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THE HEADREST MANUFACTURING INDUSTRY: EVALUATION THE ENVIRONMENTAL IMPACTS

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ABSTRACT

As a matter of fact, the automotive industry has expanded and experienced growth increasingly. Approximately 2.9 cars are produced and sold every single second with a view to meeting the high demand in a flourishing market. As a result, this has led to a growth in the location of production plants to meet the needs of the market and at the same time an impact on the environment. In this context, the objective of this article is to evaluate the environmental impacts of a sector of the automotive industry. That is to say, the objective is about the manufacturing industry of headrests in Morocco for the purpose of better analyzing and identifying the processes and the categories, which have negative impacts on the environment. The evaluation was conducted via the use of Life Cycle Assessment (LCA) methodology using the OpenLCA software, the Ecoinvent database and the Impact 2002+ endpoint impact characterization method. Therefore, we concluded that the manufacture of the head restraints for a car seat has negative impacts on the environment.

Keywords: life cycle analysis, LCA, headrest, automotive industry, environmental analysis, environmental impact.

1. INTRODUCTION

The high demand for consumer needs leads to a growth in the location of production lines and consequently their impact on the environment. Today the car seat manufacturing industry has a significant value. In 2014, the sector had more than 150 equipment manufacturers in three main regions: Tangier (43%), Casablanca (39%) and Kenitra (7%) [1]. These industries mainly cover the manufacture of headrests for car seats. On the other hand, the latter ensure the maintenance of the head and upper spine in case of accidents of the driver or passenger. In other words, it represents the upper part of the seat. [2].

In general, the environment plays the role of emitting environment with the objective of finding: raw materials, energy and water that impact the depletion of natural resources. And also the receiving medium of all liquid, solid and gaseous discharges that pollute water, air and soil. Accordingly, an environmental assessment is required for all industrial activities that stand for a pressure on the environment.

In this context, we have chosen to evaluate the industrial manufacturing activity of headrests in Morocco so as to determine the potential impacts on the environment through adopting the life cycle assessment (LCA) methodology.

2. MATERIALS AND METHODS

LCA is a tool for evaluating the potential environmental impacts of a system comprising all the activities which are associated with a product or a service from the extraction of raw materials to disposal [3]. It is a multi-criteria approach to take into consideration the different classes of impacts on the environment, which has been the subject of many works. It is a standardized methodological framework according to ISO 14040-44 standards. LCA is based on four main stages [4] (Figure-1):

- **Step 1:** Definition of objectives and scope of the study (ISO 14040) corresponds to: the objective of the study, the field of study, the function and the functional unit, the reference flow, the system boundary and cutoff rule [5].
- **Step 2:** Inventory and Inventory Analysis (ISO 14041) corresponds to: data collection, inventory analysis, data calculation, data quality, and inventory determination methods of life Cycle (ILC) [6, p. 14041].
- **Step 3:** Impact study (ISO 14042) corresponds to: software process modelling, impact calculation method and impact category simulation [7, p. 14042].
- And finally the fourth stage (ISO 14043) [8].

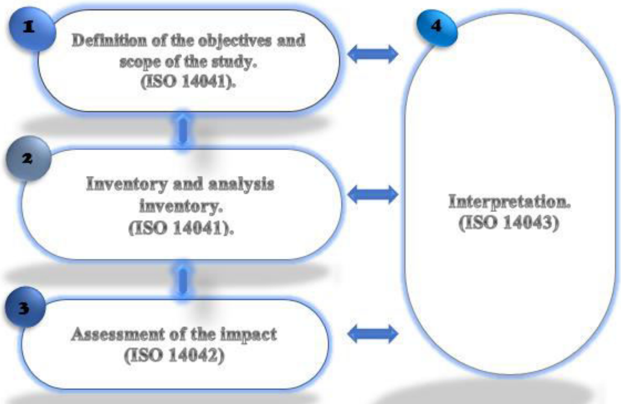

Figure-1. Metrology steps of LCA [9].

Then all the data which is collected in terms of the studied production unit was processed by the OpenLCA v1.3.4 software and using the Ecoinvent database. The choice of software was made through evaluating several criteria such as usability, functionality, results and availability [10]. Same goes for the database in

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relation to its compatibility, transparency and the reliability of the data used.

In addition, the IMPACT 2002+ Endpoint method was adopted for the assessment of the different environmental impacts which are generated at the level of each impact category.

3. RESULTS AND DISCUSSIONS

We conducted a life cycle analysis study on the manufacture of a headrest for automotive seating with a view to assessing environmental impacts through meeting the requirements of the LCA standards.

3.1 Définition des objectifs et champs de l'étude

The objective of our study was not only to evaluate the environmental impacts of the headrest manufacturing industry in Morocco but also to identify the most polluting categories related to the environment.

The manufacturing process of a headrest encompasses the receipt of the raw material delivered by the suppliers. The production steps are the processes of cutting, sewing and injection: after cutting the textile and mattresses into inserts, the seam allows the assembly of two or more pieces with sewing thread to obtain a cap. The injection corresponds to the insertion of a rod (Rods), expanded polypropylene (EPP), in addition to the nozzle (Nozzle), which is done with the help of a robot allowing the casting of a mixture of Isocyanate and Polyol. These compounds quickly form foam at the level of a cap, ultimately resulting in a headrest as the final product of manufacture (Figure-2).

Figure-2. Example of a headrest.

As established by the LCA, we have opted in this work to choose the functional unit corresponding to the manufacture of a headrest (Figure-2). The boundaries of the system assigned within the production unit include the transportation of raw materials from the suppliers to the production unit (Figure-3).

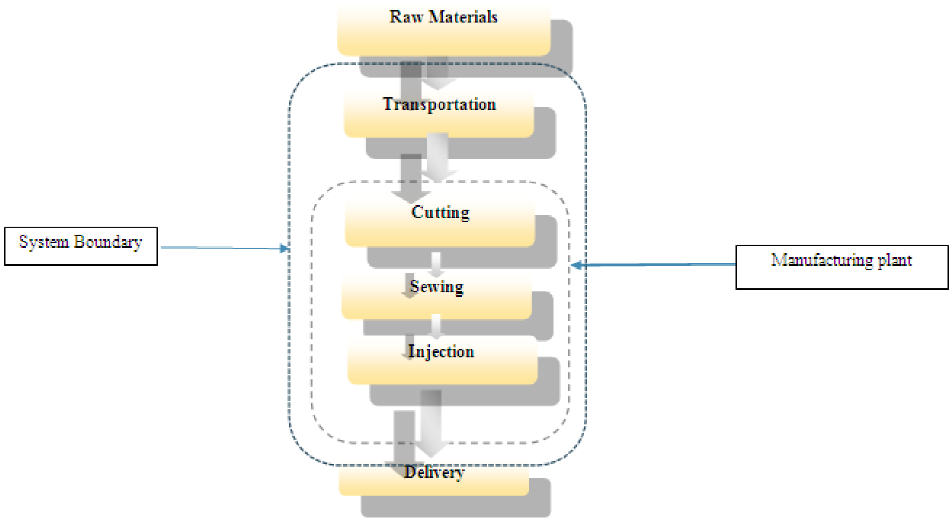

Figure-3. Production flowchart of caps and headrest.

3.2 Life cycle inventory analysis (or LCA)

This phase is the most complex in an LCA, because of the collection of data on the considered system. The inventory of the life cycle is the census and the quantification of the entrants and the outgoing of each elementary process according to the flow of reference [4].

First of all, we have dissected the headrest with the objective of knowing its composition. It is composed of four main elements namely: the cap, the rod, the expanded polypropylene (EPP) and the polyurethane foam, (Figure-4).

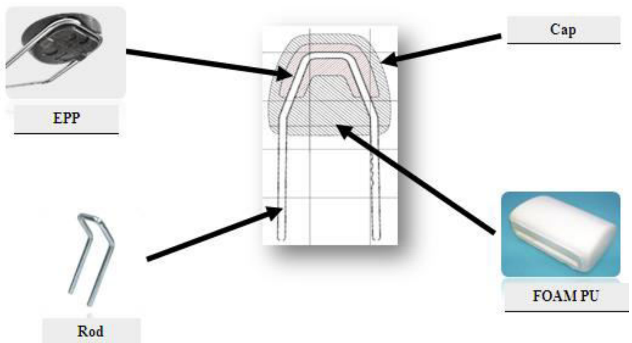

Figure-4. Composition of the headrest.

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Subsequently, we estimated and quantified the quantities and nature of materials that make up the headrest Table-1.

Table-1. Composition of material to produce a headrest.

Material description	Nature	Quantity	Unit
Textile	Fabric	0,082075	m^2
TEP	Vinyl	0,073224	m^2
Thread	Thread	5	m
Polyol	Chemical Product	0.155	kg
Isocyanate	Chemical Product	0.106	kg
NOZZEL	Plastic	1	P
EPP	Plastic	1	P
Rod	Metal	1	P

Since transportation is an integral part of the system under study, we have included an inventory of the types of transport of raw materials by the supplier to the manufacturing plant, as well as the journeys and distances travelled, (Table-2).

Table-2. Type of transportation and distances travelled to transport the raw material.

Type of raw material	Distance	
	Maritime (km)	Maritime (km)
Fabric	41	759
TEP	41	759
Thread	41	2639
Polyol	41	2399
Isocyanate	41	2399
Nozzel	41	3450
EPP	41	1109
Rod	10822	81
Total	11109	13595

A life cycle inventory following the process diagram method [11] has been implemented at the level of each process. Accordingly, we determined the inputs and outputs (elementary product and generated waste), and hence we established a material flow analysis (Figure-5).

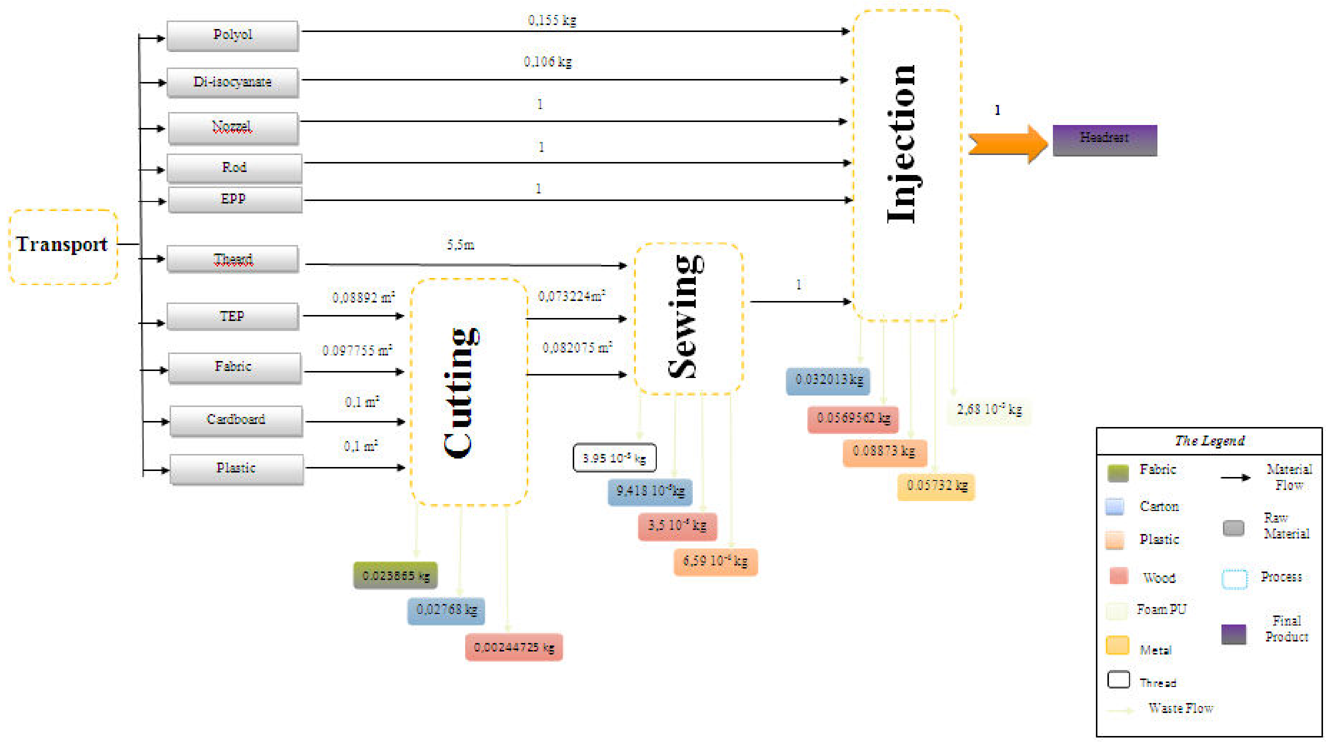

Figure-5. Material flow for the manufacture of a headrest.

3.3 Environmental impact assessment (or Life Cycle Impact Analysis (LCIA)

The Life Cycle Impact Assessment (LCIA) aims at understanding and assessing environmental impacts based on inventory analysis, within the framework and the scope of the study. In this phase, the results of the inventory are assigned to different impact categories, which depend on the types of environmental impacts expected. According to ISO 14044, LCA impact assessment consists of mandatory elements: classification and characterization, and optional elements:

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standardization, grouping weighting and data quality analysis [12].

In our study, we chose the IMPACT 2002+ method which proposes a combined effects / damage (midpoint / endpoint) approach. In other terms, linking all types of ICV results via several categories of medium human toxicity, respiratory effects, ionizing radiation, ozone depletion, photochemical oxidation, aquatic ecotoxicity, terrestrial ecotoxicity, aquatic acidification, eutrophication, terrestrial acidification, global warming, non-renewable resource depletion and climate change [7].

As the method integrates several environmental impact indicators, which cannot all be presented? Then we went to the Categories of damages (Endpoint). Indicators of human health and ecosystem quality will be addressed. For the global impact, only the climate change indicator is presented to better understand the trend of environmental impacts (Table-3).

Table-3. Impact assessment by category of the manufacture of a headrest.

Impact category	Result
Climate Change	$9{,}81.10^{-5}$
Climate Change - Total	$9{,}81.10^{-5}$
Ecosystem Quality: Aquatic ecotoxicity	$2{,}9.10^{-7}$
Ecosystem Quality: Land cover	$9{,}48.10^{-7}$
Ecosystem Quality: Terrestrial Acidification and Nitrification	$1{,}88.10^{-6}$
Ecosystem Quality: Terrestrial ecotoxicity	$8{,}02.10^{-6}$
Ecosystem Quality - Total	$1{,}11.10^{-5}$
Human Health: Human toxicity	$7{,}73.10^{-6}$
Human Health: Ionizing radiation	$3{,}92.10^{-7}$
Human Health: Depletion of the ozone layer	$1{,}11.10^{-8}$
Human Health: Photochemical Oxidation	$2{,}54.10^{-7}$
Human Health: Respiratory Effects (inorganic)	$9{,}14.10^{-5}$
Human Health - Total	$9{,}98.10^{-5}$
Ressources: Mineral extraction	$1{,}38.10^{-7}$
Ressources: Non-renewable energy	0,00016
Ressources - Total	0,00016

3.4 Interpretation

The purpose and the reason behind the interpretation of LCA is to draw conclusions and recommendations or decision makers consistent with the purpose and scope of the study. It is a phase that must meet the objectives of the study identified in the first step with the objective of proposing recommendations that are appropriate for them. At this stage, it is also quite important to identify the relevant solutions to redesign the product based on the quality of the data. In consequence, it is necessary to complete the analysis by completeness check, sensitivity check and consistency check [12].

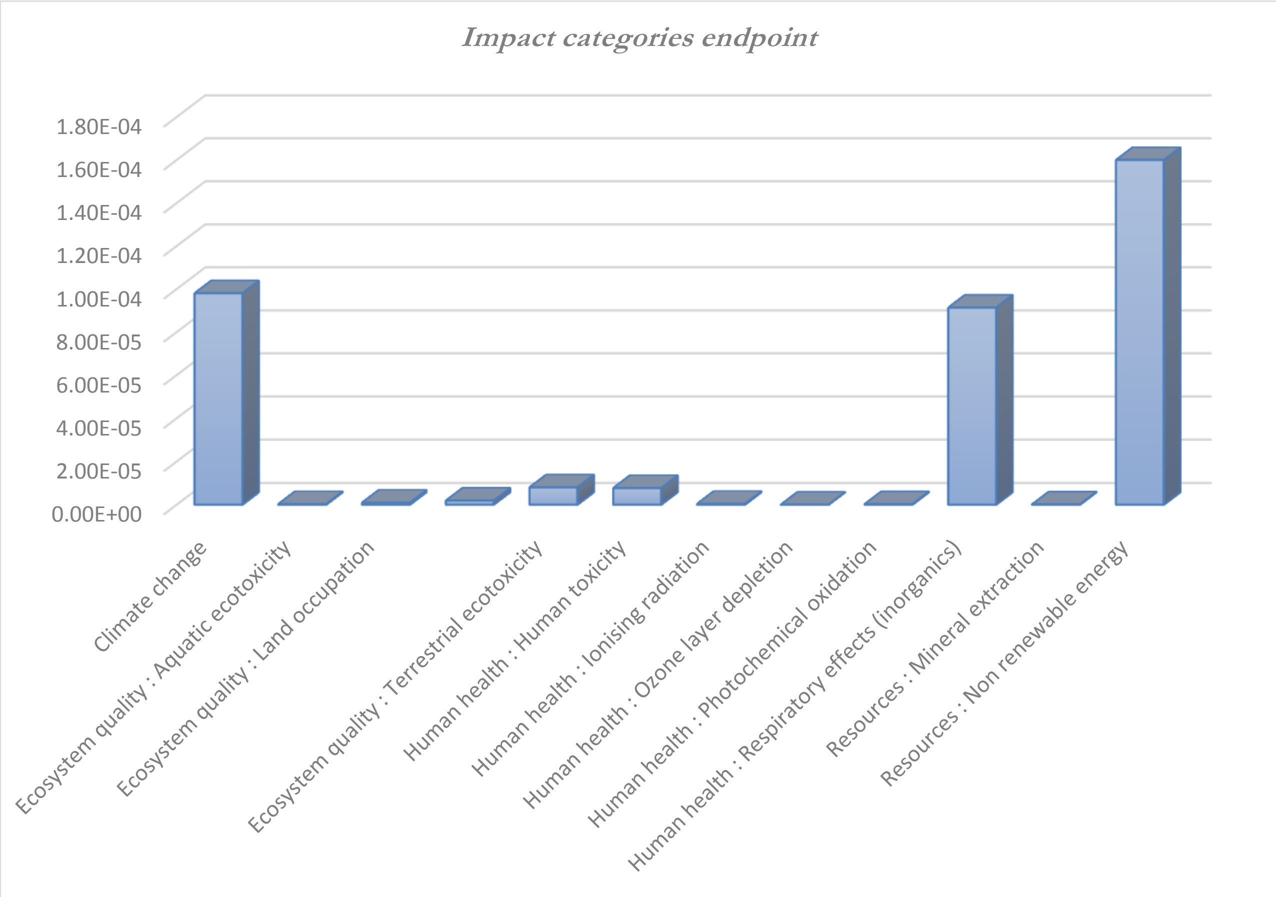

Figure-6. Endpoint impact categories.

Figure-6 shows the weighting of each impact category according to the most impacting element in the manufacturing process of a headrest. It can be seen that the category of Resources: Non-renewable energy stands for an estimated impact of 0.00016 points. Besides, as compared to the categories Climate Change and Human Health (Respiratory effects by inorganic substances) which represent in succession: 9.81.10-5 points and 9.14.10-5 points?

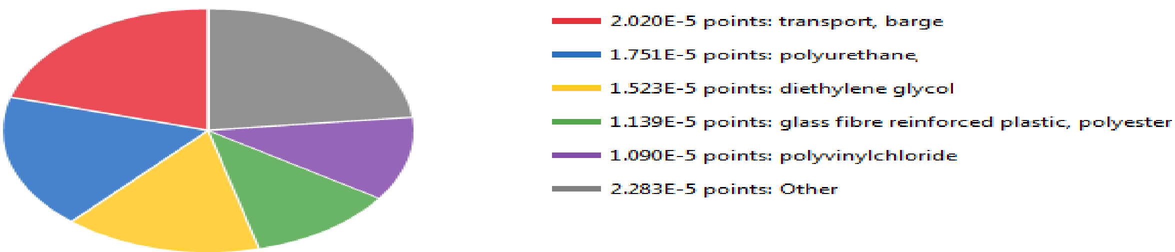

Figure (a). Climate change

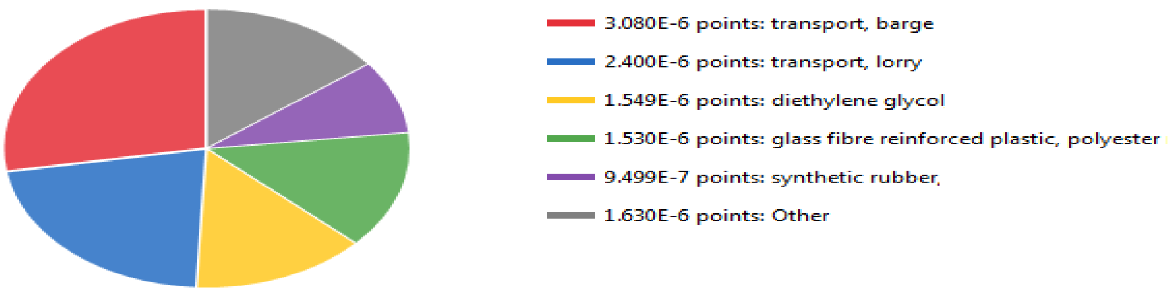

Figure (b). Ecosystem quality.

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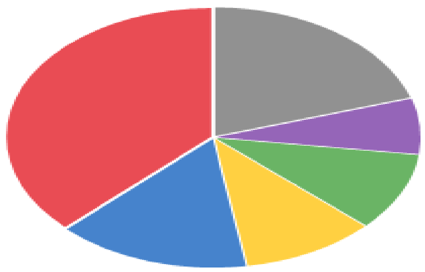

Figure (c). Human health.

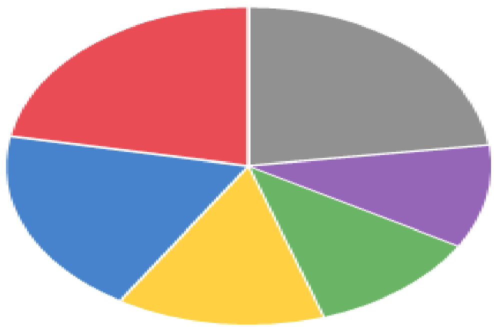

Figure (d). Resources.

Figure-7. The impact categories by elements.

The impact elements are shown in Figures (a, b, c and d) of Figure-7 that: The transport category of raw materials represents the largest share in the manufacturing cycle for the industry in question regardless of the impact considered. In fact, it represents at the level of:

- Climate change has an impact of approximately: 2,020.10-5points.
- Human health: 4,4237.10-5 points
- Quality of ecosystems: 5, 48.10-6 points.

Then comes the production and use of polyurethane and finally the plastics and synthetic textiles which are used for the manufacturing of the headrest.

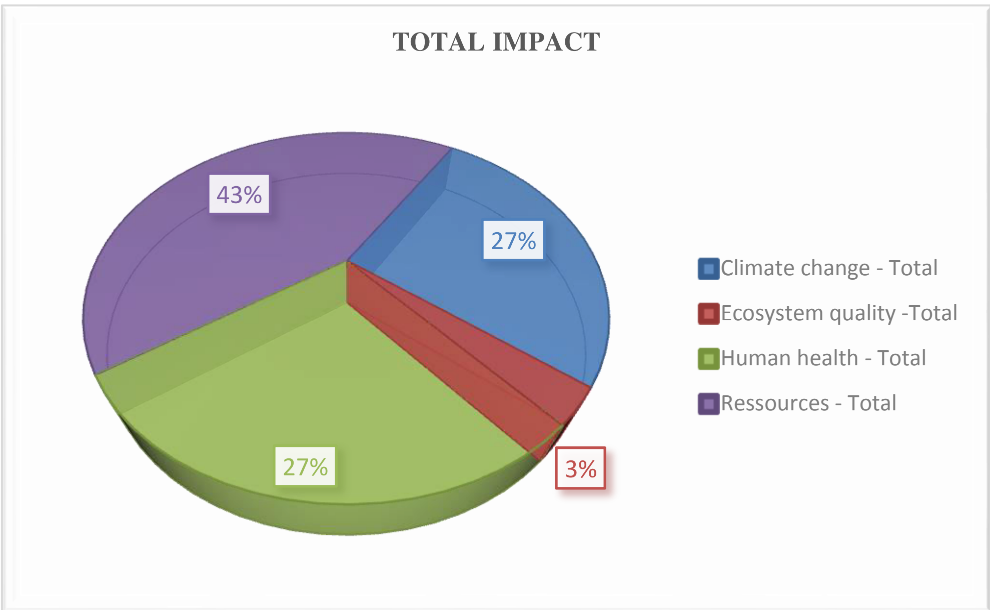

Figure-8. Percentages of impact for each category for making a headrest.

This study made it possible to target the environmental impacts of each stage of the production of a headrest. Moreover, it was possible to observe that about 43% of the environmental impact generated is linked with the categories of resources used, followed by 27% of climate change and human health. Finally, the impact of the quality of the ecosystem represents only 3% of the impact process of the headrest manufacturing (Figure-8).

4. CONCLUSIONS

Life Cycle Assessment (LCA) is a method for evaluating the environmental performance of products and services in a comprehensive manner. It is now widely used for eco-design and environmental labelling of products.

This approach, which is newly applied in the automobile headrest manufacturing sector and in accordance with the steps set by ISO 14040-44 standards, has highlighted the most polluting resources during the manufacturing process. As a result, this very approach aims at better understanding and comparing environmental impacts during manufacturing. The results obtained make it possible to highlight that:

- The production phase (cutting, sewing and injection) consumes resources, especially non-renewable energies, and generates most of the emissions.
- The impacts of climate change and human health representing the same impact value 27% to produce a headrest.
- The transportation category accounts for a larger share of all impacts. Followed by the use and manufacture of polyurethane foam, after the other components of the headrest.

This work illustrates an example of the life cycle analysis of the automotive industry, through an LCA of impacts related to the process of manufacturing a headrest from receipt of the raw material to the final product. These categories of impacts, which are of paramount significance for the environment, generate a considerable pressure that can be evaluated and, subsequently, can be remedied for responsible eco-production.

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