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Evaluation of the Reverse Logistics Performance in Civil Construction

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Abstract

Reverse Logistics is an activity that excels adding value to customers upon returning the consumer product to its origin. This return, when applied to products at the end of its useful life, makes this practice a "green" dimension because it provides an environmentally correct disposal of waste and assists the reuse of material, recycling and remanufacturing. Therefore, the operations performance evaluation arouses interest and acquires relevance. However, this activity is still little practiced in developing countries, such as Brazil and Colombia. It is the purpose of this article, to present a model for the Reverse Logistics performance evaluation in the construction industry - one of the sectors that most generates waste and which has a tremendous economic impact on the nations. The research began with a search in databases for publications concerning the performance evaluation of this practice with the aim to serve the model construction. The search resulted in only one article in the civil construction sector. Thus, it was researched in an exploratory way for studies that would enable the mapping of reverse flows of civil construction in developing countries. From this mapping a model was elaborated with indicators that address the logistics of supplies, internal and reverse, in order to evaluate the companies performance of this sector. A test was performed in a Brazilian construction company and in another Colombian one with the aim to demonstrate its applicability, where it was possible to highlight improvement points for each company and for the model that can be reapplied in other organizations of the sector. Despite the excellent performance presented by companies, it was noticed the lack of attention with this logistics area.

Keywords: *Reverse logistics. Civil construction. Performance evaluation.*

1. Introduction

Currently, enterprises have been looking for greener approaches to their processes, including logistics, which seeks to organize and distribute directly transport, storage, packaging and inventory management from the producer to the consumer (Rodrigues et al., 2001). All these activities can be carried out in reverse flow, from the consumer to the producer. This is the case of Reverse Logistics (LR), which is responsible for materials return to the supplier. This return can occur after the sale, for products repair or exchange, or after their consumption, for the correct disposal of waste (Leite, 2009). Rogers and Tibben-Lembke define LR (1999, p. 2) as:

> The process of planning, implementing and controlling of efficient flow and low cost of raw materials, in-process inventory, finished product and related information, from the

consumption point to the origin, with the value recovery purpose or proper disposal for collection and treatment of waste.

LR, when appropriately managed, can provide organizations with numerous opportunities, among them to reduce costs, increase revenues and enhance customer satisfaction (Badenhorst, 2003), as well as provide an improvement in the company's environmental performance in general (Carter & Ellram, 1988). Therefore, it is necessary that LR is well planned, executed and controlled. However, rarely does the literature discuss its performance. Butzer et al. (2017) state that it is not possible to efficiently run the reverse supply chains without evaluating their performance. According to Shaik and Abdul-Kader (2011), few measures are developed to assess the LR performance.

Thus, the present study aims to develop a model for the LR performance evaluation in civil construction, due to financial value that the waste in this sector has, besides the environmental hazard generated when these materials are not properly treated (Zutshi & Creed, 2015; Rahimi & Ghezavati, 2018). Civil construction is one of the sectors considered as priorities by the *European Commission* (2017), which, in terms of volume, is among the largest sources of waste in Europe, despite the fact that many of their materials are recyclable or can be reused through LR. The model was tested by means of two case studies applied in a Brazilian company and another Colombian. The countries chosen for the application need greater attention on the part of researchers due to the challenges of LR implementation in emerging economies (Guarnieri, Silva & Levino, 2016) and the low number of publications in these countries, although this number is growing in the BRIC countries (Govindan & Bouzon, 2018).

2. Theoretical Referential

The application of the performance evaluation in LR seeks to measure the efficiency and effectiveness of the activities involved in the materials reverse flow with the aim to assess whether these activities can be improved and where it is necessary to invest more resources to increase their benefits. Shaik and Abdul-Kader (2011) point out the reasons which led companies to invest in a system of logistics performance measurement: to gain a holistic view of the logistics process; follow the development of logistics activities over time; a better understanding of what is happening; obtain competitive results; improvement of customer service; and improvement of processes.

The management and recycling activities of wastes are associated with environmental regulations, and many countries are endeavoring to improve efficiency in this area, due to this, the concept of chains closed originated, that combines the traditional with the reverse logistics in order to fall in the compliances of public policies (Trochu et al., 2018). In civil construction, the search for buildings that are environmentally responsible and efficient throughout the entire life cycle encourages a more effective use and efficient use of energy, water and materials used as a way of ensuring the environmental effect minimization (Camgöz Akdag & Beldek, 2017). Also, there is a need to worry with the sustainability in all stages of the building life cycle, since the conception, design, construction, maintenance, and its demolition (Esin & Cosgun, 2007). That is the civil construction industry must administer since the construction project until the destruction of the same, considering not only aesthetic and the use of the building, but also the efficiency of the resources used (Camgöz Akdag & Beldek, 2017).

Despite all this concern, the studies about the LR benefits did not become common in the construction sector, remaining very limited in this field (Rameezdeen et al., 2015). This is due to the presence of some barriers that hinder the success of this practice; therefore, it is necessary to prioritize the understanding of these barriers and solutions to face them (Prakash et al., 2015). In Brazil, it is perceived that the main barriers are the financial investment and the legal issues, such as lack of tax incentives and legislation in the country (Souza et al., 2017). In Colombia, in turn, the barriers to the LR implementation, according to Arevalo Escobar (2016), are framed in 4 areas: cultural, due to the lack of respect for the social and environmental responsibility; legal, due to the lack of legislation in this area on the part of the government; Technical; due to lack of planning and technologies for the LR implementation; and economical, because the cost of investment in LR is very high, it is estimated that is nine times greater than the direct logistics.

3. Methods

For the construction of the conceptual-theoretical basis of this research, a bibliographic search was performed in databases searching for papers published in high-impact journals. The first axis deals with the "reverse logistics*" and the second *"performance evaluation" OR "performance assessment" OR "Performance measurements" OR "evaluation of Logistics Performance"*. After the removal of duplicate documents and a filtering for elimination of studies outside the scope, 39 articles were selected for the design of the bibliography of this research. Among these articles only one works the LR performance evaluation in civil construction, which results in a lack of studies in the construction area. This article highlights how the LR activities applied in civil construction can bring profits to the company (Raj & Seetharama, 2013). The proposal of this research is to develop a model for LR performance evaluation in civil construction for companies in developing countries. Thus, it was sought for papers in this area applied in countries in Latin America to map the LR because, according to Nawrocka and Parker (2009), it is important to consider the specific reality of countries when this subject is studied, with the aim of building foundations for comparison of the research results. This search was performed in an exploratory way and the work of Morales (2009), in Colombia, and Nunes, Mahler and Valle (2009), in Brazil, were selected and used in the mapping construction shown in Figure 1. The proposal of Nunes, Mahler and Valle (2009) shows a more general view of LR in civil construction, with a focus on direct and reverse flows of materials. Morales (2009) highlights activities that occur within the company during the LR implementation. This way the approaches are complementary and allow the LR mapping construction with focus on civil construction.

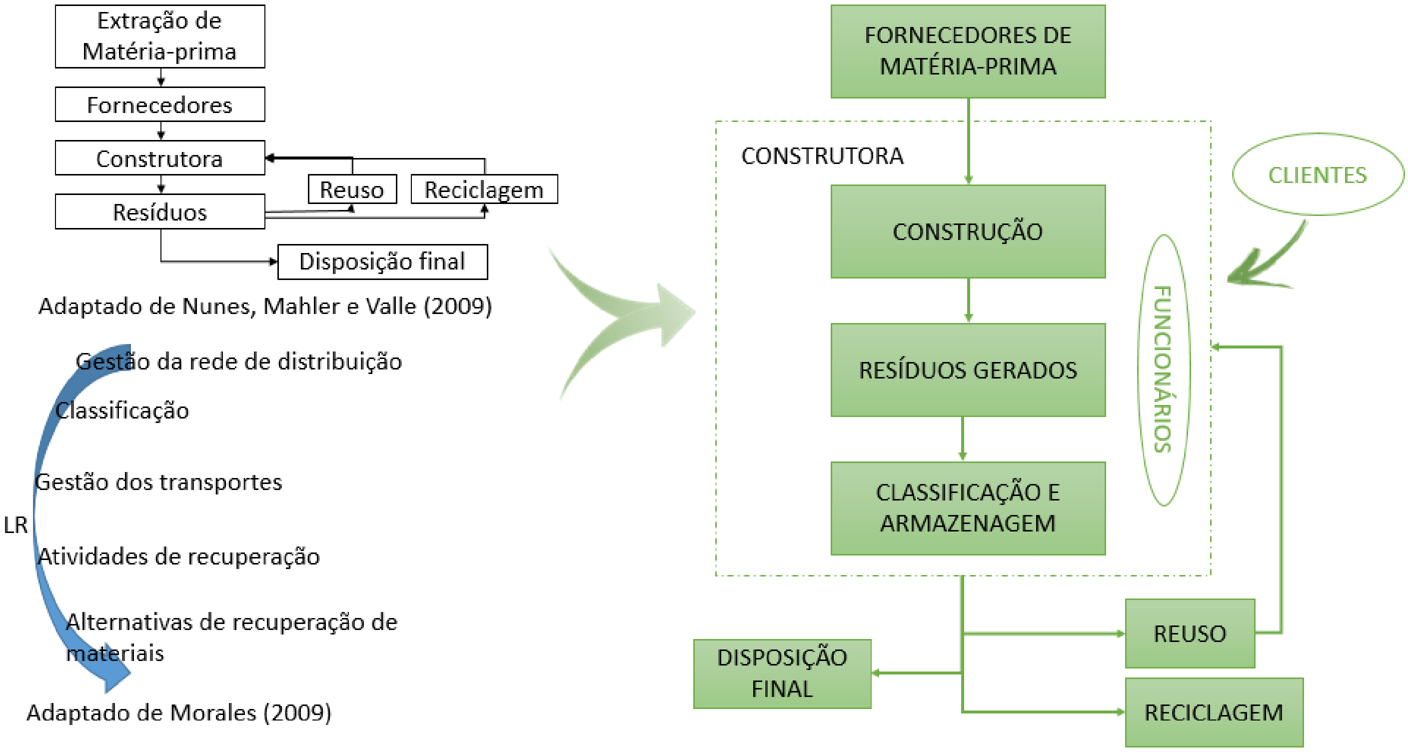

Figure 1. LR mapping of civil construction. Adapted from Nunes, Mahler and Valle (2009) and Morales (2009)

From the mapping three basic LR areas highlighted: the logistics of supplies, which involves the relationship with suppliers, the construction company's internal logistics, where occurs the use of materials, the financial part and the customer's satisfaction; and finally the reverse logistics, responsible for classification and storage of waste, transport these until the recycling companies or to the final disposition and the involvement of employees in carrying out these activities. Based on the found literature a set of indicators was elaborated for a model for LR performance evaluation. The model was tested in two construction companies, one located in Brazil and one in Colombia, to demonstrate its applicability.

4. The Proposed Model

To meet the legislative and their customers' requirements, companies seek to apply sustainable activities. The performance evaluation contributes to determining goals, indicators and organize data collection so that the certifications, the preparation of reports and continuous improvement activities occur. With this purpose, a model for measuring the LR performance in the civil construction sector was elaborated. Based on the literature, a set of indicators is proposed and in the end, they result in a single index by means of a simple arithmetic average. The simple standard was used because it is a generic model, but, when applied in companies, this average should be weighted by managers by the strategy of the same.

The model is shown in Table 1, with indicators for the logistics of supplies, the internal logistics, which deals with the waste and the reuse of materials in the processes that occur within the company and the costs involved, and to the reverse logistics. The term " construction bay" refers to the place intended for the storage of each residue.

Table 1 - Evaluation of the LR performance

	INDICATORS	# OF INDICATOR	MEASURE	DESCRIPTION
SUPPLIES	Green Purchases	LS - 1	$\frac{Products\ allowing\ LR}{Total\ of\ Products} * 100\%$	Percentage of purchased products that facilitate their return after use. The Closer to 100% the better.
INTERNAL LOGISTICS	Use of Materials	LI – 1	$\frac{Consumed\ Materials}{Planned\ Materials} * 100\%$	Percentage of utilization of materials: 100% = all materials are used. Greater than 100% = there was an error in the calculation of the number of materials or waste (requires investigation) Less than 100% = there is a waste of materials because the consumption was higher than planned.
	Reuse of materials	LI – 2	$\frac{Quantity\ of\ reused\ material}{Quantity\ of\ used\ material} * 100\%$	Percentage of reused materials during construction. The closer to 100% the greater reuse.
	Return on Investment	LI – 3	*[(profit on sales of wastes + savings in purchasing of materials that are reused) / Capital invested in LR]*100%*	Percentage of return on investment.
	Customer Satisfaction	LI - 4	Does the waste management affect his or her choice of purchase? $\frac{Positive\ answers}{Total\ of\ answers} * 100\%$	The percentage of positive responses in the customer satisfaction survey.
REVERSE LOGISTICS	Storage	LR – 1.1	$\frac{Nº\ of\ bay}{Total\ number\ of\ different\ wastes} * 100\%$	Percentage of waste, which have their individual construction bay For its correct destination it is important that each type of waste, has its *construction bay* to be stored. This indicator measures whether all wastes are stored individually or not.

		LR – 1.2	$\frac{Volume\ of\ waste\ "y"\ in\ the\ bay\ "x"}{Total\ Volume\ of\ waste\ "x"} * 100\%$	Percentage of materials found in the wrong storage site. "x" represents the residue that shall be stored in the assessed *construction bay* and "y" represents the volume of waste other than "x" present in the *bay*. The lower this percentage, the lower the number of errors.
	Transportation	LR - 2.1	$\frac{Volume\ of\ transported\ material}{Truck\ capacity} * 100\%$	Percentage of use of space in the means of transportation. Values below 100% indicate waste of space.
		LR - 2.2	$\frac{Volume\ reaching\ destination}{Volume\ leaving\ the\ construction\ site} * 100\%$	Percentage of material waste during transportation. Values below 100% indicate waste of materials.
		LR - 2.3	Mileage travelled * emission factor of fuel per kilometer	Carbon emissions in the transport sector in accordance with the mileage travelled and the emission factor present in Table 4.
	Awareness of workers	LR – 3.1	$\frac{Nº\ of\ skilled\ workers}{Total\ of\ company's\ workers} * 100\%$	Percentage of workers trained to work with the LR processes.
		LR – 3.2	Do You find waste management important? $\frac{Positive\ answers}{Total\ of\ answers} * 100\%$	Percentage of positive responses.

Source: Elaborated by the authors

As a way to suit the environmental laws, an indicator was created for the emission of carbon dioxide (CO2), which involves the emission factor according with the fuel used. This factor can be observed in Table 2. The calculation of carbon emission should be adapted to each type of vehicle used. The carbon emission should be the lowest possible, and due to this, it is included in the calculation of the overall LR indicator, in order to facilitate the implementation of all types and sizes of businesses in the civil construction. In order to generalize the calculation of this indicator to allow comparability among companies the equation of Cancelli and Dias (2014) was used.

Table 2 - CO2 emission factor of fuels

Gasoline	Ethanol	Diesel	Natural Gas (CNG)
0.227 kgCO2/Km	0.176 kgCO2/Km	0.445 kgCO2/Km	0.286 kgCO2/Km

Source: Adapted from cancelli and Dias (2014)

The percentage of materials found in the wrong *baia* (LR 1.2) should be the lowest possible, so that there are not errors. The other indicators involved have their maximum value (100%) as desired. Therefore, the equation of the overall LR indicator is presented in Equation 1.

$$LR = \frac{LS\ 1 + LI\ 1 + LI\ 2 + LI\ 3 + LI\ 4 + LR\ 1.1 + (100 - LR\ 1.2) + LR\ 2.1 + LR\ 2.2 + LR\ 2.3 + LR\ 3.1 + LR\ 3.2}{11}$$ Equation (1)

The result of this overall indicator assesses the current LR situation in the company. Values below 30% are an alert sot that managers give greater attention to LR and create improvement solutions for the reverse activities. Values between 80-30% indicate a LR in median operation, requiring improvements in its system and attention on the part of managers. Values above 80% indicate a well-administered LR, but that still needs monitoring and continuous improvement of its processes so that this value does not decrease. These values were assigned in consideration to the generality of the model. The limits for each stage of performance must be assigned by the managers of each company in accordance with the targets to be reached to reflect the adopted strategy.

5. Application of the model

The model was validated in two countries of Latin America: Brazil and Colombia, in companies in the civil construction sector. The Brazilian company has over 30 years of experience in the construction of more than 100 residential and commercial buildings of high standard in the region of Grande Florianópolis, in the South of the country, under the seal of quality ISO 9001 and PBPQH level A.

The Colombian company, in turn, has over 10 years of experience in the civil construction, such as roads, bridges and buildings in the Caribbean region of Colombia, under the seal of quality NTC-ISO 9001. The application of the model in the two construction companies is presented in Table 3. Construction company's managers validated the model and the indicators were calculated to demonstrate its applicability.

Table 3 - Application of the model for LR performance evaluation

	INDICATORS	# OF INDICATOR	BRAZILIAN COMPANY	COLOMBIAN COMPANY
SUPPLIES	Green Purchases	LS – 1	0%	64%
INTERNAL LOGISTICS	Use of Materials	LI – 1	100%	92%
	Reuse of materials	LI – 2	100% for forms of wood and props	91% for forms of wood
	Return on Investment	LI – 3	It is not possible to measure the indicator	37%
	Customer Satisfaction	LI – 4	It is not possible to measure the indicator	88%
REVERSE LOGISTICS	Storage	LR – 1.1	100%	100%
		LR – 1.2	It is not possible to measure the indicator	It is not possible to measure the indicator
	Transportation	LR - 2.1	100%	87%
		LR - 2.2	It is not possible to measure the indicator	96%
		LR - 2.3	2.1*0.445= 0.9345kgCO2	5.3*0.227= 1.2031 kgCO2/Km
		LR - 2.3	6.0*0.445= 2.67kgCO2	7.2*0.286= 2.0592 kgCO2/Km
		LR - 2.3	-	6.1*0.445= 2.7145 kgCO2/Km
	Awareness of workers	LR – 3.1	100%	96%
		LR – 3.2	It is not possible to measure the indicator	89%

Source: Elaborated by the authors

Some indicators were not calculated due to lack of information. Among the available values, it is possible to calculate the performance of each construction company. In the Brazilian scenario, the company performance is 83.33%, according to Equation 2.

$$LR\ (BR) = \frac{0 + 100 + 100 + 100 + 100 + 100}{6} = 83.33\%$$ Equation (2)

Whereas the Colombian scenario presents a performance 84%, according to Equation 3.

$$LR\ (CO) = \frac{64 + 92 + 91 + 37 + 88 + 100 + 87 + 96 + 96 + 89}{10} = 84\%$$ Equation (3)

Both companies have a satisfactory performance for activities with available data. A comparison among the companies and suggestions for improvements are presented in the next topic.

6. Discussions

It is realized a negligence on the part of the Brazilian company, due to the large number of indicators that were not possible to calculate because of lack of information. This complicates the management of reverse processes because the system of performance assessment should indicate the LR weak points and provide information for the decision regarding the improvements of these activities. Therefore, this lack of management in some activities hampers the implementation of improvements in the same and in the LR performance as a whole. The available data by companies demonstrate satisfactory values for the calculated indicators, that is, the company performs well the activities which has control. The Colombian company offers a greater number of data and only one indicator is not managed. Next the companies performances are analyzed in each of the indicators.

6.1 Logistics of supplies

The concern with green purchases stands out by the Colombian company, which has this care with 64% of its purchases, while the Brazilian company has no concern on this issue. The green purchases assist in LR and environmentally correct disposal of waste generated, which can improve the performance of this process.

6.2 Internal Logistics

The indicator LI 1 presented higher values for both companies. The calculation of the amount of materials to be purchased by the Brazilian company is done by a team of engineers who takes into consideration the materials in stock (remains of other purchases) to avoid waste. In this case, the reuse of materials is a recurrent practice and materials intended as waste are those that can no longer be reused. Despite this, the Li 2 indicator can only be calculated for the forms of wood, which are reused throughout the construction, resulting in 100% utilization. The company has no data for the remainder of the materials. In the case of the Colombian company, there is a calculation of security in the purchase of materials, which, when not used, end up being wasted due to the difference in the types of work that the company performs not allow their use in another construction.

The investment return indicator could not be calculated for the Brazilian case because the company does not know how much capital was invested for the LR implementation, because this happened gradually as a way to adapt to the legislation in force. As a way of encouraging adherence on the part of the employees in the management of waste and LR, all the profit on the sale of materials for recycling companies is reversed for purchase of awards for employees to be drawn on the feast at the end of the year of the company. Thus, the company uses the social bias of the sustainability of ITS LR, which in the year 2017 collected R$4.500,00. The Colombian company had a return of 37% of its investments in the first two months of 2017, where the company invested $COP 5,000,000.00, had a return of COP1,150,450 with the sale of materials for recycling and saved $COP 680,900 in purchases of raw materials due to reuse of materials.

Regarding the customer's satisfaction, the Brazilian company does not have a question involving the LR in its satisfaction search. Thus it was not possible to calculate this indicator. The Colombian company has an average of 88% of positive responses regarding the preference of purchase when the company has waste management.

6.3 Reverse Logistics

Both companies have a suitable and special location for each type of waste (LR 1.1 = 100%). The indicator regarding storage errors (LR 1.2) was not calculated in both companies due to lack of data of the same. In spite of classification, errors happen they are not computed due to the low number of occurrences. This would be an indicator to be rethought in the model, due to the difficulty in its control.

For the indicators of transport, the Brazilian company has 100% in LE 2.1 utilization due to only dispatching the waste when they reach the volume capacity of the truck. Therefore, there is a regular date for submission. In the Colombian case, this indicator is 87% because the characteristics, dimensions and safety of the load will vary. There are occasions where the load is sent, but is not complete, which ends up resulting in an space on the truck. When the waste of material during transport (LR 2.2) the Brazilian company has no control of this indicator since the material leaves the company without being checked. The residues are weighed when they reach their destination for financial control and not regarding waste. During the transportation of the Colombian company, on average, 4% of wastes are lost. This value varies according to the type of material and its conditions of carriage and handling. Regarding the carbon emission, although the Colombian company use fuels with lower emissions (petrol and natural gas), as well as diesel, the transportations are longer, fact which results in a greater CO_2 emission.

The two companies have skilled and trained employees to work in the management of their wastes. The Brazilian construction company performs internal training to all its employees both collectively and in teams. The Colombian company held training with 96% of its employees. Also, it has a question about the importance of waste management in its internal satisfaction survey, where 89% consider it important that the company carries out activities of waste management.

6.4 Overall Indicator

In general, both companies have good results for the performance of its reverse flows, despite the lack of some data, which may be masking the overall indicator, especially in the case of the Brazilian company. A performance evaluation system should be able to show the strengths and weaknesses of the operation so that enables continuous improvement activities.

The Brazilian company only has control of activities which performs well, which resulted in a high performance in the overall indicator, but this may present lower values when all activities are assessed. The Colombian company result is closer to reality because only an indicator was not measured due to lack of data. Thus, it is possible to highlight some points of improvement for the model and for the companies. Namely:

- Rethink the indicator LR 1.2 regarding the improper storage of waste, which was difficult to data collection. For companies that have been implementing a LR system, the data collection for this indicator can enter into the planning of activities and, thus, be calculated;
- Search for partnerships with their suppliers to return their waste and get credit on the next purchase;
- Search for fuels with lower CO_2 emission factor or look for means of transportation with lower emission rate, as well as decrease the waste delivery distance;
- Integrate the wastes transportation with the raw materials transportation in order to take advantage of the return journey;

- The Brazilian company must seek for green products, which facilitates the LR, have control of the quantity of waste leaving the company and manage the LR financial indicator, such as the expenses with the reverse practices and the value of benefits generated;
- Adhere to the issues involving the management of wastes and the LR in the customers and employees satisfaction survey in the brazilian case; and
- The Colombian company should make better use of the space for the transportation of waste and perform the transportation always with the maximum capacity of the truck and take greater care with the losses during transportation.

Upon fulfilling all points of improvement proposed the companies can improve their overall performance and carry out their activities more efficiently and effectively. It is highlighted the fact that the Brazilian company does not have control of the data of all the activities carried out, which makes it difficult to evaluate its performance.

7. Conclusions

LR can bring several benefits to the company that implements it. Besides the observance of the environmental laws and the pressures on the part of customers, the economic benefits can also be significant when the reversals flow are well managed. In order to have a better perception of the LR company a performance evaluation system should be implemented, with the goal to know the flow reversals and find the areas that need improvement.

Civil construction is a sector with great generation of waste and LR is a way to reduce the environmental impact through the correct disposal of this waste for recycling, remanufacturing and reuse. Despite being, a common practice in developed countries LR still needs studies and greater adherence in developing countries. Due to this, this article developed a model for performance evaluation for civil construction and showed its application in a Brazilian construction company and another Colombian, where it was possible to compare the reality of both countries. It was realized the need for further monitoring of data in the Brazilian case and greater care with the transportation in the Colombian case. Despite this, both companies have good performance.

Through the application of the case it was possible to realize that one of the indicators proposed in the model does not have a practical bias because the necessary data are difficult to obtain. As a proposal for future research a comparison is suggested between the LR of developed countries with developing countries, so that it is possible to highlight the best practices of each country and propose improvements for both cases, which may make the LR performance evaluation a recurring practice in civil construction.

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