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RESEARCH PAPER

Evaluation of Truck Balance Locations for Hazardous Materials Using Empirical Approach: Case Study in Argentina

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ABSTRACT
The logistical problems that companies must face tend to have conflicting interests between customers and service providers, which makes them difficult to solve. In turn, when the activities involve the transport of hazardous materials, the problem becomes critical in security terms, and makes logistics operations even more difficult. In the hazardous materials transportation literature, problems related to the routing of vehicles and the geographic location of supply or service centres are often addressed. However, there are not many studies related to the study of the loading, unloading and weighing operations of trucks that handle hazardous materials within industrial plants. That is why this work presents a case study of the installation of a new truck balance in an industrial plant in Argentina. To do this, the internal logistics operation and the current state of the plant's infrastructure are analyzed. A detailed study of the alternatives for the location of the balance was carried out following the criteria set by the company's management and the problem was solved using an empirical weighting method coordinated with the heads of the Supply Chain Department. A satisfactory solution was obtained.

KEYWORDS: *Truck transport; Logistics; Hazardous chemical; Operations management; Supply chain.*

1. Introduction

Supply Chain Management (SCM) is one of the essential activities that companies must efficiently solve in order to survive in today's competitive world [1] [2]. The efficient management of the SCM involves not only management throughout the entire product value chain [3][4], but also managing the internal components of the company itself appropriately [5] [6]. This paper deals with a case study on issues related to the internal logistics of a company, especially in the management of means of transport: trucks.

The truck transport system is the most used in Argentina due to its great flexibility [7]. The trucks allow access to industrial plants, load the product, transport the product long distances, and finally, deliver it to the customer that demands it [8] [9]. While it is true that transportation by means of trucks is not the most economical or efficient, its flexibility makes it to impose itself many times [10] [11] [12]. The case study considered in this work contemplates a truck-based system. For analyzing the problem, it was required to analyze the internal logistics operation of the truck load that withdraws the product produced by the industrial plant. This company is a chemical company from the Province of Buenos Aires, Argentina. The main shortcoming that seeks to be resolved in this work is the location of a new balance within the industrial plant so that certain criteria defined by the management of the company are met. The location of the new balance should provide the weighing operation more work capacity in order to accelerate truck dispatching.

Among the different aspects that must be considered for the resolution of this problem are the safety of the handling of dangerous chemical substances [13], internal transit systems and the management of operations within the industrial plant [14] [15]; building conditions that must be respected and analysis of investments in new infrastructure [16]. The proposed approach to solve the problem consists in a thorough analysis

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of the possible locations of the new balance, and then, perform an empirical qualification together with the company managers of each of them. Finally, a sum of the qualifications is carried out to identify that of the options that best solved the problem considered.

The rest of the work is organized as follows. In section 2 the current system of the company is presented, presenting the concrete problem and the objective of improvement. In Section 3 each of the alternatives of the solutions are presented and detailed. In section 4 the criteria for evaluating the different alternatives are presented and evaluated. The conclusions of this work are presented in Section 5.

Current system

The company has two scales, one to weigh the entrance and the other the exit of trucks. They are 20 meters long and 3 meters wide, have a maximum weighing capacity of 50,000 kg and are located approximately 130 meters from the entrance checkpoint. Any vehicle that intends to enter the company's facilities must be announced first in entrance checkpoint, this is also the case of trucks, which must submit the corresponding documentation. Once the documentation is verified, the truck enters the premises and is placed in the queue waiting to be weighed. This queue cannot be more than two trucks, while one is weighing in the balance, so as not to congest the streets where internal transport trucks of finished product circulate, trucks leaving the structure of truck covering, garbage trucks or vehicles internal.

Once the truck goes up to the scale, a physical control of the equipment, condition of the covers, lights, recoil alarms, windshield status is carried out. In addition, for example, if a hazardous substance (such as a Toxic chemical) is to be transported, drivers must have a valid national license and CNRT (National Transportation Regulation Commission) license for the transport of dangerous goods and the training certificate for the transport of such products. In the event that the tank, on its previous trip, has transported a different chemical, such as oils, solvents or any other organic product, it must be washed internally with steam before loading. The driver must present the certificates that guarantee the cleaning performed. The balance checks that everything is in optimal condition, weighs the same and then it goes to the parking until receiving the order of the logistics task manager to go to load the sector to which he indicates. The cargo sectors are the container beach, where the sheds are from 1 to 6; parking (not very usual), discharge silos located in the production area, sheds from 7 to 15, production shed, transfer shed. Once the loading or unloading operation of the truck has been carried out, according to whether it transports finished product or raw material, it is directed to the queue to be weighed at the exit and in case the queue is long, it waits in the waiting parking.

In the case of semi-trailer trucks with covers or traps, once loaded and weighed in the output balance, they are directed to the covering structure hat is located a few meters from the checkpoint booth. At the end of this task (covering the load), the local market trucks leave the plan. Meanwhile export trucks, must await the authorization of the customs personnel working in the plant in order to leave the company's facilities.

1.1. Problem motivation

The main drawback with the current system arises because of the requirements of the National Institute of Industrial Technology (INTI), entity in charge of controlling and regulating the proper functioning of the scales and enabling them to be used as fiscal balances. The two scales that the company has are analog technology and have many years of intensive use, which has caused their deterioration and that they have to be maintained more frequently than usual. Particularly, balance 1 no longer has the required precision, which forced INTI to demand the company to imminently change it for a scale that meets the requirements.

In addition, balance 1 is older than 2, and is out of market and no longer has spare parts. Therefore, if any of its load cells is broken, it would be the end of its useful life, even for approximate non-official weighings. This potential scenario, of catastrophic failure of balance 1, would imply for the company significant delays and losses of money by not being able to meet all customers' demands. In addition, it should be changed disruptively, so it would not be possible to provisionally plan the circulation for trucks and internal vehicles, altering the proper and normal operation of the plant.

1.2. Objetive

Therefore, in this work it is proposed to install a new digital balance that can be used as a fiscal balance. This will be used as a reinforcement of the two current balances, which will allow to use balance 1, which is obsolete and cannot be used

as a fiscal balance, for approximate non-official weighing. In addition, it seeks to reduce the queue of trucks waiting outside the entrance checkpoint, reducing congestion and preventing them from waiting in the surrounding areas to enter the company's facilities (which implies an obstruction against an emergency evacuation). It also seeks to reduce the queue inside the plant.
Hence, in this work we will analyze the different location variants of the new balance in the facilities and spaces available trying not to modify the infrastructure, or do it as little as possible so as not to generate unnecessary costs.

1.3. Literature review

Logistical problems are usually complex problems involving several agents who directly influence the problem, who tend to have conflicting interests, such as service providers and customers [17]. This characteristic makes logistical problems suitable for multi-criteria approaches [18], as in our case study presented here. A particularity of the problem studied in this work is the presence of hazardous materials, which makes the problem critical. As Holeczek [19] highlights in his recent literature review, hazardous material logistics require a special effort in safety considerations. However, most of the papers that address the logistical problems of hazardous materials address the problem of routing between different destinations, such as different versions of Vehicle-Routing-Problems [20] [21] [22]. However, in our work the focus is not on the routing or transportation of the hazardous material, but on the location of balances for trucks within the industrial plant and on the weighing operation with hazardous material.
The issue of truck weight has recently been addressed by [23] and [24]. In these works, the effect of the weight of trucks on the roads and the negative impacts that the overweight generates deteriorating the roads were addressed [23]. The development of efficient truck weight control strategies is also studied, analyzing the location of control stations [24]. A similarity between this last work [24] and ours, is that overweight control stations consist of balances that allow trucks to be weighed. However, the logistics and environment in which these balances are located is very different from that proposed in our work. In [24] the balances are not settled in a fixed place, the inspectors can move around the road network and place the balances at different points in the network temporally. In turn, the weighing operation is simpler than the one studied in our case. Since, being routine controls on the route, the operation of requesting services, checking hazardous materials licenses, etc. is not necessary, meanwhile in our case study these conditions must be checked. Precisely, this last difference is the one that adds meaning to our problem since it is necessary to analyze a complete operation immersed within a functioning industrial plant, which naturally implies solving different conflicting interests. For the study of different methods of multi-criteria decision making can be visited [25] [26] [27] [28].

Possible locations of the new balance

The logistic process that is currently carried out was studied taking into account the location of the entrance checkpoint and balancing office, movements of small and medium-sized vehicles both private and of the company, transfer of internal trucks to transport finished product from the production shed towards the corresponding sheds where the final product is stored either in 1250 kg bags or pallets with 55 bags of 25 kg (1375 kg per pallet); movement of cargo sampis, pedestrian paths, service street, movement of trucks that transport both raw material and finished product, container trucks for export. Access routes for tank cars which load and transport the chemical. Access and parking lots for private vehicles, etc.
Based on these criteria, several of the spaces available for the placement of the new scale are considered, and the selection of better options are:

- Alternative 1: Truck entry street just before the entrance checkpoint barrier.
- Alternative 2: Street where the truck covering is currently carried out.
- Alternative 3: Entrance street to the container beach.
- Alternative 4: Next to balance 1.
- Alternative 5: Next to balance 2.
- Alternative 6: In waiting beach.

All these options are depicted in Figure 1.

Fig. 1. All possible locations of Balance 3--

1.4. Alternative 1: truck entry street just before the entrance checkpoint barrier.

The first alternative is to locate the new balance, balance 3, as closely as possible to the current balances 1 and 2 (Figure 2 illustrates this location). Therefore, if balance 3 is installed there, it could be operated from the same office as the other two. Which would imply a very simple infrastructure work, requiring only wiring. In turn, the rest of the company's infrastructure would not be affected. The balance 3 can only weigh trucks entering the premises, whether full or empty. An important aspect to analyze is the distance between the goal and the balancing office: 130 meters, which the driver must walk walking to show the relevant documentation. This long journey implies considerable time, which would have an impact on the operation not only the operation of the new balance but also the other two, by inhibiting the entry of new trucks.

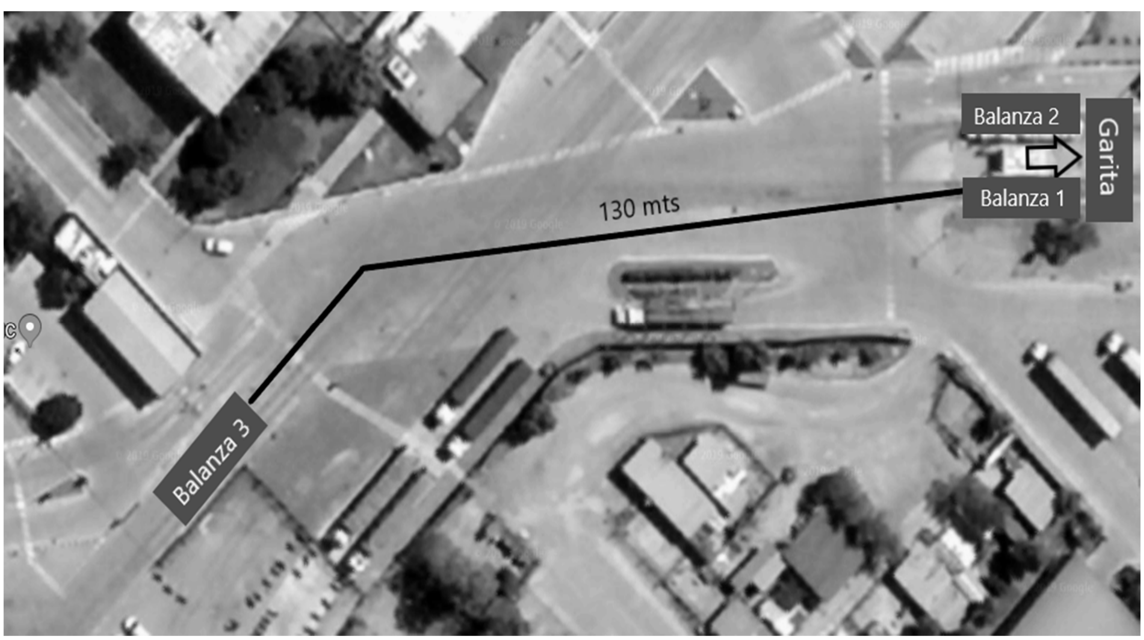

Fig. 2. Balance 3 located at the entrance checkpoint

Another option for this same location for balance 3, would be if balance 3 can be operated by a person from the entrance checkpoint (currently, it is not like this) or from a new balance office that could be located on the right side (considering the entrance perspective to the plant). In this checkpoint, the truck may present both the papers it currently presents at the entrance checkpoint and those corresponding to the loading order (received by the balancing operator). The placement of the scale in this place does not lead to a change in the circulation plan of trucks or internal vehicles. Although, it does require the construction of the new balancing office or the adaptation of the entrance checkpoint for such a function.

1.5. Alternative 2: street where the truck covering is currently carried out.

Alternative 2 raises the location of balance 3 in the street where the covering of trucks is performed. This new location, illustrated in Figure 3, makes it possible to reduce the distance between the balance 3 and the office of the balancers with respect to alternative 1, which is 63 meters. In turn, from this new location, heavy trucks on balance 3 have direct access to the beach of containers, waiting and unloading salt. Reducing the route and manoeuvring of trucks to access the waiting beach. Another positive aspect is that the balancing office could be used to accommodate the balancer assigned to balance 3, as well as the required instruments. This last option, despite requires investment in setting up the office, it would eliminate the walking distance for the driver.

However, this location of balance 3 implies a change in the infrastructure and in the design of internal transit of the company facilities. Since the place where the trucks are covered must be relocated, involving the construction of the covering structures again, as well as facilitating access and exits to the new location.

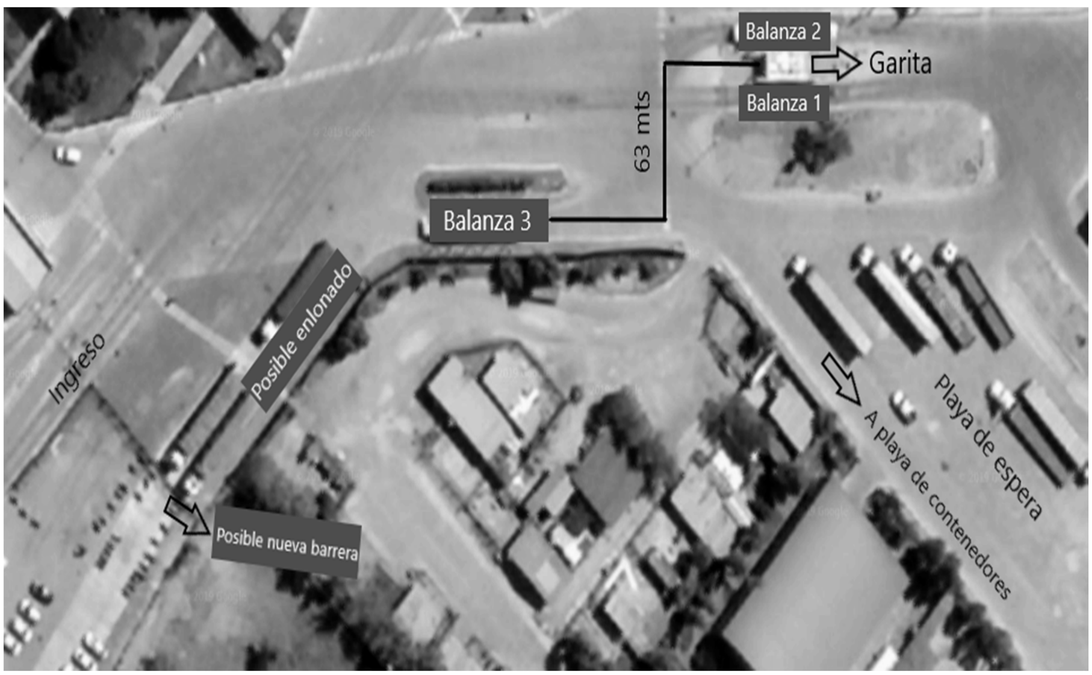

Fig. 3. Alternative 2: the new Balance 3 located at truck covering place

To deepen the analysis of the location of this alternative 2, the potential places to locate the truck covering structure will be analyzed. Three potential places are considered (illustrated in Figure 4):

Option 1. The covering structure could be mounted, as a first option, a few meters from the current place, specifically, in a place that is usually used by export trucks, already weighted and covered, waiting to receive customs clearance to leave the plant. Locating the covering structure in this place, would imply adapting said place to improve the exit of covered trucks, having to move a gate to increase the available space at the exit of the covering, so that the truck driver can perform the "U" turn movement, to be able to go back a few meters and take the current truck exit.

Option 2. Another option for the covering structure is to enable an additional output by placing a barrier in line to the covering structure. This implies reducing a private car parking lot that the company has in that sector, thus managing to free up space for the circulation of the truck that leaves the plant. Also, it requires that the doorman must walk more than he currently does, from the entrance checkpoint to this new exit. Note: the doorman must control entrance and exits of vehicles.

Option 3. A third option for the covering structure would be in the area of the container area. However, a very important point of this option is that the space to manoeuvre the trucks will be very limited, since the container requires a lot of space due to safety restrictions.

Fig. 4. Possible places for truck covering place.

1.6. Alternative 3: entrance street to the container beach.

Alternative 3 to locate balance 3 consists of locating it in an access road to the container beach, as shown in Figure 5. The distance to travel between the balancing office and balance 3 will be approximately 200 meters, producing the same problems of delays as in the first alternative. A main aspect of this alternative is the important modification in the current truck circulation plan. Thus, the placement of the balance here involves the construction of a new balancing office at the entrance to the beach for the exclusive use of balance 3. The maximum queue of trucks waiting near balance 3 should be zero or one truck to avoid clogging the roads where cisterns and wagons that transport hazardous chemicals circulate. Further, the trucks that leave the container beach (after loading product in the sheds 1 to 6) must be given place, as well as the trucks that enter the container beach. It is important to consider that the traffic of these vehicles requires complex manoeuvres, so space is a fundamental requirement.

Fig. 5 . Alternative 3: the new Balance 3 at entrance of container beach.

In turn, the light that must be left on the tracks must be enough so that the tanks that carry hazardous chemicals circulate, and thus, avoid any type of accident. In addition, by placing balance 3 in this position, it will practically limit its use exclusively for container trucks (for export) and trucks that load product available only in the sheds from 1 to 6. For trucks that load in silos (sector where it is loaded in bulk), production shed, sheds from 7 to 15 and transfer area would not be viable since the route of the trucks increases excessively. All this increases the traffic of trucks on the container beach by limiting the movements of the container and increasing the chances of collision or accidents between it and the trucks. Moreover, it also reduces the space available for the placement of both empty and full containers.

1.7. Alternative 4: next to balance 1.

The fourth alternative to place balance 3 is by doing it next to Balance 1, like in Figure 6.

Fig. 6. Alternative 4: the new Balance 3 next to

Placing balance 3 in this place would not produce variations in the current vehicle circulation plan. The infrastructure modifications that are required for this location are very slight compared to other alternatives, mainly, eliminate some sidewalks, trees and relocate a luminaire and the hydrant (for case of fire). The width of the circulation street where salt trucks enter and exit should also be increased. This widening will allow a double-lane street where salt trucks enter through one lane and trucks leave through the other. Also, trucks that transport different finished products may wait in that new exit lane, then move on to balance 2 or 3 and leave the plant.

In addition, the elimination of an old washing station is proposed in order to expand the waiting space for trucks.

One aspect to consider is that if at any time the balance 3 had to be adapted for the weighing of "bitrenes" (i.e. trucks with double trailer), this would imply the definitive elimination of the hydrant from that area. Which should be contemplated in the safety plans of the plant.

To specifically analyze how balance 3 would work in this position, it is necessary to analyze the operation logic, since all 3 balances will be together, and not all trucks need to be weighed in balance 3 (new and qualified for official weighing). Logic of entry and exit according to the type of truck:

- Salt truck: Entry through balance 1 and exit through balance 2.
- Garbage truck: Entry through balance 1 and exit through balance 2.
- Truck of chemical: Enter by balance 3 and exit by balance 2.
- Truck of finished product hopper or in bulk: Income balance 3 and exit by scale 2.
- Truck of finished product semi-trailer export: Income balance 3 and exit by balance 2.
- Truck of finished product semi-trailer local market: Income balance 1 or 3 and exit by scale 2.
- Container Truck: Enter balance 3, exit through balance 2.

As seen in the previous detail, the balance 1 is sought to weigh light loads. In addition, as long as the truck traffic is not intense, it will be prioritized to weigh the entry in balance 3. This seeks to reduce the frequency of use of balance 1 to increase its useful life.

1.8. Alternative 5: next to balance 2

Alternative 5 raises something similar to alternative 4, but instead of placing balance 3 next to balance 1, it does so next to balance 2. This alternative is depicted in Figure 7.

Fig. 7. Alternative 5: the new Balance 3 next to balance 2.

This potential location of balance 3 entails a slight variation of the truck circulation plan, but a significant change in the circulation of smaller vehicles (cars and vans) of both the company and individuals, as well as some building modifications. In particular, some existing building structures that limit the maximum height of circulating vehicles should be eliminated. In turn, part of the sidewalks must be removed so that trucks can access the balance 3. These modifications should always consider that truck traffic should not be linked to that of smaller vehicles, since trucks may be hazardous chemical transporters. dangerous. So, on that street only trucks could pass, and smaller vehicles must do so along the service street next to the truck beach. This division of traffic allows, in addition to complying with security issues, to order the great traffic that is generated in that sector of the company.

As in alternative 4, the logic of assignment of the balances should be analyzed. Logic of entry and exit according to the type of truck:

- Salt truck: Enters by balance 1, and exits by balance 3.
- Garbage truck: Enters by balance 1, and exits by balance 3.
- Truck of chemical: Enters by balance 2, and exits by balance 3.
- Truck of finished product hopper or in bulk: Enters by balance 2, and exits by scale 3.
- Truck of finished product semi-trailer export: Enters by balance 2, and exits by scale 3.
- Truck of finished product semi-trailer local market: Enters by balance 1 or 2, and exits by scale 3.
- Container Truck: Enters by balance 2, and exits by balance 3.

As in the previous option it is sought that balance 1 weighs light loads. In addition, whenever possible and the traffic of trucks is not intense, it will be prioritized to weigh the entry in balance 2. This seeks to reduce the frequency of use of balance 1 to increase its useful life.

1.9. Alternative 6: in waiting beach.

The last alternative is to locate balance 3 on the truck waiting parking. In this case, the distance between the balance 3 and the balance office will be approximately 50 meters (as shows Figure 8), which means that the travel times between both points are shorter than those of alternatives 1, 2 and 3, resulting in a shorter delay in the Weighing than in the mentioned options. An exclusive checkpoint for this scale could be built next to it, but it will not be so necessary due to the close distance with the current building of balancers. However, the space available for truck manoeuvres in the considered area is limited. And the truck waiting parking should be relocated to another physical space, which would significantly affect the company's current internal transit plan. A subsequent drawback is that the only available sector suitable for a new truck waiting parking is the container area. What would generate a complete restructuring of the internal logistics system by having to reposition the container area.

Fig. 8. Alternative 6: the new Balance 3 located in container area.

Evaluation and comparison

For the evaluation and comparison of the different alternatives, eight criteria will be taken into account. These criteria are presented and explained below:

- **Criteria 1.** Investment cost: this is the sum of all the costs generated by the location of balance 3, both in material and labor goods, which are derived from placing the balance in a certain location, for example, demolition and / or construction of walls, cords, buildings, lampposts; movement of bonding structure and hydrants, etc.
- **Criteria 2.** Modification of the company's infrastructure: considering that, beyond the costs of the new infrastructure, it is desired to generate the least possible changes due to the indirect consequences of any infrastructure work: places restricted by work, times, building permits, etc.
- **Criteria 3**. Distance between the new balance and the balancing office: the smaller the distance the truck driver has to travel to present the corresponding documentation to the balance, the faster the weighing will be carried out and the waiting queue will be reduced by increasing the free spaces before an eventual emergency.
- **Criteria 4.** Gain of space: the spaces available for the circulation, waiting, loading and unloading of trucks are currently very limited, in the event of any modification that occurs, avoid reducing them even more, trying to increase the spaces.
- **Criteria 5.** Modification of the truck circulation plan: modifying it would imply training the truck drivers on the new streets enabled for their circulation in an efficient and safe way. Therefore, changes will be avoided, or failing that, minimized.
- **Criteria 6**. Modification of the route of internal and private vehicles: modifying it would imply a training for all the company's personnel including collaborators who provide outsourced

services and drive medium or small vehicles on the new streets enabled for their circulation.

- **Criteria 7.** Distance traveled by trucks inside the plant: It is desired that the truck circulates as little distance and time as possible within the company's facilities to reduce the possibility of accidents and increase the efficiency of operations.
- **Criteria 8.** Safety: truck traffic should be avoided or minimized by places near the area of circulation and operation of the container, pedestrian paths, small and medium-sized vehicle traffic and railway tracks.

To assess the alternatives presented in section 3, the criteria presented above will be considered. In turn, for each criterion a scale of 1 to 4 will be used, with 4 being the highest and 1 the lowest level for that criterion.

An alternative will have a high score in one of the variables when it adequately meets the requirements imposed by the company through the criteria presented. For example, if one of the alternatives obtains a 4 in “investment cost” it will mean that the The company is willing and can cover all the expenses generated by placing the equipment in that place. Or get 4 in “distance travelled by trucks inside the plant” will mean that trucks increase the distance travelled with respect to the current one very little or not at all.

To make the comparison within the different locations of the truck balance 3, a weighted sum of the values obtained for each criterion was made. The relative weight assigned to each criterion was discussed with a committee of experts made up of people from the Supply Chain department of the company. Thus, was resolved to make a uniform distribution of the criteria and assign twice the weight to the "safety" criterion because it is a company's strategic policy. Therefore, each weight w of criterion i, w_i, was 0.11 for all criteria, except for the safety criterion that the value of the weight was 0.23. So that the weights met the condition $\sum_{i\in I} w_i = 1$. Note that the security weight is worth 0.23 instead of 0.22, for reasons of the restriction that the sum is equal to 1. To perform the weighted summation of the score of each alternative, the score obtained by each alternative must first be normalized for each criterion. The table with the normalized values is shown below, in Table 2:

Tab. 1. **Assessment of all alternatives regarding management criteria. Rank of qualifications, from 1 to 4, being 4 the best qualification.**

	Alt.1	Alt.2	Alt.3	Alt.4	Alt.5	Alt.6
Cri 1	3	1	2	4	3	2
Cri 2	3	2	2	4	3	1
Cri 3	1	2	1	4	4	3
Cri 4	3	2	2	4	4	1
Cri 5	3	2	1	4	4	2
Cri 6	4	4	4	4	2	4
Cri 7	4	3	1	4	4	2
Cri 8	4	2	1	4	4	3

Tab. 2. Normalization of the scores of each alternative following equation (1).

	Alt.1	Alt.2	Alt.3	Alt.4	Alt.5	Alt.6
Cri 1	0,75	0,25	0,5	1	0,75	0,5
Cri 2	0,75	0,5	0,5	1	0,75	0,25
Cri 3	0,25	0,5	0,25	1	1	0,75
Cri 4	0,75	0,5	0,5	1	1	0,25
Cri 5	0,75	0,5	0,25	1	1	0,5
Cri 6	1	1	1	1	0,5	1
Cri 7	1	0,75	0,25	1	1	0,5
Cri 8	1	0,5	0,25	1	1	0,75

After normalizing the score obtained by each alternative in each of the criteria, the score obtained by each of the alternatives was calculated. To obtain the final score for each alternative, S_l , the weighted sum (1) was performed:

$$S_l = \sum_{i \in I} w_i * s_{l,i} \quad (1)$$

Where, S_l is the total score obtained by alternative l. Which is calculated by multiplying the score $s_{l,i}$, which represents the standardized score of the alternative l for criterion i, by the relative weight of that criterion w_i. Since weights and scores are normalized, the range of S_l is : $S_l \in [0,1]$.

Performing the calculation of the weighted sums of the standardized scores for each criterion, Table 3 is obtained.

From the analysis of the results shown in Table 3, it is clear that alternative 4 (place balance 3 next to balance 1) is the best option with perfect score. Reviewing the criteria together with the characteristics of the alternatives, it is important to note that placing balance 3 in that position allows the maximum use of both the current facilities (balancing office), as well as the current truck circulation plans. In addition, it does not affect the transit of small vehicles. The second best alternative is to place balance 3 on the other side of the balancing office, next to balance 2 (alternative 5), with 0.89 weighted score. However, with respect to alternative 4, the biggest drawback is the street of small vehicles that circulates nearby, which must be modified. Also, placing balance 3 in this position implies demolishing some constructions generating costs. Alternative 1, locate balance 3 at the truck entrance, is the one that follows with respect to score with 0.8 of score. This option does not affect the transit of smaller vehicles, but it does significantly affect the distance between the balance 3 and the office of balancers, which implies a large distance that the driver must walk. And the possibility of building a balancing office in this sector, would improve the score of that criterion, but would significantly worsen the score of the criteria "investment costs" and "infrastructure modification". Alternatives 6 and 2 have the similar scores around 0.55 and 0.6, being deficient in many aspects, although alternative 2 is worse classified at the safety level, this being a criterion of utmost importance in all industrial chemical activity. Finally, alternative 3 is the worst of all alternatives because it implies major building modifications, logistics systems and all this without ensuring an adequate level of security.

Tab. 3. Final score of each alternative weighted by the weight of each criterion.

	S_l
Alt 1	0,8075
Alt 2	0,555
Alt 3	0,415
Alt 4	1
Alt 5	0,89
Alt 6	0,585

Conclusion

In this work a problem of logistics operations with hazardous materials was approached, through a real case of the location of a new truck balance in an industrial plant. The selection of the correct location for the balance involved an analysis of the weighing operation itself, as well as the internal circulations of the industrial plant. On the other hand, the possibility of minimizing costs at the time of installation was an important factor. However, the safety factor was the most critical when considering the locations. The study and analysis of the different alternatives allowed achieving an adequate weighting of each of the alternatives according to the set of criteria. To solve the decision-making problem, a simple approach was used, this approach allowed managers to have control and to follow the decision process step by step. On the other hand, the result showed a single option as the best alternative.

Finally, as future research lines this case study would be interesting to consider other multi criteria methods as TOPSIS, VIKOR, among others.

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