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How to identify opportunities for improvement in the use of reverse logistics in clothing industries? A case study in a Brazilian cluster

Eliane Pinheiro*, Antonio Carlos de Francisco, Cassiano Moro Piekarski, Jovani Taveira de Souza

Federal University of Technology — Paraná, Sustainable Production Systems Laboratory, Postgraduate Program in Production Engineering, Monteiro Lobato Av., Km 04, Jardim Carvalho, 84016-210, Ponta Grossa, Paraná, Brazil

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ABSTRACT

Waste disposal is a worldwide concern. In the case of the textile and clothing industries, consumption has increased steadily, especially in the clothing business, which generates large amounts of post-industrial waste. The objective of this article is to identify opportunities for improvement in the use of reverse logistics (RL) in clothing industries, as well as to list the existing strengths in the valuation of textile waste (TW) and minimize environmental impacts. To achieve this objective, a questionnaire was developed, validated and applied in a clothing cluster. The questionnaire assessed strengths and weaknesses in 8 dimensions using 32 assertions involving reverse logistics and management of textile waste. We identified in the research that: (i) there are no route facilitators between RL and TW in clothing industries; (ii) there are opportunities for the textile companies to increase the adoption of RL to combat TW; (iii) the main improvement opportunities for increasing cluster advancement in terms of RL and TW are: reuse of TW by the generating company and separating waste according to the composition of materials, which would facilitate the possibility of recycling and disclosing to consumers the importance of social and environmental practices. Conclusion remarks point that, despite the existence of strengths in the use of the RL for the TW valuing in the clothing industry, it is still required a readjustment of the destination of TW as a by-product to be used in a new cycle.

1. Introduction

New technologies, mass consumption, lifestyle and the reduction of the life cycle of products have increased production and the global consumption of textile fibers (Mohammad, 2016). Therefore, great amounts of post-industrial waste and post-consumer fibers are generated and, as a result, available landfills are being exhausted (Mair et al., 2016). Global textile consumption is estimated to be more than 30 million tons per year (Niinimäki and Hassi, 2011).

Although industrial development presents directions for decreasing environmental impacts and sustainability issues, production and consumption increased to levels where the benefits of technological development do not compensate the impact (Niinimäki and Hassi, 2011). Therefore, a change is needed to achieve a systematic transformation in production (Turker and Altuntas, 2014). As discussed by Vintró et al. (2014), transformations are required through adaptation of existing strategies or adoption of new approaches to meet the demands and deal with the compatibility between productive activities and environmental concerns.

The textile and clothing industries play an important role in the economic progress of many developing countries (e.g., Brazil, Turkey, Bangladesh), contributing both to wealth generation and employment. However, throughout their value chains, they also generate waste and have negative social and environmental impacts on their products' lifecycles (Clancy et al., 2015), which include the selection of textile fibers and waste from textile production that emits greenhouse gases, as well as silver and chromium (Muthu, 2014). They also include increased pollution, emissions and effluents from dyeing processes, finishing and washing as well as the depletion of water resources, fossil fuels and raw materials (Altun, 2012).

The clothing sector in Brazil comprises about 29,000 companies

* Corresponding author.
E-mail address: eppinto@uem.br (E. Pinheiro).

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nationwide (legally registered), 90% of which are defined as micro and small enterprises that contribute significantly to the generation and distribution of income. The Brazilian clothing sector in 2017 showed a textile and apparel value chain with revenues of $45 billion. Approximately R$ 1.9 billion were invested in the industry, which had an average production of 5.9 billion pieces that included apparel, socks, accessories and home textiles. Average textile production was 1.7 million tons. This is crucial for the Brazilian economy, as it demands 1.5 million direct employees and creates 8 million indirect jobs. The income effect also stands out because 75% of the workers in the sector are women, which increases average household income in Brazil. This sector is the second largest employer in the manufacturing industry following the food and beverages industries and the second largest generator of first jobs in the country. Furthermore, the Brazilian Fashion Week is among the top five fashion weeks in the world (TEXBRASIL, 2018).

The main raw material used in the manufacturing of apparel products is the textile material (Wang, 2010). During the manufacturing process, industrial waste is generated and the allocation of textile waste (TW) continues to be a concern in developed and developing countries (Altun, 2012).

As a crucial process, highly relevant to the global trend towards sustainability, reverse logistics (RL) has attracted the attention of a growing number of researchers (Guo et al., 2017). The increased interest in reverse issues can clearly be seen in the large number of publications devoted to this topic, especially those which consider case studies in various industries, particularly in waste management (Govindan and Soleimani, 2017).

Under this scenario, the use of RL is encouraged in sectors dealing with the return of after-sales and post-consumer goods (Seadon, 2010). It includes industrial waste and involves all activities associated with the collection and recovery or disposal of used products (Akdoğan and Cingšz, 2012).

The resulting promotion of RL and use of alternative resources increase profitability and productivity by reducing inputs and materials that might otherwise end up in landfills (Tibben-Lembke, 2002). Other competitive reasons favoring RL include differentiation of service, reduction of impacts of distribution channels, protection of profit margins, and value recapture (Moon et al., 2013).

The most current environmental research in the context of textile industries mostly regards technology. Therefore, it is necessary to reach a better understanding of the textile waste management and the use of RL, due to the incompleteness of other studies regarding the assessment of positive and negative results and opportunities for improvement involving the use of RL to tackle TW in the clothing industry, considering the possible collaborations among geographically related companies.

The objective of this study was to identify opportunities for improvement on the use of RL in clothing industries, as well as to list the existing strengths in the valuation of TW and minimize environmental impacts by means of the elaboration, application and validation of a questionnaire that assessed the strengths and weaknesses in 8 dimensions using 32 assertive statements involving RL and TW management. The contribution and innovation of the present study can be summarized in 2 points. First, to the best of the authors' knowledge there is no analysis that allows identifying environmental performance improvement related to TW and RL in the textile sector with companies working in clusters. Therefore, the authors included a general view of the TW, used statistical analyses for a greater consistency of the data collection instrument and presented the benefits of the valuation of the TW that can assist minimizing the potential environmental impacts by changing the waste destination. Secondly, the authors enumerated the existing strengths in collaboration in the assessment of TW, highlighted the research gaps regarding RL and defended the importance of valuation of the waste as co-product. The strengths and highlights that can assist in the development of public policies are pointed. These contributions can be used by researchers and industry professionals to encourage and guide reform of such activities to optimize the environmental performance by means of valuing TW towards a circular economy.

2. The challenge of disposing of solid textile waste in the clothing industry

The textile and clothing industries are notorious for excessive waste generation and pollution that affect the environment (Islam et al., 2014). In general, the clothing industry is characterized by short product life cycle, volatile and unpredictable demand (Pookulangara and Shephard, 2013). It also includes a wide range of products and a complex source of production processes to turn raw materials into products to meet the fashion trends, desires, and needs of consumers (Zhou et al., 2015).

The clothing industry is dominated by just-in-time processes and subject to rapid changes in fashion trends (Clancy et al., 2015). Hence, it manufactures simple textile products during seasonal intervals, faster production and lower quality, which, consequently, generates pre-consumer and post-consumer waste (Tobler-Rohr, 2011).

In Brazil, in addition to these characteristics, another important aspect is related to the number of micro and small enterprises, that in the clothing industry represent 99% of the national companies, while large companies represent less than 1% (IEMI, 2014).

Local Productive Arrangement (LPA) is seen as a strategy that micro, small, and medium-sized enterprises (MSMEs) can use to strengthen their competitiveness. These agglomerations, also known as local clusters, represent an opportunity for MSMEs, allowing them to complement one another, and increase their production capacity, survival, and growth opportunities. For Đorđević et al. (2011) the clusters present an important element in the process of improving competition, productivity and development of small and medium-sized enterprises in the international market.

LPA is defined as a geographically concentrated group of interrelated companies that are formed by economic, political and social agents, and related institutions within a predetermined area (Porter, 1996). LPAs present consistent links of articulation, interaction, cooperation, and learning, and they have distributional effects on the sectoral and regional dimensions of assets and employment (Lastres and Cassiolato, 2010).

In this industry, textile materials are used as raw materials to manufacture products. Towards that end, two main types of fibers are used: natural fibers derived from vegetable and animal proteins and cellulose, and manufactured fibers derived from natural and synthetic polymers, such as nylons, acrylics and polyesters (Mohammad, 2016). The fibers are grown, fabricated or made from a combination of both processes (Islam et al., 2014). Each fiber source and each production method comes with its own set of environmental concerns (CONMETRO, 2008), but they can all be improved by employing best practices in their systems or by implementing new, more efficient technologies (Muthu et al., 2012).

During their manufacturing, products generate feedstock waste referred to as chips, flaps, or parts rejected due to defects and other waste from production processes, such as TW (CNTL, 2018). TW generation varies depending on the volume, shape, and textile composition and the number of produced parts, the size of the product, the shapes of the molds, the widths of the fabric, and its adequate rest rollers. The steps involved in the manufacturing process also affect the generation of waste, including the modeling method, fitting, and marking, which could be automated or manual. Each of these influences the quantity of waste that is generated. According to Laursen et al. (2007), the waste generated from cutting may vary between 6% and 25%, depending on the complexity of the pattern. Beton et al. (2014) reported that the yield for the cutting of small rectangular pieces from new fabric was 95%.

With regard to rejected textiles, the main elimination pathways are incineration or co-provision with municipal solid waste (MSW) (Fletcher, 2013). That is, most of the textile waste will be treated with the main MSW treatment option in a country (Jeihanipour et al., 2013), while the valuation of these materials may reduce their impact on the environment (Bahareh et al., 2014).

In Brazil, according to the Brazilian Association of Technical Standards (NBR 10004: 2004), TW is classified as Class A, non-inert, if it has properties such as biodegradability, combustibility, or water solubility, and if the material comes into contact with materials such as machine oil, which can change it (ABNT, 2004). If it is contaminated, it is classified as solid waste Class I-dangerous. Materials on this classification pose a risk to public health, causing or accentuating a significant increase in mortality or the incidence of diseases and/or risks to the environment, especially when the waste is handled inappropriately (CNTL, 2018).

Even with the amount of textile and clothing flow generated by manufacturers in the clothing industries, little research has been conducted to assess the possibility of promoting the sorting and recovery of TW in terms of sustainability (Jeihanipour et al., 2010). Still, there are significant issues that involve the final destination of solid textile waste that can be reused, recycled or disposed of (Goworek, 2011) by landfill or incineration (Kryzaniak et al., 2010) when the waste could still become an important raw material in the national and international markets (Wu et al., 2012).

Eryuruk (2012) explains that the pre-consumption TW are composed of byproducts of textiles, fibers and cotton components. These residues can be recycled and become raw materials to industries such as the automotive, furniture, mattress, coarse yarns, home furnishings, paper and sometimes they are given to charities.

Thus, in order to avoid waste disposal, resource depletion, environmental concerns, increased landfill costs and waste return policies, there has been an increase in the importance of RL perceived by producers and their stakeholders throughout the world (Bouzon et al., 2016).

To prevent the disposal of waste materials, improvements in TW allocation processes are needed. In the process of looking for improvements, RL has become a strategic factor in business (Hall et al., 2013), which makes the study of this strategy relevant. In the 1990s, new approaches in RL encompassing increased concern with environmental issues and the constant search for loss reduction by companies and distributors emerged (Carter and Ellram, 1998).

Wath et al. (2010) reported that RL processes could minimize environmental impacts and promote the sustainable flow of production, consumption, and proper disposal of waste, valuing them in other processes, rather than simply discarding them, thereby extending the material life cycle.

Many companies have recognized that reverse logistics is an important tool for promoting their economic advantages, strategic planning, competitiveness, and profitability by means of waste recovery (Alshamrani et al., 2007), or to ensure the proper disposal of waste in order to develop and provide a relevant response to the request of consumers and society for environmental sustainability (Eltayeb et al., 2011).

Furthermore, RL provides the possibility of reducing the uncertainty of the availability of raw materials by increasing the scale; hence, it reduces production costs. It is understood that economies of scale are achieved through industry agreements that allow cargo transportation consolidation, resource management, and cooperative logistics operations (Dhanda and Peters, 2005).

RL refers to the sequence of activities required to collect used products from customers or industrial waste. The main processes are identified as: product purchasing, collection, inspection/sorting, and disposal (Agrawal et al., 2015). The process of separating the products should be conducted by meticulously selecting the materials based on their similar characteristics (Xanthopoulos and Iakovou, 2009). After the materials (waste) have gone through inspection/selection and are classified, they are reused, repaired, remanufactured, recycled, or discarded, based on the arrangement established in the RL chain agreement (Rogers and Tibben-Lembke, 1999).

Companies really do have a competitive advantage when they act to minimize their environmental impact by reusing, remanufacturing, and recycling industrial waste. Zhang et al. (2011) noted that, from the beginning, managers, suppliers, industrial producers, and distributors must be involved in the strategic planning and operational execution of reverse logistics to carry out an effective system of solid waste management. Thus, they can obtain economic advantages and contemplate how best to address their environmental impacts (Caniato et al., 2014).

3. Materials and methods

A questionnaire was constructed, based on the existing literature. The content of the questionnaire included closed-structure sentences designed to identify the management of TW, mapping the possible RL processes and the benefits provided by these actions, with a view to those aspects of the process involving the reduction of impacts on the environment and costs, and compliance with legislation that is aimed at waste recovery.

The questionnaire consisted of 32 questions, arranged in 8 closed dimensions. Each dimension was composed of four sentences, using a five-point Likert scale, with 1 indicating complete disagreement and 5 indicating full agreement with the statement. The questionnaire was evaluated by the clothing cluster director and an expert researcher in the field. After professional recommendations and corrections were made to the questionnaire, an invitation to participate in the study was sent to 300 companies affiliated with the garment union, all representing the cluster, which is located in the Northwest of Paraná, Southern Brazil.

Among the invited companies, 32 agreed to participate (i.e., the sample was selected by accessibility criteria). The participants represented a chain of micro and small clothing companies, providing various kinds of clothing, with all design and production done in Brazil.

The studied sample, according to the National Classification of Economic Activities (CNAE), is classified in Section C, Division 14, Group 141, Class 1412-6. This class includes making men's, women's and children's clothing (shirts, T-shirts, blouses, dresses, skirts, pants, suits, coats, etc.) made of any type of material (flat fabrics, knitted fabrics, etc.) (CNAE, 2007).

The interview period was from November 2013 until May 2014. The respondents were company managers who were responsible for the disposal of solid TW. It was found that 43.7% of the respondents had worked in the industry between 0 and 5 years, 25% were there between 6 and 10 years, 15.62% operated between 11 and 15 years, and 15.62% operated between 16 and 20 years.

The methodological steps for the construction of the questionnaire and the steps for application in the specific cluster are presented in Fig. 1.

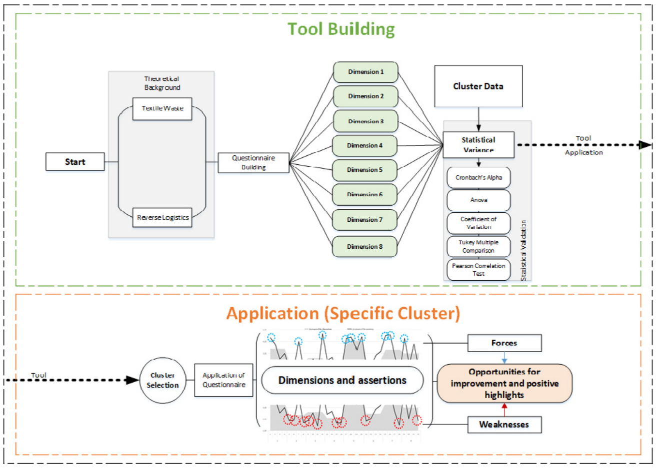

Fig. 1. Stages of tool building and application.

3.1. Data analysis

To ensure the reliability of the questionnaire and the responses obtained, a series of statistical analyses was conducted. The internal consistency of the questionnaire was analyzed using Cronbach's alpha. The α coefficient was calculated from the variance of individual items and the variance of the sum of items of each evaluator of all the questionnaire items, using the same measuring scale. The formula for calculation is as follows:

$$r = \frac{n}{n-1}\left(1 - \frac{\sum \sigma_1^2}{\sigma_{sum}^2}\right),$$

where: σ_i^2 is the variability of the items and σ_{sum}^2 is the total variability.

The analysis of variance (ANOVA) was performed by the average data size, assessing whether there is a significant difference between the dimensions of the questionnaire. The coefficient of variation (CV) was calculated, assessing the homogeneity of the dimensions proposed. In order to identify the average difference between the dimensions, the p-value was calculated. In addition, the Tukey Multiple Comparison (*post hoc*) was used to determine between what dimensions the differences occurred, by comparing the dimensions in pairs.

The degree of correlation between the dimensions was measured in order to verify the influence of one dimension on another using the Pearson correlation test, which is recommended for values below 0.8. The correlation is a value ranging from (−1) to (1), but for readability and understanding the values were transformed into percentages (i.e., multiplied by 100).

Finally, a comparison was performed between the results of the average and standard deviations for each dimension and its respective assertions to analyze the strengths and weaknesses susceptible to improvements. This enables the analysis of the connections between the destination of post-industrial waste and the use of RL and, by means of the results, making proposals that promote the valuation of the TW.

4. Results

In the first stage of analysis, the results of the parametric statistical tests were used, as the data were quantitative and continuous. The accepted level of significance is 0.05 (5%) (i.e., all confidence intervals were constructed with a 95% statistical confidence). In addition, the sample is composed of 30 subjects, which by the Central Limit Theorem ensures that the distribution tends to a normal distribution. Thus, there was no need to test the normality of the issues with direct parametric tests. This shows that the response rate is satisfactory for this study. The Cronbach's alpha (i.e., the internal consistency) of the questionnaire was 0.743, providing a set of reliable data.

The ANOVA test showed that the dimension with the highest average was "environmental practices adopted by the company" (D5), with an average of 4.05. Table 1 shows that D5 is statistically different from all other dimensions.

The variability of the dimensions of the data showed homogeneity. The coefficient of variation (CV) found in this study is shown as the ideal (<50%). This indicates a low variability and, consequently, a homogeneity of results.

The p-value shows that there is an average difference between the dimensions. To determine the difference, the Tukey Multiple Comparison (*post hoc*) was used to compare the dimensions in pairs. Next, with the use of the Pearson correlation, it was found that the highest correlation occurred between the dimensions "waste control action" (D3) and "competitive aspects related to RL" (D4), with a value of 58.8%; this shows the influence of the dimensions. In order to validate the correlations, the correlation test was used. The fact that this value was positive indicates that the higher the average for "waste control action" (D3), the greater will also be the average for "competitive aspects related to RL" (D4), and vice versa. This correlation is classified as regular (Fig. 2).

The dimension "performance of reverse logistics" (D1) showed a positive correlation with all other dimensions. It can be observed that the highest correlations obtained were with D4 (competitive aspects RL) (50%), D2 (return practice of textile waste) (49.7%), and D7 (practices for the disposal of solid textile waste companies in a cluster) (49.4%) (D1-D4, D1-D2, D1-D7).

The other high correlations identified in the survey were between D3 (waste control action) and D5 (environmental practices adopted by the company) (58.8%). (D3-D5). Dimension D2 (return practice of textile waste) has a correlation with dimension D7 (practices for the disposal of solid textile waste companies in a cluster) (43.7%) and dimension D6 (Practices for cost reduction) (41.0%) (D2-D7, D2-D6).

Table 1
Analysis of the questionnaire dimensions.

Dimensions	Average	Median	Standard deviation	CV	Min	Max	N	IC	P value
Performance of reverse logistics (D1)	3.41	3.50	0.89	26%	2.00	5.00	32	0.31	<0.001
Return practices of textile waste (D2)	2.34	2.00	0.82	35%	1.00	4.00	32	0.28	
Waste control action (D3)	2.62	2.63	0.70	27%	1.50	4.00	32	0.24	
Competitive aspects related to RL (D4)	2.13	2.00	0.99	46%	1.00	4.50	32	0.34	
Environmental practices adopted by the company (D5)	4.05	4.25	0.83	21%	1.25	5.00	32	0.29	
Practices to reduce costs (D6)	2.52	2.50	0.82	33%	1.00	4.25	32	0.29	
Practices for disposal of TW companies in LPA (D7)	2.86	2.71	0.75	26%	1.57	4.86	32	0.26	
Production processes (D8)	2.98	3.00	0.50	17%	2.00	4.00	32	0.17	

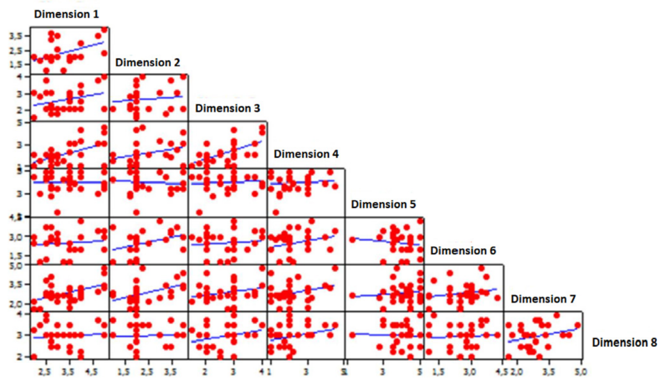

Fig. 2. Correlation of dimensions.

Thus, the correlations between the dimensions that reveal the influence of reverse logistics on the return practices of solid textile waste are evidenced. D5 presented the lowest correlation values among the other dimensions, as it can be observed in Fig. 2. The three negative correlations obtained involved dimension D5 “environmental practices adopted by the company” (D5-D2, D5-D6 and D5-D8).

The second phase of analysis calculated and presented the averages of the respective dimensions and the assertions that comprise the survey instrument. Fig. 3 shows outliers (average < 2 and >4) identified between dimensions that allow verification of the sector actions that need to be modified so that the allocation of post-industrial textile waste by means of reverse logistics processes enhances the textiles.

The dimension “performance of reverse logistics” (D1) has an average of 3.41 points (5 is equivalent to 100% effectiveness in the performance of the reverse logistics for companies in the cluster). The highest value found among the assertions average was 4.4 (the company uses reverse logistics in some process of the industry, in the return of products, and/or in the recovery of waste).

Peaks and valleys are found in D2 (return practices of textile waste), with an average of 2.36 (Table 1). The dimension “waste control action” (D3) has an average of 2.62. D4 (competitive aspects of RL) has an average considered low (2.10), indicating the need for action to improve the indices. D5 (environmental practices adopted by the company) presents the environmental practices adopted by the company, including compliance with laws and regulations at the local, state, and federal levels, involving environmental licenses applied to the clothing manufacturing industry. This dimension is different from all the others and it has the highest average (4.08).

The dimension “practices to reduce costs” (D6) obtained the average 3.31. D7 (practices for disposal of textile waste in companies that are participating in the cluster) has strengths to be highlighted and weaknesses to be improved upon (3.31). D8 (modeling processes developed by the survey companies) addresses the stages of the production processes that are needed to build the product, specifically the modeling industry, which may interfere with the better utilization of the textiles before the cutting of the textile materials; it obtained an average of 2.99.

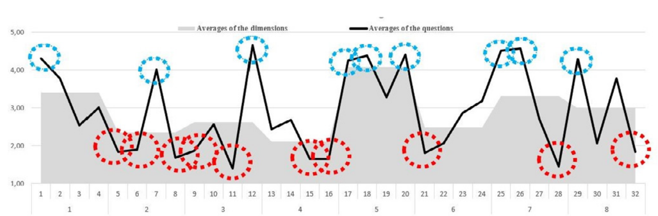

Fig. 3. Averages and standard deviation of the dimensions and their respective assertions.

Table 2 shows the main opportunities identified for the cluster, through the results given in Fig. 3, and lists the key points at which there is thematic advancement of the companies in the cluster.

Among the main opportunities for increasing the advancement of the cluster analyzed by the proposed questionnaire are: segregation, reuse, and commercialization of waste generated by the companies in the cluster; creation of mechanisms to strengthen partnerships for TW destinations; improvement of management and organizational operation and control of TW; creation of means, dissemination and promotion of information, and highlighting of the importance of TW with external audiences; and, directing new investments for sustainability. The actions presented in this study are recommended to the participating companies in the cluster in order to increase the advancement of the theme of RL and management of TW.

Yet, with reference to Table 2, it can be noted that the cluster presents thematic advancement regarding some actions evaluated in the assertions. The positive points have a certain correlation with compliance with the companies' mandatory legal requirements, such as proper TW allocation, segregation of contaminated TW, and waste disposal by specialized companies. It should be noted that the analyzed companies have RL processes and adequate management of TW, as well as a level of TW considered moderate, especially because they have automated modeling, fitting, and marking processes. The highlighted facts increase the advancement of the cluster in relation to the themes of management of TW and RL. Lessons learned, experiences, and outstanding practices can serve as benchmark to other companies in the sector. Finally, the results found by the developed model are discussed with other findings from the available literature.

5. Discussion

The results show aspects of the destination of TW that can be readapted or implemented. For example, it is possible to promote actions that minimize the environmental impacts generated by the disposition of textile waste, since the studied cluster does not perform specific actions in this regard.

The results demonstrate that the actions of RL (D1) and the return practices of solid textile waste (D2) show convergence. However, 75% of the respondents dispose of waste by using specialized companies. This reality converges with the routine disposal of textile residue by means of incineration (DEFRA, 2008), which involves a greater use of primary energy and a greater potential of global warming or disposal in an embankment, whereas the recovery of these materials can reduce the impact on the environment (Bahareh et al., 2014).

One possible path towards preventing industrial solid textile waste from being sent to the landfill is to choose processes according to the characteristics of the raw material, such as reuse (recycling), commercialization or disposal by a specialized company (a process frequently used in companies, as identified in previous research) (García-Rodríguez et al., 2013).

In addition, Govindan and Popiuc (2014) explain that product recovery and reuse contribute to reducing negative effects on the environment, reducing waste disposal, extraction of raw materials, and reduction of the emissions involved in transportation and distribution of these waste materials. Fletcher (2013) contends that there is a shift in emphasis from the current *status quo* that unquestioningly accepts the presence of waste as a byproduct of designing, producing, and consuming textiles by the sector, where provision and consumption of fashion and textiles are integrated.

Table 2
Opportunities for improvement and positive highlights.

WEAKNESSES	Dimensions and Assertions	OPPORTUNITIES FOR IMPROVEMENT TO INCREASE THE ADVANCEMENT	
	2	5	Reuse of textile waste by the generating company
		6	Market textile waste for entrepreneurs from other sectors
		8	Creation of partnerships with other companies for proper disposal of solid textile waste
	3	**9**	Control sheets for the amount of waste generated
		11	Separation of waste according to the composition of materials that facilitate recyclability
	4	**15**	Dissemination and integration of information on sustainability issues with society, customers, and suppliers
		16	Investments in technologies aimed at sustainability
	5	**21**	Promotion of programs to inform customers about the benefits generated by the proper disposal of waste
	7	**28**	Promotion of the importance of social and environmental practices to consumers
	8	**32**	Internal development of modeling steps, fitting, and cutting
STRENGTHS	**Dimensions and Assertions**	**POSITIVE HIGHLIGHTS**	
	1	**1**	Companies applying processes of reverse logistics
		7	Disposal of waste is done by companies specialized in waste
		12	The flaps are stored in an appropriate place before collection
	5	**17, 18, 20**	Knowledge and application of municipal and state laws and regulations relating to environmental aspects
		25	The oil-contaminated machine flaps are separated for proper disposal
	8	**26**	Textile waste material is considered moderate
		29	The process modeling, fitting, and marking are automated

On the scenario of textile waste in the studied cluster, Pinheiro and Francisco (2016) identified the generation of 57,707 kg of textile residue, essentially comprised of cut waste products. The study covered the production of 32,239 pieces of clothing over the course of November 2013 to May 2014 (Table 3); the clothing produced included blouses, dresses, pants, and other items.

The total amount of residue in the cluster significantly demonstrates the relevance of joining waste to collection since, if considered individually, the quantity is not attractive for activities such as recycling. Moreover, it should be noted that an important aspect of partnership between companies is the economies of scale that are obtained by means of agreements among the companies, allowing the consolidation of freight transportation, resource management, and cooperative operations logistics (Dhanda and Peters, 2005).

The actions by the cluster to control residue can allow the residue to be commercialized and reused (Table 3 and Fig. 3). For this purpose, the materials must be well preserved (their properties should remain intact, and they should remain clean, and dry), achieved through correct storage and, ultimately, disposed of in an environmentally appropriate way (Xanthopoulos and Iakovou, 2009). This variable does not depend only on the company generating the waste, but on agreements with other entrepreneurs interested in acquiring this raw material (solid textile waste).

Reclamation and reuse are ways of optimizing the life cycle of textile chips, preventing cut and unused textile waste from being sent to incineration and used for energy recovery (Chang et al., 2015). Jeihanipour et al. (2013) identified in their study that textile waste consists mainly of cotton and artificial cellulose fiber and, because of the content of this fiber, it maintains significant potential for the production of different biofuels, such as biogas. Bahareh et al. (2014) pointed out that the material reuse process presents the best environmental performance, with savings of eight tons of carbon dioxide equivalent (CO2eq) and 164 GJ (GJ) of primary energy per ton of waste, which would minimize environmental impacts.

In the same way, the reuse of unmodified textile products provides significant environmental savings. For example, the energy used to collect, classify, and resell secondhand clothing is 10–20 times lower than what is necessary for producing new pieces (Fletcher, 2013), and this insight can also be applied to textile waste. In addition, the waste management hierarchy advocates the reuse of products through material recycling, which in turn is preferable over landfilling and energy recovery, as it is the least preferred option (Wang, 2006).

The practices adopted by the respondents for the final disposition of waste do not represent advantages in economic growth and cost reduction. It is assumed that this perception is related to the fact that the waste is considered scrap. Furthermore, regarding investments in technologies (such as the automation of the modeling and cutting sectors directly involved in the generation of waste), the respondents report that there are no investments in this sense.

It was not identified in the research that the waste of textile materials is related to the work performed by the individuals involved in these activities, but rather to the productive processes that the product goes through. The designer, responsible for the creation process, can interfere in the optimization of textile materials according to the models created (Niinimäki and Hassi, 2011), but this discussion is not part of the present study.

In addition, the regulation and understanding of sustainability are reasons why companies decide to implement sustainability standards on the environmental dimension with specific practices (Sharma et al., 2011). Thus, it is understood that the use of RL processes (control, separation, storage, and collection of materials) make it possible to value waste through commercialization and reuse, being it a strategic tool for designing a relevant response to the legislation requirements, and the request of the company itself,

Table 3
Characterization of textile materials used in clothing industries in the period of November 2013 to May 2014.

Composition	Consumption (Kg)	Stock (Kg)	Waste (Kg)
97% CO - 3% PUE	303,450	48,080	9340
100% CO	167,850	27,180	19,086
100% PES	154,850	24,550	11,441
97% PES - 3% PUE	131,075	16,150	7906
100% CV	66,000	7320	2735
96% CV - 4% PUE	61,590	5450	1655
100% PA	42,769	3760	1750
90% CO - 10% PA	36,000	6000	1500
53% PES - 44% CO 3% PUE	20,000	0	900
87% PA - 13% PUE	11,000	2100	1394
Total	**994,584**	**140,590**	**57,707**

Legend: CO = Cotton; PUE = spandex; PES = polyester; CV = rayon; PA = polyamide.
Source: Pinheiro and Francisco (2016).

for the recovery of waste (BRAZIL, 2010). The possibility of extending the life cycle of waste products, which can be understood as a raw material for other companies of this or other industrial sectors, also means benefits for those agents, by promoting actions that can be cost-effective and environmentally sustainable (Lee and Lam, 2012). It is assumed that this is a vision to be projected in the long term in the clothing industries participating in the research, since it was verified in the study that those activities need to be reviewed and implemented in the cluster.

Finally, the main contributions provided by RL refer to competitive advantages which, in turn, are achieved by influence of the regulations and, consequently, result in profits for the company (Hall et al., 2013). Thus, it is understood that, with the establishment of cooperation between companies and the insertion of economies of scale, there is the possibility of reducing costs and increasing profits, provided that the environment of a cluster is prepared for such purposes. However, it is evident the need to implement a solid waste disposal policy that encompasses key aspects such as planning, investment, preparation, prevention, recognition of reusable and recyclable solid waste as an economic good and that considers social value, generation of labor and income, and promotion of citizenship, among other aspects (BRAZIL, 2010).

6. Conclusions

The research results allowed identifying the existing strengths in the use of RL to recover textile waste from clothing industries. As presented in the results section, the main opportunity to increase the cluster advance is given by readjusting the disposition of textile waste by means of reuse and commercialization of the waste generated by the companies in the cluster. The authors believe the use of RL processes (control, segregation, storing and collection of materials) enables recovery of waste by means of marketing and reuse. However, this variable depends not only on the generation of waste by one company, but also on agreements with other entrepreneurs interested in acquiring such material (textile waste).

Table 2 showed the opportunities of improvement to increase the advance and positive highlights are affirmed by the literature to reinforce the positive impact of adequate disposition. It was found that textile waste must be seen as a coproduct (raw material) to be used in a new cycle, therefore reaching the strategic objective of RL. In future studies it is of utmost importance that be identified the barriers to the implementation of RL processes aiming the disposition of post-industrial solid textile waste, such as costs, territorial dimension, conflicts in the production chain and in product development. It was not possible to compare this study's questionnaire to others, due to the specific objective of the present instrument not having been identified in other studies.

The need to minimize scrap generation deserves worldwide attention. Therefore, opportunities for scientific and technological development that stimulate the reform of those activities by means of valuing waste is crucial to indicate alternatives to political decision-makers regarding regulations. Such opportunities can strengthen research and cleaner production activities and waste commercialization can favor the market and circular economy initiatives.

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