A FUZZY AHP APPROACH FOR EVALUATING REVERSE LOGISTICS INDICATORS IN BRAZIL

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Abstract
Due to the raising of environmental consciousness in the last recent years, companies are increasingly concerned with Reverse Logistics (RL) activities. Despite the growing relevance, RL remains not adequately managed or assessed when compared to direct logistics processes. For instance, managers face difficulties to select the most appropriate RL key performance indicators (KPI) in spite of its great amount available in the literature.

This paper contributes to close this gap by exploring RL performance indicators in theory and practice. Thus, this work brings to light the most relevant RL performance indicators in order to support decision makers to effectively improve their purposes in reverse flow of end-of-life products.

To this end, a three-step methodology was applied. Firstly, a systematic literature review on RL indicators was carried out. The most frequently cited indicators were selected and categorized into pre-defined domains.

Secondly, a questionnaire was submitted to academic experts and industrial managers from Southern Brazil in order to obtain the relevance of indicators by means of pair-wise comparison matrices. Finally, a data analysis was undertaken and the indicators were ranked using fuzzy analytic hierarchy process (Fuzzy AHP). The fuzzy approach was elected to deal with incomplete information and vagueness of responses.

This work may help companies to select performance indicators for a better implementation and management of RL. The preliminary results of the work show that KPIs strongly associated to the economic area still represent a crucial issue when assessing RL processes. At last, the paper concludes by discussing further insights on RL as well as by suggesting future paths of research on this topic.

Keywords:
Reverse logistics, performance indicators, AHP, fuzzy.

1 INTRODUCTION
Aiming to quickly react to the increasing demands of wider, faster and more flexible supply chains nowadays, there is a significant increase on the interest in reusing materials and products in order to enable: creation of closed-loop supply chains, product recovery and reverse logistics (RL) [0,0]. Furthermore, the use of RL systems is an environmentally, socially and economically sound way to achieve many of the goals of sustainable development [0] and companies that seek to obtain holistic competitive advantage are now raising awareness that choices on their products and processes can deeply have impacts on those three factors [0].

The reverse flows of materials field of study has gained more interest not only in the academia but also by many companies that intend to implement or improve their reverse processes [0,0]. Despite its enormous relevance, reverse supply chains have not been broadly researched or developed yet [0]. This may be caused by the differences when compared with direct flows. For instance, there is a difficulty concerning the shared responsibility among supply chain players to minimize waste generation by means of reuse, remanufacturing, recycling and safe disposal of unwanted items [0]. In addition, network design for reverse logistics is more complicated because of uncertainty in quantity, quality and time of the returned products [0].

In Brazil, RL has been gaining attention mainly due to the recent implementation (2010) of the new National Policy on Solid Waste (NPSW), which requires many industries to incorporate reverse logistics of End-Of-Life (EOL) products [0]. In addition, organizations, now obliged to develop reverse product flows, are also finding competitive advantages such as economic issues as the recovery of the value of used products, improvement of social conditions and green marketing [0].

Unfortunately, Brazilian managers still face many challenges originated from the many flaws in logistics infrastructure that may act against expansion of reverse systems [0].

Based on this current demand for reverse logistics systems improvements, the need for an adequate management of close loop supply chains and, consequently, the use of appropriate key performance indicators are crucial, considering an industrial practical approach. However, despite of the increase of studies on RL area, these ‘wished-list’ of Key Performance Indicators (KPIs) is still not consolidated. This means that there is a need for organizing and ranking KPIs that should or should not be used to assess the reverse flow of product, services or information. This gap might be mitigated with the support of scientific research works such as this one, which is supported by theory and practice.

To attain this research gap, this paper is organized as follows: Section 2 presents a literature review based on international relevant papers on RL, KPIs and Fuzzy AHP. Section 3 depicts the three-step methodology which includes a systematic literature review on RL, a questionnaire development and application with experts on RL field and a data analysis of the results with a fuzzy approach to deal with incomplete information and vagueness of responses. Finally, the conclusions are presented and suggestions for future work are made.

2 LITERATURE REVIEW
This chapter presents relevant information on concepts used during this research e.g. forward and reverse logistics and KPIs as well as an explanation about the methods used.
2.1 Forward and reverse logistics

The concept of logistics is not new and is already consolidated among authors. It can be understood as the correct flow and storage of goods from the point of origin to the point of consumption aiming at the customer satisfaction [0]. And this flow of goods includes not only physical flows, but also information flow [0]. This direct logistics flow is also known as Forward Logistics (FL) and with this correlation the reverse flow is named Reverse Logistics, which is similar to the FL but refers to the opposite sense, that is, from point of consumption to the point of origin [0].

Although RL has few similarities with forward logistics, its concept has evolved over time [0]. Back in the 1980s, when its first definition was outlined, RL was considered as the flow of goods from consumer to the manufacturer through a reverse distribution channel [0]. This concept has gained new values and areas of application moving on to concepts that include not only economic aspects but also environmental and social as well, Stock and Lambert [0] affirms that RL is the area of logistics that seeks economic and environmental value addition to EOL industrial goods enabling their return to product cycle as secondary material. RL is now considered to take part of many other areas that contributes for the value addition such as ecological, legal, logistical and corporate image [0].

Table 1. Differences between forward and reverse logistics. Source: Adapted from Silva et al. [0], and Tibben-Lembke et al. [0]

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Forward logistics</th>
<th>Reverse logistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product life cycle</td>
<td>Manageable</td>
<td>Complex to manage</td>
</tr>
<tr>
<td>Cost of distribution</td>
<td>Easily identifiable</td>
<td>Hardly identifiable</td>
</tr>
<tr>
<td>Destination or routing</td>
<td>Clear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Packaging of products</td>
<td>Uniform</td>
<td>Depends on several factors</td>
</tr>
<tr>
<td>Inventory management</td>
<td>Consistent</td>
<td>Inconsistent</td>
</tr>
<tr>
<td>Options of disposal</td>
<td>Clear</td>
<td>Unclear</td>
</tr>
<tr>
<td>Distribution outlets</td>
<td>One to many transportations</td>
<td>Many to one</td>
</tr>
<tr>
<td>Price</td>
<td>Relatively uniform</td>
<td>Depends on several factors</td>
</tr>
<tr>
<td>Forecast</td>
<td>Relatively straightforward</td>
<td>More difficult</td>
</tr>
<tr>
<td>Quality of products</td>
<td>Uniform</td>
<td>Depends on several factors</td>
</tr>
<tr>
<td>Visibility of process</td>
<td>More transparent</td>
<td>Less transparent</td>
</tr>
</tbody>
</table>

According to Table 1 it is possible to conclude that FL still has many advantages over RL particularly in regards to infrastructure, cost and forecast. A further analysis shows that managers struggle to find well consolidated strategic KPIs to measure RL performance.

2.2 Key Performance Indicators

Key Performance Indicators (KPIs) represent an important feature when analysing business management as the measurement of value and work are fundamental to effectively achieve business objectives.

Historically, companies have focused their measurement effort on studying mostly financial indicators. However, it is known that even non-numerical KPIs can also provide valuable information [0]. The selection of adequate KPIs can, nevertheless, be a hard task. On the one hand, if one uses a big amount of indicators it can lead to a big quantity of data collection which in tum, might implicate in high costs [0]. On the other hand, using few indicators can implicate on misinterpretation on current events and bad decision making.

2.3 Analytic Hierarchy Process

To rank and select adequate and most suitable KPIs for business, many methodologies can be undertaken. One of them is the Analytic Hierarchy Process (AHP), first suggested by Saaty [0], as a quantitative decision-making tool using pairwise comparison of factors [0] in order to obtain their importance.

Since its introduction, AHP became one of the most widely used multiple criteria decision-making (MCDM) method [0] and it can be integrated with a vast number of other analysis alternatives e.g. linear programming, quality function and fuzzy logic [0].

AHP method helps describe the decision making ideology like the way people naturally behave and think by decomposing a complex problem into many multi-level hierarchic structure of objectives and alternatives [0]. Another advantage with the use of AHP methodology is the possibility to compare dissimilar alternatives with one another [0], and that is mainly possible due to its impartial and logical grading systems that reduces personal biases.

3 RESEARCH DESIGN

The main goal of this work is to identify the most relevant RL KPIs as well as their level of importance to facilitate managers in selecting the best form to analyse reverse processes. To reach this goal, a three step methodology was conceived as described in the framework below.
Table 2. KPI searched.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>No. of papers which mentioned</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of recycled products</td>
<td>15</td>
</tr>
<tr>
<td>% of remanufactured products</td>
<td>2</td>
</tr>
<tr>
<td>Average total cycle time</td>
<td>11</td>
</tr>
<tr>
<td>Customer evaluation</td>
<td>5</td>
</tr>
<tr>
<td>Employees reached by the reverse logistic projects</td>
<td>5</td>
</tr>
<tr>
<td>Energy use</td>
<td>6</td>
</tr>
<tr>
<td>Investment in reverse logistics programs</td>
<td>8</td>
</tr>
<tr>
<td>Involvement of customers</td>
<td>12</td>
</tr>
<tr>
<td>Maximum capacity of processing in reverse logistics</td>
<td>7</td>
</tr>
<tr>
<td>Partners supporting reverse logistic</td>
<td>5</td>
</tr>
<tr>
<td>Product return rate</td>
<td>9</td>
</tr>
<tr>
<td>Quality error rate</td>
<td>10</td>
</tr>
<tr>
<td>Recapture of value</td>
<td>14</td>
</tr>
<tr>
<td>Remuneration of workers engaged in reverse logistics</td>
<td>11</td>
</tr>
<tr>
<td>Revenue from resale of recycled materials</td>
<td>11</td>
</tr>
<tr>
<td>Stable of employees who work in reverse logistics</td>
<td>6</td>
</tr>
<tr>
<td>Shipping cost</td>
<td>5</td>
</tr>
<tr>
<td>Total cost of reverse logistics</td>
<td>22</td>
</tr>
<tr>
<td>Traceability of products</td>
<td>3</td>
</tr>
<tr>
<td>Training of employees who work in reverse logistics</td>
<td>4</td>
</tr>
<tr>
<td>Use of water</td>
<td>2</td>
</tr>
<tr>
<td>Value of office or instructions for reverse logistics</td>
<td>5</td>
</tr>
<tr>
<td>Waste generated by the reverse logistics</td>
<td>9</td>
</tr>
</tbody>
</table>

KPIs were classified into six sub-areas which were defined according to the findings in the literature review.

Figure 2. Distribution of the paper portfolio by year of publication.

3.2 Questionnaire application

To obtain opinions on the relevance of the indicators found in the literature, ten experts in this field were chosen. This list of experts was equally divided between industrial managers who work with RL processes currently or used to work in the field in the last few years, and academic figures who works in RL or related areas such as logistics and environmental management.

The questionnaire was conceived in an Excel worksheet with an interface designed to provide an easy pairwise comparison between the KPIs included in the preliminary list. Taking into consideration that its fulfillment process would be without any kind of assistance by the research team, the questionnaire was clearly designed, including an introductory presentation of the research and a detailed explanation of each indicator.

Analyzing experts’ judgment can be, in many times, hard to be precisely interpreted into quantitative values [0] and, therefore, the use of Fuzzy is needed to overcome the problem of vagueness and imprecision.

3.3 Data analysis

3.3.1 AHP analysis

A questionnaire was developed and sent to ten experts in RL, with academic and/or industry background, so that they could provide a pairwise comparison between in order to facilitate the analysis process, the pre-selected

Throughout the questionnaire, it was possible to extract valuable knowledge from the respondents due to a pairwise comparison as well as the provision of numerical values for the priority of each element using a rating scale [0].

Before further analysis, it was necessary to guarantee that the consistency ratio (CR) did not transpass 0.1. If this criteria was not respected, the questionnaires would be resent for corrections until CR<0.1.

3.3.2 Fuzzy

The first proposal for a methodology that combines AHP with a Fuzzy approach was initially introduced by Chang [0] and it is applied to deal with uncertainty of responses and tries to illustrate the best of the respondents’ opinions by prioritizing the selected criteria and weights.

Triangular fuzzy number (TFN) is considered as a special fuzzy set \( F = \{(a, b, c), \mu_f(x), x \in \mathbb{R}\} \), where the values of \( (a, b, c) \) vary from \( \mathbb{R}: -\infty < a \leq b \leq c < \infty \) and \( \mu_f(x) \) is a continuous mapping from \( \mathbb{R} \) to the closed interval \([0, 1]\) [0].

When comparing all the variables in equation 1, a and c represent, respectively, the lower and upper bounds, while b consists of the strongest value \( \mu_f(x) = 1 \). The triangular type function on Fuzzy number respects the condition given by Kaufmann and Gupta [0] that when \( a = b = c \), it is a non fuzzy number by convention.

\[
\mu_M(x) = \begin{cases} 
\frac{x-a}{b-a}, & a \leq x \leq b \\
\frac{c-x}{c-a}, & b \leq x \leq c \\
0, & \text{otherwise}
\end{cases}
\]
For this fuzzy approach, it was agreed to symbolize fuzzy numbers with tilde (~) and scale starting from 1 to 9 and the linguistic variables used are expressed in positive TFNs as seen in Figure 5.

![Figure 5. Linguistic variables given for the importance weight of each criterion.](image)

Table 3 shows the correlation between the values selected in AHP system and, afterwards, analysed with the fuzzy approach. It also shows the fuzzy domain and its TFN.

### 4 RESULTS AND DISCUSSIONS

After conducting the fuzzy AHP analysis of the preliminary KPIs list, a final ranking was achieved (Table 3). As expected, Economic KPIs were top ranked. In fact, this result was already expected given the vast amount of authors pointing out and highlighting the importance of such indicators in the reverse processes. This is understandable as measuring costs and profit is fundamental and strategic in almost any kind of processes inside an industry for the sake of its financial stability and long term sustainability.

The second best top ranked category was the environmental related KPIs. This reflects the increase on environmental consciousness in countries such as Brazil and reinforces the importance of the field. Nevertheless, it is important to mention that categories related to Environment and Marketing-Image are usually ranked very close to each other. This occurs due to the so-called green marketing. In other words, when environment comes to light, marketing uses to take advantage of this situation to indirectly benefit. Surprisingly, the results achieved by this work show a different path with Marketing-Image category being place in the 4th position.

Logistic and Production KPIs are placed third. This probably means that after an throughout economical analysis and the environmental consideration, RL managers concentrate efforts on process effectiveness, mainly those related to planning and implementation. This category was expected to be close linked to KPIs associated to Technology and Quality. However this category was very low ranked (last position) together with Social KPIs category (second to last position).

This situation might be explained by two perspectives: the actual stage of development of RL processes in Brazil - an area which is still considered incipient in Brazil - and the social maturity level of the country.

Similar conclusions are obtained when the analysis takes into consideration global weights from indicators. Total cost of reverse logistic (A1-1) and revenue from resale of recycled materials (A2-2) are top ranked, confirming the relevance of economic KPIs. Parallel to this results, KPIs from Social and Technology-Quality are found with lower global weights e.g. employees reached by the reverse logistics projects (A5-4) and traceability of products (A6-2). The reasons of each indicator’s global weight obtained are similar to the ones discussed for the categories order.
5 CONCLUSIONS
The major contribution of this research is the development of a list of the most adequate RL KPIs aiming to help decision-makers and industrial managers to achieve their goals concerning reverse logistics processes. However, it is important to mention that a thorough validation of the final KPI rank will only be possible if managers implement it in their day-by-day work together with a post-analysis approach.

Although this research was carefully performed, it is also important to mention some limitations that were faced during the carry out of this work, such as the impossibility to cross-compare the indicators of the different categories given the AHP methodology restriction. Additionally, having the experts involved in the survey coming from diverse fields of expertise and practice (several different industries’ segments and academia) might be a handicap as well - or an advantage.

The obtained final rank should be seen as one of the possibilities to be considered. Other alternatives exist and should be explored in order to enhance good management. Suggestions for future work include: the application of the same methodology in countries with economical situations similar to Brazil (BRICS, for instance) as well as the application of other methods in Brazil in order to check if there are considerable variations in the rank position of the KPIs categories. To this end, the authors suggest the use of methods combined with Fuzzy, such as Fuzzy Delphi, Fuzzy Balanced Scorecard, Fuzzy Analytic Network Process or Fuzzy with neural network. Finally the authors would like to emphasize that the more knowledge available and accessible on RL KPIs, the better the implementation and management of reverse flows in industries implying in greater green solutions for the future.

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7 REFERENCES


