UPS Mexico and the retailing case respectively.

Table 1. Importance of availability waste in two cases

Efficiency factor	Retailing case	UPS México
Administrative availability	41	45
Operating availability	39	84
Performance	51	27
Quality	96	58
TOVE	7	6

### 3. Concepts and Methodology

Routing activities could be defined as In-Transit (IT), that is, while the transportation service is in process, otherwise it would be Non-In-Transit (NIT); i.e. loading or unloading product at a distribution center. Let us define as the transportation journey (TJ), the time specified for the transportation activity for the team of operators and the vehicle. This may be a fixed period such as a shift of eight hours, or variable depending on the distance required to travel to the customer. We will assume that there will always be 24 hours per day available for the service, and so, several routing journeys (or services) are possible during a day. An activity is defined as Internal if it is carried out during the TJ by the team of operators with the vehicle. If it is carried out off the TJ or by another organizational entity, the activity is called External. The ideal would be that NIT activities are also external, and IT activities are carried out internally. The identification and analysis of transport waste is facilitated by the use of the Transportation Value Stream Map (TVSM) developed in Villarreal (2012).

A general procedure for reducing transportation waste is provided in Villarreal, et al., (2009a) and Villarreal, et al., (2009b). This is adapted from the broad scheme suggested by Hines & Taylor (2000) to apply a lean improvement approach. Another scheme to reduce waste in transportation is given by Villarreal, et al., (2010) and Villarreal (2012). This is described in Figure 2. The first step in this scheme is the description of the transportation activities in detail complemented by the estimation of the TOVE index and the elaboration of the corresponding TVSM. The structure of the map can be divided into the macro context and the micro analysis phase. The following stage consists of identifying waste at the macro level and particularly looking for opportunities to improve administrative availability. The macro context is directed to identify the macro characteristics of the route, namely: Average journey duration, the modified TOVE index and its components, vehicle administrative availability utilization based upon calendar time, availability wastes occurring off the route (such as vehicle nonscheduled time and scheduled maintenance time) and the proportion of internal and external activity time. This part of the map may serve to guide the improvement efforts according to the values of the TOVE factors: namely availability, performance and quality. At the same time, if all the transport activities are internal there will be an important opportunity to improve vehicle efficiency. The following stage focuses on identifying waste at the micro level. Especially, waste that impact on performance, operating availability and quality factors. The micro analysis phase completes the analysis of the wastes that drive vehicle operating availability, vehicle and route performance, and important route quality wastes.

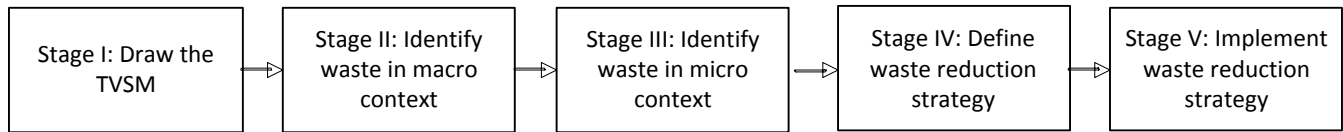


Figure 2. Description of improvement scheme

In this phase, the availability wastes considered are driver breaks, excess load/unload time and excess time taken by the operating team to carry out administrative activities with the customer. Performance wastes include speed and fill losses and excess distance required to fulfill customers demand. Quality wastes in transporting could refer to administrative errors, product defect generation and route customers not served on time and/or fully.

## 4. Implementation and Results

This section is devoted to describe the application of the previous scheme in the distribution of a bottled beverage of an important company located in the north of México. In particular, we will focus on the distribution from regional distribution centers (DC's) to retailing points such as convenience store chains, independent retailers and supermarket chains. The company has several regional distribution centers, and, for convenience, the one located in Monterrey will be described.

This regional DC includes a fleet of about 90 trucks. The DC serves about 6200 customers that include selling points (convenience stores and the like) and consumption points such as bars, restaurants and the like. The distribution of beverage is made daily through 64 fixed routes. The main strategic concern of the company in México refers to cost reduction. In order to handle this situation, the firm established a company-wide strategy for reducing cost. Since routing cost became an important component of the total cost structure in recent years, mainly due to fuel increases above inflation rate, it was mandatory to set a goal for distribution cost reduction.

### 4.1. Mapping the Transportation Process

The first step of the methodology is to map the transportation processes of interest which in this case corresponding to the vehicle routing distribution from Monterrey DC to convenience stores. The current TVSM for the routing operation is shown in Figure 3. This includes a follow up of the trucks inside the warehouse until a new journey is initiated.

### 4.2. Identify relevant wastes at macro level

As previously stated in Section 3, waste identification at this level emphasizes the overall context of the routing process chosen to study. The average journey time for the distribution of goods from the Monterrey DC to its corresponding retailing stores is 11.5 hrs, increasing the cost associated to overtime labor very significantly. All the activities included in the process, from preparing the routes, serving the stores until closing every route are executed during the journey: i.e. all are internal. Internal NIT activities take 2.5 hrs on average about 22% of journey time. The average number of stores served by a route is 15. TOVE index is estimated at 3%. The factors with greatest areas for improvement are operating and administrative availabilities with 19% and 31% respectively. Performance factor with 47% presents also a great area for improvement. The quality factor is estimated at 96% due mainly to product defects found at the customer premises.

### 4.3. Identifying key wastes at micro level

This stage is concerned with the analysis and identification of wastes and their causes in detail. The main area for improving in this case is to increase both the administrative and operating availability efficiencies. The main waste that drives administrative availability efficiency down is the unplanned truck time of 13 hours. Thus, routing capacity utilization is less than 50%! The wastes that impact the most operating availability efficiency are internal NIT activities that account for 2.5 hrs and an excess customer service time of 65%. NIT activities include loading, load inspection and closing the routes, which includes unloading returns. These should be improved and executed off the journey time by warehousing personnel. If this is done properly, the driving crew will utilize its working journey time in transit activities and will be able to serve more customers.

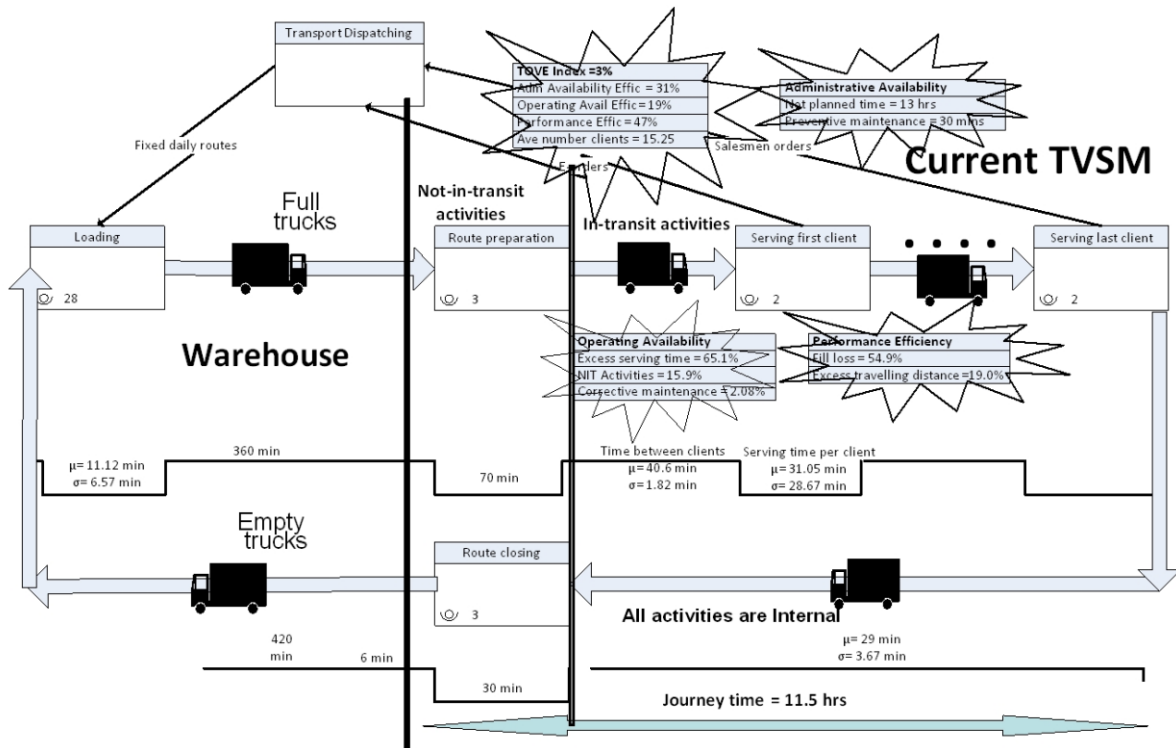


Figure 3. Current TVSM of routing operations

Customer service time includes the time taken to perform unloading product, inspecting and verifying with the store leader if the order is complete and getting (see Figure 4) and loading returns. The time taken to loading returns correctly is very important. Driver breaks were not scheduled and unscheduled maintenance is nil.

The best option for increasing performance is the reduction of distance travelled in excess and fill loss wastes (see Figure 4). Both wastes were impacted by the utilization of daily fixed routes with disregard of customer demand behavior. Daily demand from Monday to Wednesday was lower than the level shown during the period from Thursday to Sunday. Additionally, even though the firm owns a license of the UPS Roadnet suite, routes are not designed according to daily demand. Furthermore, route sequences are determined by the driver every day. Fill loss of 55% was estimated from the loads carried by a significant sample of routes. Excess distance of 19% was estimated by comparing current route distances against the optimal determined by the UPS Roadnet for a significant sample of routes.



Figure 4. Classifying returns and sub-utilization of truck capacity

#### 4.4 Defining waste elimination strategy

The strategy established to decrease the main wastes identified is originally aimed to significantly improve both the operating availability and performance factors. This consists of the following initiatives:

- Automating product loading and load inspection.
- Improving unloading procedure and assigning it to warehousing operators.
- Redesigning procedures to serve customers with the use of technology.
- Negotiating full time window flexibility with store leaders including night hours.
- Implementing UPS Roadnet software to design dynamic routes according to demand.

Once these initiatives are implemented, the responsible management of the company will assess the possibility of increasing administrative availability by scheduling at least two journeys per truck.

#### 4.5 Strategy implementation and projected results

The implementation of the previously described strategy is under way. This has been divided into three fronts:

The first front is concentrated on improving warehousing activities having in mind their impact on transport efficiency. The first project considered is to automate product loading and inspection before routing. This activity will be carried out by arm robots that will pick product according to customer orders from moving conveyors. The robots will be equipped with devices that will insure that the correct quantity and product type is picked. This eliminates the inspection stages executed by the driving crew and warehousing personnel for 70 minutes on average. The investment required by this project is estimated at 100k USD. The project is justified by the elimination of 25 operators.

The second front consists on decreasing excess customer serving time. This includes the implementation of three initiatives. The first project considers the application of technology to receive and verify daily orders at the store, in particular, for those under franchise. The second initiative consists of insuring that customers return bottles in their corresponding beercases. Finally, a team responsible for negotiating time windows considering night hours has approached store leaders. The previous initiatives have the potential of increasing the number of customers to be served per route and, moreover, decrease the number of routes required to satisfy all stores.

The third front is concerned with route design. The initial step in this front consists of the implementation of the UPS Roadnet system. This will reduce the number of daily routes according to the behavior of daily demand, and assigning customers based on their location and demand. This will greatly improve performance efficiency by increasing the utilization of truck capacity and reducing excess distance travelled per route. Management will also consider the utilization of trucks for two daily routes that favorably impact the administrative availability efficiency. Finally, there will be a periodic updating of routes to consider new store introduction.

The future TVSM considering that all the initiatives are implemented is shown in Figure 5. It is expected that the performance efficiency factor increases to 97% and operating availability efficiency factor to 78%. If trucks could be scheduled twice per day, the administrative availability efficiency can be increased to a level of 57%. This will push the TOVE level to 43%. The average number of stores per route increases from 15 to 25. The projected impact on transportation cost for this project is a conservative estimate of 40%. In addition, there will be a significant decrease of truck investment requirements since the average number of trucks necessary to satisfy daily demand is reduced 40%.

## 5. Conclusions

This paper deals with an application of lean methodology to the field of transportation and, in particular, to routing operations. It contributes with an application of a different approach suggested by Villarreal, et al., (2010) and Villarreal (2012) to identify and eliminate specific waste associated with the transportation of goods to improve its efficiency. This is applied to the distribution of goods from the Monterrey DC to its corresponding customers of a firm leader of the Mexican brewing industry.

The most significant improvement areas are related to the performance and availability factors. The particular wastes to be reduced are: Excess customer service and waiting times, excess route distance, truck fill loss capacity and the reassignment of NIT activities from internal to external status. The application of this improvement scheme proved to be very helpful to provide a guide to support management on investment decision making.

The strategy for reducing waste is in process of being implemented. The results obtained from the analysis and preliminary implementation actions give the responsible management high hopes and confidence that the overall initiative will be very successful.



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