Development of Post-Consumer Polymer Suppliers

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Abstract

The development of post-consumer polymers suppliers is defined as any effort made by the buyer company to its suppliers, to improve their performance or capacity, which guarantees the fulfillment of the supply in the short or long term. The main objective of the study is to improve the performance of matter that is outside impurity and density specifications through criteria of selection, intervention and evaluation of suppliers. These criteria were implemented with the following method: identification of needs for improvement of raw material by the final recycler, establishment of criteria for the evaluation of suppliers, intervention of suppliers, evaluation of results and development of a program of monitoring suppliers. At the end of the intervention, 12.5% of impurities were reduced and 400% density was increased, which caused an average increase of 8% in the raw material yield factor of the final recycler.

Keywords
Developmet, Suppliers, Post-consumer Polymers, Recycler, Performance

1. Introduction

Recycling in the Ecuador has increased in recent years due to the increase of solid waste generated by the consumer society, as well as by the increase in prices of imported raw materials for the industry, these variables have led to the companies are interested in buying significant volumes of recycled materials such as PET, paper, cardboard and scrap. The increase in collection that has had products recycled in the period from the year 2012 to 2014, is 170% in the case of the PET which passes from 28.402 to 48.384 tons per year. This growth is due to the incentive of the national Government, the adoption of the "law of promoting environmental and optimization of the income of the State", published in the supplement of the registry official No. 583 of November 24, 2011. In this, the redeemable tax to the non-returnable plastic bottles was established, this means the internal revenue service to pay two cents per bottle collected to centers of collection or companies accredited by the Ministry of the environment and certified by the Ministry of industries and productivity (Ministerio del Ambiente, 2015). The redeemable tax non-returnable plastic bottles are a green tax which is based on the principle of polluter pays. This is intended to transfer the costs of environmental protection to the players causing pollution, which can be companies or consumers (Perez, 2016)

The recycling cycle that currently operates in the Ecuadorian market has a diversity of activities, actors and processes. The actors that are linked in the recycling system are: final consumer, primary recycler or manager, collection center or intermediary and final recycler, and finally the industry. The case analyzed is the final recycler, which are all industries that transform the recyclable raw materials from the collection centers by mechanical and chemical means. Which become new virgin or degraded raw materials, which are used for the development of new consumer goods (Organización Internacional del Trabajo, 2013).

The final recyclers process the post-consumer polymers to obtain scale, through the following activities: separation of plastic waste, crushing, washing and drying of flake or flake (Vázquez et al., 2013). This production process does not comply with 80% yield because post-consumer polymers have a large amount of impurities and low density, therefore, it is identified that the lack of development of post-consumer polymers suppliers directly impacts the performance of the production process. The strategy of improving productivity in the manufacture of goods and services by companies

is linked to the development of suppliers, its implementation generates higher profit margins, product cost savings, increased production, among others. Commonly companies offer help to suppliers by sending experts to advise them on their operational processes. The suggested improvements increase the quality of the raw materials, which directly impact the productivity of the subsequent transformation processes (Delfín and Márquez, 2016).

It should be noted that final recyclers are generally dependent on suppliers of post-consumer polymers, which in some cases reach more than 50% of their cost of the final product. Therefore, the purchasing department is one of the critical actors for reducing costs in the company through the selection, evaluation and monitoring of suppliers (Vargas, 2014). The establishment of criteria for the selection of suppliers depends on the strategy defined by the company that buys, an example of this is the application of the price criterion for the reduction of costs of inputs in the short term, which is normally carried out by auction. Another example is the use of the relationship capacity criterion, where long-term businesses are defined with a single provider that allows working on projects to improve costs through the application of influential criteria (Arroyo and Ramos, 2014), for mutual development between the collection center and the final recycler in a win-and-win business relationship (Gonzalez, 2014).

Although it is true that the intervention to develop suppliers is initially costly, the benefits of having qualified suppliers give impressive results within the productivity of the operations (Castro-Castell et al., 2016). In this sense, a methodology for the development of suppliers was implemented through five phases. These are: identify needs for improvement in the raw material, establish criteria to evaluate suppliers, intervene suppliers, evaluate the results and define a follow-up program to suppliers.

2. Materials and Methods

The most used methodologies for the development of suppliers include the establishment of criteria for the evaluation and the method of selection. Table 1 shows the criteria for evaluation of the most cited providers.

Table 1. Criteria for the evaluation of most cited suppliers.

Criterias	Cite	%
Quality	47	89,93
Price	46	82,14
Delivery (punctuality and compliance)	45	80,36
Technological capacity	21	37,5
Production capacity and facilities	16	28,57
Customer service	12	21,43
Flexibility	10	17,86
Financial position	9	16,07
Geographic location	9	16,07
Cooperation capacity	9	16,07
Practices and quality management systems	7	12,5
Credibility / reputation	7	12,5
Management and organization	7	12,5

From Table 1 it is observed that the most frequently cited criteria are: quality 89.93%, price 82.14%, delivery (punctuality and compliance) 80.36%, technological capacity 37.5%, production capacity 28.57%, customer service 21.43%, flexibility 17.86%, financial position 16.07%, geographic location 16.07%, cooperation capacity 16.07%, credibility 12.5%, management and organization 12.5% (Coelho and Hazin, 2012). Of which the following criteria will be used: post-consumer polymer quality that is related to the percentage of impurities, technological capacity with the density of the post-consumer polymer package, the production capacity with the monthly delivery volume and the capacity to cooperate with the attitude of the collection center in front of the project.

Figure 2 shows the percentage of use of methodologies used to select the most used providers, which are: multicriteria matrix 50%, fuzzy theory 25%, mathematical programming 23%, data enveloping analysis 12.5%, artificial intelligence 7 %. From the results obtained, it is concluded that the most appropriate method for selection is the multicriteria matrix (Coelho and Hazin, 2012).

Based on this, it was based on the methodology of Ruppenthal and Duarte (2012) because it considers criteria and selection of suppliers to determine the following phases in the present project:

a. Identification of needs for improvement of the raw material.

In identifying the needs for improvement of the raw material, the activities required by the final recycler's production process were analyzed. In this, the specifications of purity and density were determined. Then it is contrasted with the status of the raw material of the collection center with the specifications of the process, which identifies the needs to develop in the collection center.

b. Establishment of criteria for the evaluation of suppliers.

In the establishment of criteria for the evaluation of collection centers, the activities needed by the recycling production process were differentiated with the judgments of the multicriteria matrix. At the end, the guidelines that will be used for the selection of collection centers that are going to intervene were defined.

c. Intervention to selected suppliers.

The intervention of selected suppliers will begin with the selection of the same through the weighting of results in the multicriteria matrix, with which training will be implemented and generating compliance with the specifications of the final recycler from the collection centers, with the possibility of continuing with the evaluation of results.

d. Evaluation of the results of the intervention to the developed suppliers.

For the evaluation of the results of the intervention, the registry of the before and after the diagnosis of the raw material was defined, and the factor of yield or partial productivity of the same, with which it is possible to leave raised the program of monitoring of developed suppliers.

e. Development of a follow-up program for developed suppliers.

The monitoring program for collection centers that have already been intervened evaluates monthly the criteria defined in point two, through control sheets and field inspection works.

3. Result

Table 2 shows the raw material specifications of the final recycler, which are: 3% maximum impurity and 150 to 350 kg / m³ density. The impurity was related to the classified activities of post-consumer polymers by color and without other materials other than plastics.

Table 2. Activities of the recycling process.

Raw material specifications	Diagnostic categories
Impurity 3% maximum	Post-consumer polymers classified by color
	Without other materials: liquids, metals, sludge and other waste
Density 150 to 350 kg / m^3	Bales of post-consumer polymers

Next, the contrast between the specifications of the raw material with the current diagnosis of the same, as well as the consolidated characterization of raw material made to the suppliers, the specification of impurity results in post-consumer polymers mixed with colors and others. materials as shown in Table 3.

Table 3. Contrast between the raw material specifications with the current diagnosis.

Raw material specifications	Diagnostic categories	Results
Impurity 3% maximum	**a)** Post-consumer polymers classified by color	95,5%
	b) Other materials	4%
	c) Packing	0,5%
	Total (a+b+c)	100%
Density 150 to 350 kg / m^3	**a)** Bales of post-consumer polymers	
	Large	202,0 kg/m^3
	Medium	200,0 kg/m^3
	Small	311,1 kg/m^3
	b) Bulk	
	Big bags	50 kg/m^3

Table 4 presents the needs for improvement of the process, as well as the specifications from the collection center, the related components are feeding criteria and the activities to be developed. The summary of the improvement needs to be developed in the collection centers is presented for each specification according to the contrast between Tables 2 and 3. For impurity, the activities of selection, classification of post-consumer polymers are considered. In the specification of density is considered exclusively for the presentation to loose or bulk cargo, the realization of bales of post-consumer polymers as the only improvement activity. On an exposed basis, it can be said that the needs for improvement of the raw material have been identified, therefore, the establishment of criteria for the evaluation of suppliers can be continued.

Table 4. Activities to be developed in the suppliers.

Specifications	Improvement needs
Impurity 3% maximum	- Selection of post-consumer polymers - Classification of post-consumer polymers by color
Density 150 to 350 kg / m3	- Bale making

Table 5 presents the analysis between the raw material specifications, with the diagnostic categories from the recycling process described in Table 2 and the multicriteria assigned. Which are described as: a) Quality and capacity for cooperation with impurity, b) Technological capacity and capacity for cooperation with density. The relationship described in (a) of Table 3 where it is described that the material sent by the collection centers is out of quality specification, therefore, it is required that there is capacity of cooperation of the supplier to be within 3% impurity. The judgment described for (b), part of the need for bulk wholesale post-consumer polymers, have equipment so that they can change the presentation to bales.

Table 5. Analysis of criteria for the evaluation of suppliers.

Specifications	Diagnostic categories	Multicriteria
Impurity 3% maximum	Post-consumer polymers classified by color	Quality, relationship / cooperation capacity
	Without other materials: liquids, metals and other	
Density 150 to 350 kg / m^3	Bales of Post-consumer polymers	Technological capacity Production capacity and facilities

Table N ° 6 presents the current results of raw material per collection center, by evaluation criterion of the previous point and the locations of the collection centers. These are: Esmeraldas, Quito, Santo Domingo, Otavalo, Tulcán, Ibarra, Lago Agrio, Cuenca, Ambato, Portoviejo, and Ambato. The quality results in the impurities show an irregular behavior, since the maximum value is 23% and the minimum 4.5%. The difference between both is 18.5%. The highest data concentration is between 12% to 16.5%. Above all, it can be said that the lowest quality data are comprised from 17% to 23%, which belong to the locations of the collection centers of: Esmeraldas - Atacames, Quito - Guamaní, and Quito - Santa Rosa.

The results of technological capacity are related to the presentation of raw material per collection center. Where seven delivers in bales, and seven in bulk. This means that the former has the right machinery to generate the density required by the production process, the latter do not have the necessary equipment. On the exposed base, we can say that seven supplier locations do not have the necessary technological resources. Those are: Esmeraldas - Atacames, Quito - Guamaní, Quito - Santa Rosa, Santo Domingo - Vía Chone, Otavalo - Peguche, Lago Agrio - Centro, and Ambato - Vía Riobamba.

The result of production capacity is related to the average of monthly deliveries, where maximum values of 100 ton / month and minimum of 20 ton / month are shown. The result of cooperation capacity is described in the level of cooperation of the collection centers, which indicate five with high level, and nine with low. The perception of the former is that they comply with the attitude required to develop improvement projects and the latter do not.

Table 6. Results of the collection center selection.

Suppliers location	Esmeraldas-Atacames	Quito-Guamaní	Quito-Santa Rosa	Santo Domingo-Vía Chone	Otavalo-Peguche	Tulcán-Centro	Quito-Calderón	Ibarra-Mayorista	Quito-Carapungo	Lago Agrio-Centro	Cuenca-Vía Azogues	Portoviejo -Vía Manta	Quito-Parquenor	Ambato-Vía Riobamba
Impurity (%)	23	22	17	17	17	17	16	16	15	15	12	9	6	5
Presentation (1)	BK	BK	BK	BK	BK	B	B	B	B	BS	B	B	B	BK
Deliveries (Ton / month)	80	100	30	40	20	30	50	60	40	20	30	50	100	50
Cooperation (2)	HL	HL	LL	LL	LL	LL	HL	HL	HL	LL	LL	LL	LL	LL

(1) B: Bales BK: Bulk
(2) HL: High level LL: Low level
Improvement opportunities

Table 7 presents the record of the diagnosis of the raw material, before and after the intervention. This presents the impurity specification; whose previous average result is 14.5%. This value is the result of the sum of: 10% of post-consumer polymers mixed with colors, and 4.5% of waste. After the intervention, 2% of impurity is visualized, which is composed of: 0.5% of post-consumer polymer mixed with colors and 1.5% of waste. When buying the results of the before and after the intervention it is observed that the average value of impurity went from 14.5% to 2%. This means that the raw material has a reduction or improvement of 12.5% impurities.

In each of its components the improvements are: (a) 9.5% in post-consumer polymers mixed with colors, and (b) 3% in waste. On the exposed basis it can be concluded, that after the intervention of fulfilled the specification of 3% of impurity, in the suppliers of: Quito - Guamaní, and Esmeraldas - Atacames. In the specification of density, it is observed that before there was 50 kg / m³ for the presentation of post-consumer polymer in bulk. After the intervention, the change to bales is visualized with an average of 202.0 kg / m³. With the base exposed, it is concluded that after the intervention, the specification of density and feeding lots was complied with.

Table 7. Record of the diagnosis of the raw material, before and after the intervention.

Before	After
95.5% of mixed post-consumer polymers	98% of classified post-consumer polymers
waste**: 4,5%**	waste**: 2%**
Other materials: 4,0%	Other materials: 1,5%
Packaging: 0,5%	Packaging: 0,5%
Bales:	**Bales:**
Large: 202 kg/m^3	Large: 202 kg/m^3
Medium: 202 kg/m^3	Medium: 202 kg/m^3
Small: 311,1 kg/m^3	Small: 311,1 kg/m^3

Figure 1 shows the raw material yield record of the final recycler process, before and after the intervention in the collection centers. Prior to the intervention, in the month of May, a regular behavior was observed with an average value of 75% of use.

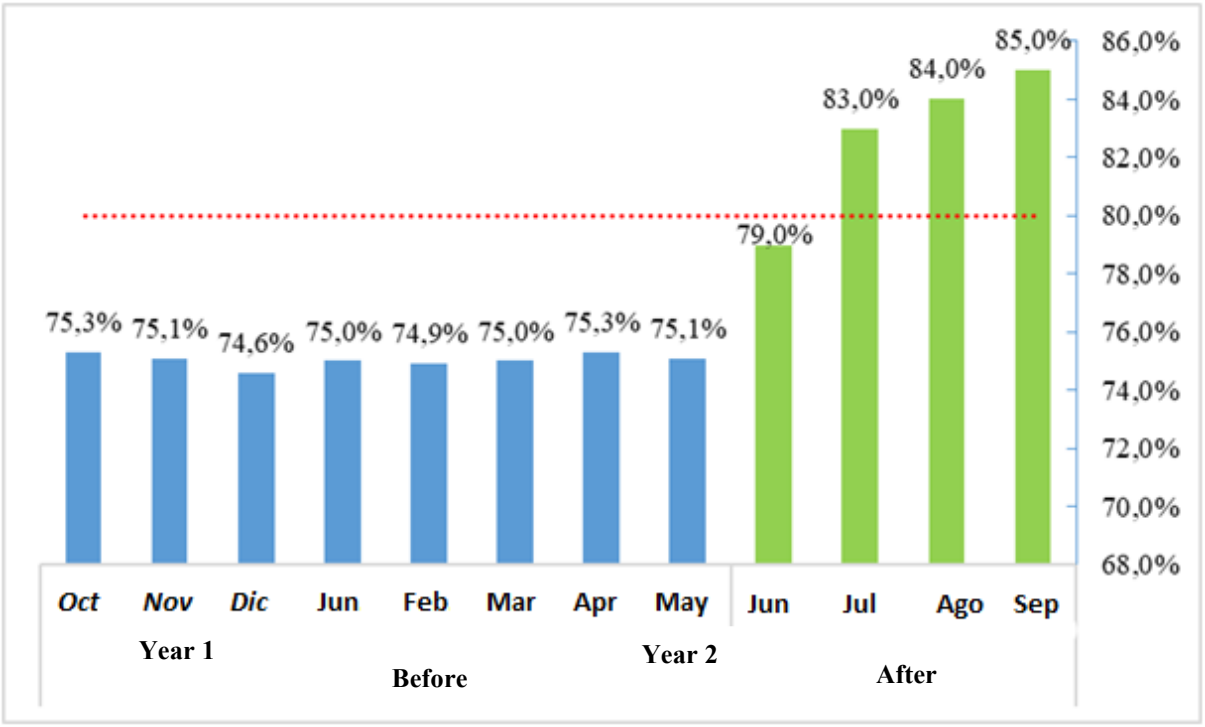

Figure 1. Record of raw material yield before and after the intervention.

Development of a follow-up program for developed suppliers

Figure 2 shows the matrix of the follow-up program for developed suppliers, which includes the following criteria: visits, sharing results and finding opportunities for improvement. The components involved: (i) the field of suppliers where the names of the suppliers are registered, (ii) the schedule of planned visits, (iii) opportunities for improvement that relates: action plans, responsible parties, start / end dates, and the status of the actions taken.

	Month 1				Month 2				Month 3				Month 3				
Collection center / Schedule	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Indicators**
																	% Impurity
																	Density
																	% Impurity
																	Density
																	% Impurity
																	Density

Improvement opportunities	**Action plan**	**Start date**	**End date**	**Status**

Figure 2. Matrix of the follow-up program for developed suppliers.

4. Discussion

With all of the above, it is proposed as the first activity that post-consumer polymers come from collection centers classified by color, with which the production process of the final recycler can program optimal batches for the transformation of recycled flake.

The second activity was specified to the collection centers that only post-consumer polymer will be received, which means discarding metals, liquids and other waste since these causes a low yield of raw material, waste and continuous stoppages in the production line of the final recycler.

As a last activity, it is specified with the collection centers the compliance of density specifications in post-consumer polymer bales, within the condition of 150 to 350 kg / m³ required by the final recycler. The presentation in bulk will not be accepted in the collection centers that have been developed. This is because it does not have the necessary density for the feeding of the productive process, so the partial productivity of it is lowered. With the entire exposed thing can continue with the contrast of the specifications with the status of the raw material. The mixture of colored polymers is 95.5%, which are composed of 4% waste and 0.5% other materials. The mixture of all these colors produces low performance and the other materials cause low quality standards of the recycled flake. The contamination by other materials impacts that the flake will be sold in the market at a low price, because in later processes it produces spots and black spots, due to the different melting temperatures of the materials. The density specification includes post-consumer polymer presentations in bales and in loose or bulk cargo, the results of the presentation of bales show that all of them (large, small and medium), meet the specification ranges. The presentation of loose cargo that generally uses big bags as container of post-consumer polymers, which has a density of 50 kg / m³, so it does not comply with the specification. Additionally, it produces an irregular feed of volume and weight, inside the final recycler.

Finally, the locations of suppliers that have all the best opportunities for improvement and management are selected, which are: Esmeraldas - Atacames, and Quito - Guamaní, therefore, they are the ones selected to intervene. Then, resources were implemented to improve the activities in the collection centers. Two bands of manual selection and two presses were purchased and implemented in the selected collection centers. From this, through training, the activities of selection, classification and pressing of post-consumer polymers were implemented and after that the results were evaluated.

After the intervention, increases are observed from June to September of the year. The average value of the yield of raw material, consumed by the process in the last three months is 83%. With the base exposed, it can be said that the registration of the before and after the intervention in the collection centers has been made Quito - Guamaní, and Esmeraldas - Atacames. With results of: 2.5% PET bottle impurities, and 83% of raw material consumed.

It is recommended to extend this study to all the processes of the company, to achieve a better organizational performance in the company. It is necessary to equip personal protective equipment in case it is impossible to act on the source, according to the need of the process in such a way that it helps the worker to carry out his activities in a more efficient way in safe conditions.

5. Conclusions

The raw material of the process did not meet the specifications of 3% impurity and 150 to 300 kg / m³ density. The results obtained are: 15% impurity, and 50 kg / m³ density in bulk post-consumer polymers.

Criteria were established for the evaluation of collection centers, which are: quality, technological capacity, production capacity and facilities, and relationship / cooperation capacity. With which the following supplier locations were selected: Esmeraldas - Atacames, and Quito - Guamaní.

The selected collection centers were intervened with machinery and improvement activities. In the first, it was equipped with two presses and manual selection bands. For the second, the activities of selection, classification and pressing of post-consumer polymers were implemented. With which the results of 2% in impurity and 202 kg / m³ in density for the bales made from bulk polymers were obtained. Therefore, the raw material specifications of the final recycler were met. After the intervention, an average of 8% of the post-consumer polymers performance factor or partial productivity of the process raw material was increased.

As a method of evaluating results to developed suppliers, the characterization of two bales per shipment received at the plant was determined. And because it is a long-term objective, the follow-up program for developed suppliers was raised.

References

Arroyo, M., and Ramos, Proceso para el diseño de un sistema de evaluación y selección de proveedores. *In XIV Congreso Internacional de Contaduría Administración e informática,* México DF, México (2014).

Castro-Castell, O., Yepes-Lugo, C., and Ojeda-Pérez, R., Desarrollo de proveedores. Elementos y procesos de promoción. *Clío América*, 7, 2016.

Coelho, J., and Hazin, L., Metodologías para la selección de proveedores: una revisión de la literatura, *Producción*, 4(22), 625-636, 2012.

Da Rosa, A., Michelin, C., and Campomanes, R., Reciclaje de PET: evaluación de la eficiencia de separación del contaminante PVC. *ECIPERU*, 8(1), 10-13, 2011.

Delfín, P., and Márquez, M., Importancia y Análisis del Desarrollo Empresarial, Pensamiento & Gestión, núm. 40, enero-junio, pp. 184-202, 2016.

Gonzalez, L., El impacto del desarrollo de proveedores en la cadena de suministros. Universidad Militar Nueva Granada, 1(1), 1-21, 2014.

Ministerio del Ambiente, Análisis de la industria y Demanda de plástico PET. Reciclaje Inclusivo y Recicladores de Base en el Ecuador, 1(1), 29-69, 2015.

Organización Internacional del Trabajo, *Obtenido de Políticas Públicas para la Inclusión de los Recicladores de Base al Sistema de Gestión de Residuos Municipales en Chile*, 2013.

Perez, F., Medio ambiente, bienes ambientales y métodos. *Equidad & Desarrollo*, 25, 2016.

Reyes, A., Pellegrini, N., and Reyes, R., El reciclaje como alternativa de manejo de los residuos sólidos en el sector minas de Baruta, Estado Miranda, Venezuela. *Revista de Investigación*, 39(86), 1-12, 2015.

Ruppenthal, C., and Duarte, J., Desenvolvimento de fornecedores: um estudo de caso utilizando a troca rápida de ferramentas. *Produção*, 1(14), 44-53, 2012.

Vargas, O., Gestión de compras eficientes y sostenibles: modelo para la gestión de la cadena de suministro y para romper paradigmas. Punto de Vista, 13, 2014.

Vázquez, A., Espinosa, R., Beltrán, M., and Velazco, M., El reciclaje de los plásticos. Universidad Autónoma Metropolitana, 1(1), pp. 1-14, 2013.

Vega, F., and Ricárdez, J., Evolución y desarrollo histórico de los impuestos verdes en el mundo y en México: una perspectiva de sustentabilidad de las organizaciones responsables. *In XVII Congreso Internacional de Contaduría Administración e Informática*. México DF, 2013.

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