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Identification of Parameters for Environmental Impact Assessment of Product Packaging

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Abstract
Analogous to products, product packaging too has a life-cycle consisting of design, manufacture, usage and disposal. Environmental impact of product packaging is of immense interest to package designers, package manufacturers as well as its users. However, there are relatively few studies centered about environmental sustainability assessment of product packaging. There is a necessity to develop a comprehensive assessment system or rating, which can measure environmental impact. To arrive at a comprehensive assessment system, it would be required to Identify parameters and formulate a framework for environmental impact assessment. The present paper is a step in this direction. The present work proposes to identify an exhaustive set of parameters which are relevant to environmental impact assessment of product packaging. The parameters identified in this work are comprehensive and overcomes some of the limitations of existing systems.
Keywords: Product Packaging, Environmental Impact, Design for Environment, Evaluation of Environmental Sustainability.

1. Introduction
The ever demanding consumption pattern of human has led to severe environmental problems. This has caused damage to local ecosystems, atmosphere, oceans, forests, agriculture, water supplies, etc. at local and by and large at global levels. The social needs which are the basis for economic activity are not only a requirement for individuals to advance their own interests, but more significantly, involves a long-term commitment to make necessary efforts to guarantee the future for coming generations [1]. Across the globe, efforts are being made to address the need of environmentally sustainable design. In 1995, world businesses council for sustainable development (WBCSD), which is a coalition of 120 international companies formulated principles of economic growth and sustainable development and published a report entitled ‘sustainable production and consumption.’ From a business perspective, this gives insight to sustainable consumption through involvement of business establishments, government organizations and social communities, giving priority for optimum use of resources for manufacturing purpose [2].

To move towards a sustainable future, one of approaches reported in literature has been to innovate technology with environmental sustainability as a goal. Changing the type of competitions, for reforming the economical competencies is suggested to help ecology regain its lost status. [3]

Through product design strategies, environmental sustainability can become an added product value [4]. One of the approaches for such strategy could be to help the designer with the environmental impact assessment of a designed product. This can be done by providing the designers a tool which can evaluate the influence of a product on the environment. In the domain of product design there have been a few attempts for environmental sustainability [5]. However, there has not been much emphasis on the environmental impact assessment of a product packaging as an industrial product. Reported research has been specific to domain like, material, manufacturing, product life cycle, etc. This approach will not be useful for product packaging as it has varied unstructured Lifecycle flows. Therefore, there is a need for a generic framework which takes care of all the aspects of the product packaging.

In this paper an attempt has been to identify specific areas of intervention from a product designer's perspective to work for environmental impact assessment of product packaging in a holistic way. Such an intervention is necessary in product packaging as it is observable contributing to the environmental impact. Product packaging has multiple requirements to be addressed, for e.g. safe delivery of the product to the user, information about the product, attracting the users to purchase, etc., however, even after achieving the commercial concerns listed above, the environmental concerns go unnoticed. The environmental nuisance of the packaging therefore becomes very much essential to control.

2. Literature review

To arrive at a set of parameters which will help measure the environmental impact of product packaging, an understanding of the approaches made to measure environmental sustainability of products has been done by literature survey. The survey covers in brief different approaches made so far to address concerns for environment for materials, production process and product life cycle management. Following paragraph discusses in detail.

2.1 Material related issues

Matos and Simplıcio [6], gives a practical example about how to address environmental sustainability through materials. In their study, they have substituted polyvinyl chloride by cork to avoid health damage and environmental burden at the same time not compromising on the innovation benefits of PVC. Lennart Y. Ljungberg [7] presents a guideline with respect to material, design and ecology. Their research presents an understanding of materials that creates less impact on the environment. It is further discussed, for a product to be successful; there should be support of environmental rating or marking. Their research discusses, a material selection method should be in line with production methods. It should also cater to function and structural demands, market or user demands, design, price, environmental impact and lifetime.

Karana et.al [8] has reviewed different sources for material selection. The authors have conducted an experiment with 20 product designers to find out the material selection sources that the designers opt for. This gives an insight about the designers need for material selection considering some intangible characteristics of material selection.

2.2 Production process related issues

A.D. Jayal et.al [9] presents an overview of recent trends and concepts involved in the production process. Their research presents the 6R concept of Reuse, Re-Cover, recycle, Redesign, Reduce and Re manufacture. In addition, the research considers six interactive elements for development of a new model for optimizing machine performance. Hence, achieve closed loop flow and environmental sustainability. J. Kopac [10] has evaluated two types of machining: Cryogenic machining and high pressure assisted machining, in comparison of conventional machining on a selected material. The evaluation was based on parameters like: environmental impact, energy consumption, safety, personal health, waste management and costs.

2.3 Product Lifecycle management related issues

The concept of Product Lifecycle Management (PLM) appeared later in the 1990's with the aim of moving beyond engineering aspects of a product and providing a shared platform for the creation, organization and dissemination of product related information (cradle to the grave) across the extended enterprise [11]. PLM is generally defined as 'a strategic business approach to the effective management and use of corporate intellectual capital [12]. Leo Alting and Jorgen. Jogensen [13] suggest that the outcome of LCA processes should be environmentally friendly. The authors have proposed methods to support environmental design of industrial products. The method is about selecting a reference product for its function and technology and then assessing the product for its several parameters through a product tree and a process tree which gives an evaluation of the product's impact on the environment.

3. Identification of parameters for environmental impact assessment of product packaging

Identification of parameters was done in two steps. In the first step. In the first step a broad set of concerns from the point of view of environmental impact for a package Lifecycle were listed form literature study. The list of parameters arrived at are displayed in Table.1. From the table it was identified that these are several parameters within material, energy, pollutants, reuse and recycle, etc. which needs to be further granulated form environmental impact assessment point of view.

In the second step a benchmarking exercise was carried out to understand how the existing tools for environmental impact assessment and promotion are measuring the phenomenon. This exercise has been detailed in section 3.2.

3.1 Hypothesis for first level parameters

For the first level of parameters during the production process issues like material used an material wastage was taken into concern. In addition to materials,

environmental concern is also for pollutants released and energy consumed during manufacture. Coming to the usage of a product packaging there is required to account for the energy required and pollutants released. At the end of product packages life energy required, ease of disassembly, recycle and reuse can become driving parameters. In addition to the general concerns there could also be a concern for source of energy wherever energy is accounted for.

There may also be a concern for the average life of the package, mean time between failure and environmental concerns for distribution. The parameters evolved from literature study is listed in Table.1.

Material used	Average life of product
Material wastage during manufacturing	Mean time between failure
Pollutants released during manufacturing	Distribution
Energy source of manufacture	Ease of disassembly
The energy required to manufacture	The energy required for end of life
Pollutants released during usage	Recyclability
The energy required to operate	Reuse
Energy source for usage	

Table.1: Parameters evolved from literature study

3.2. Benchmarking of existing tools for environmental Impact assessment of product packaging:

Benchmarking as a method is very reliable for continuous improvement in any established system. [14] The parameters which emerged from focused group discussion were further benchmarked with parameters already established by other tools being used for measuring and assisting environmentally friendly product packaging. Following paragraphs gives a description of the tools being considered to evolve into a set of parameters for environmental impact assessment of product packaging.

Compass [15] is an exhaustive online Lifecycle assessment tool for assessing of products Wal-Mart has developed a scorecard for packaging [16], PIQET [17] is also an online Lifecycle assessment tool for environmental impact assessment. Certain councils and efficient management systems have been there addressing the need of environmental friendly packaging systems like, CCME : Canadian council of ministers of the environment [18] and SAP: Efficient Recycling Management for Product Packaging [19], There are companies which work on promotion of environmental sustainable packaging like Rock Tenn: Sustainable packaging (Paper and Board) [20], Nextek Limited (PET Bottles) [21], work has also been reported in environmental impact calculators like, 360 environmental limited packaging obligation calculator [22], Valpak (LCA for packaging) [23] There has been development in ISO systems for green packaging like, ISO 18600 :2013 (Packaging and environment) [24] which has mention of Hazardous heavy metals, Contaminants, Reuse, Recovery, Energy, Optimization, Ecological.

A detailed comparison is proposed to be explored and a detailed record of parameters as used by available research/ tools is listed in Tblle 3.

3.3 Proposed parameters

From the benchmarking, and first level of parameters Fig.1. Twenty-seven (27) parameters were considered in the identified list, the decision was made based on difference in nature of addressing concerns. The parameters identified are listed in Table.2.

Life cycle phase	SL no	Parameter
Preproduction	1	Distance between major resources and production unit
	2	Depletion of resources in extraction of materials
	3	Ease of extraction
Production	4	A material used in manufacture
	5	Material wastage during manufacture
	6	Depletion of fresh water in manufacture
	7	Pollutants released during manufacture
	8	The energy required for manufacturing
	9	Energy source of manufacture
	10	Percentage of recycled material used
	11	Distance between place of manufacture and place of usage
	12	Energy source of distribution
Usage	13	Pollutants released during usage
	14	The energy required to operate/ use
	15	Energy source for use
	16	Average life
	17	Mean time between failure
End Of Life	18	Time If done manually
	19	Percentage of material recoverable
	20	The energy required for recovering the materials
	21	Energy source of disassembly
	22	Percentage of materials recyclable
	23	The energy required for recyclability
	24	Energy source for recycling
	25	Residual Life
	26	Percentage of material to be able to use
	27	Reassembly

Table 2: Parameters Identified for environmental impact assessment

The parameters identified were checked for their occurrence in the available research and tools being considered for benchmarking. This has further been listed in Table.3.

SL No/Parameter No	Tools
1	Not Addresses yet
2	Compass, PIQET, Valpac.
3	Compass, PIQET, 360 env., Valpac, ISO
4	Compass, WAl-Mart, SAP, Rock Tenn, 360env.
5	Compass, PIQET, Rock Tenn
6	Compass, PIQET, Rock Tenn, Valpac, ISO
7	Compass, WAl-Mart, PIQET, CCME, Rock Tenn, Valpac, ISO
8	PIQET, NexTek, ISO
9	Not Addresses yet
10	Not Addresses yet
11	Compass, WAl-Mart, SAP
12	Not Addresses yet
13	Not Addresses yet
14	PIQET, Rock Tenn, NexTek, ISO
15	Not Addresses yet
16	Not Addresses yet
17	Not Addresses yet
18	Not Addresses yet
19	Compass, WAl-Mart
20	Not Addresses yet
21	Not Addresses yet
22	Compass, WAl-Mart, PIQET, CCME, SAP, Rock Tenn, 360 env, ISO
23	Not Addresses yet
24	Not Addresses yet
25	Rock Tenn
26	CCME, 360 env, ISO
27	Not Addresses yet

Table.3. Parameters Identified for environmental impact assessment

4. Discussion on parameter identification

For the identified parameters a super set of parameters was arrived at. This included parameters that were combination of the parameters evolved from brainstorming as discussed in section 1.1. There were total 27 parameters which were very distinct in nature and needed a separate attention for measurement. A detailed discussion was required to attend to the parameters which can be incorporated in environmental impact assessment. The parameters were classified under four domains of the life cycle of a product packaging. They are Preproduction. Production, Usage and End of Life. A total of twenty-seven (27) parameters were identified which are discussed in detail below.

4.1 Preproduction

Preproduction phase of a product packaging is an important phase wherein the environmental issues related to a product packaging can be covered. This would be the stage when planning of production is put in place and would cover the few important parameters for environmental impact assessment. These are listed as follows.

4.1.1 Distance between major resources and production unit

In general circumstances of production, the place of production is at varying distances from the place of availability of raw materials. The additional transportation of materials, therefore, places an adverse impact on the environment. It is posited to measure the distance between the sources of raw materials/Ores and production unit. As same product packaging produced by same methods would differ in their environmental impact if the distance between the source/ origin of raw materials and location of production varies. More consumption of energy would be involved in transportation of materials to the point of production.

4.1.2 Depletion of resources in extraction of materials

The environmental impact of a product packaging is agreed to increase if the resources which are used in producing the product is scarce in nature and difficult to regenerate as compared to a product packaging which uses resources which are abundant in nature. Measuring the depletion of resources would therefore help in guiding the decision makers to understand the severity of this issue and therefore make a decision in opting for more abundant material.

4.1.3 Ease of extraction

In terms of energy involved in extraction, some of the material is easy to extract as compared to others. The increase in the amount of resources required for extraction of material is hypothesized to increase an impact on the environment. Therefore an audit system should encapsulate the ease of extraction as a parameter for environmental impact assessment.

4.2 Production

After taking into account the preproduction phase. The product packaging is suggested to have different attributes to be measured in the production phase. The

production phase incorporates all the issues related to the packaging in the production plant, they re discussed in detail as follows.

4.2.1 A material used in manufacturing

Volume of material used in the manufacturing of a product can play an important role in its impact on the environment. Product package serving same purpose can have different amount of material used. A product package having lesser material used will have less impact as compared to a package which involves more material. The effect can be cumulative on all subsequent phases of product life cycle. It becomes important to consider material usage as a parameter.

4.2.2 Material wastage during manufacturing

In general all manufacturing process involves wastage of material. Volume of material wasted, would surely account for the environmental impact of a product packaging. A production process or machine which wastes lesser material would be having a lesser impact on the environment as compared to one which wastes more material. Considering material wastage as a parameter is therefore important.

4.2.3 Depletion of fresh water during manufacturing

All Production process involves the use of fresh water. The usage may vary in volume and the intensity by which water is polluted. Many of the process pollute water being used severely and therefore depleting the fresh water reserve in their surroundings. Accounting for the volume of fresh water depletion becomes important for calculation of the environmental impact of a product packaging.

4.2.4 Pollutants released during manufacturing

A production process releases a number of pollutants in the nature. For the environmental impact of a product packaging, these pollutants have to be measured. Pollutants can vary for the medium they pollute, like: air, water, land. They can vary in the severity of pollution and duration of impact. The pollutants can be categorized as less or more harmful, having short term or long term impact.

4.2.5 The energy required for manufacturing

Energy is always a concern in the production process. The same package outcome can have varying amount of energy required. This can be due to difference in machinery, the difference in production planning and other factors. A process which uses more energy would have a higher impact on the environment as compared to a process that uses laser energy.

4.2.6 Energy source for manufacturing

The manufacturing process may have energy being used getting generated from different sources. The sources of energy could be, thermal, solar, atomic, hydro, etc. The energy sources should be ranked for their impact on the environment and taken on the account. For example, if the process involved more of renewable sources of energy, the process is bound to have a lesser impact on the environment.

4.2.7 Percentage of recycled material used

Manufacturing of product packaging can use a fresh material or a recycled material. The environmental impact would vary for the type of material used. For a package that uses a recycled material would have a lesser impact on the environment as compared to the packaging which uses only virgin material.

4.2.8 Distance between place of manufacture and place of usage

Every product packaging needs to travel from the place of its manufacture to the users who could use them. This movement of product packaging may be within local boundaries, within a nation or at global level. The product packages that travel more are likely to have a more adverse impact on the environment as compared to the product packages that travels less. The production has to take a note of the kind of travel the packaging had to undergo and therefore becomes important for taking the parameter in an account at the time of production.

4.2.9 Energy source of distribution

In line of the parameter 4.2.8. For the product packages that move from one place to another. The source of energy engaged in movement can also play an important role. The sources of energy could be, thermal, solar, atomic, hydro, etc. These can probably be ranked based on their impact on the environment. A renewable energy source can surely be more environment friendly and have a lesser impact on the environment.

4.3 Usage

The usage of product packaging is the phase for which the package is designed for. This phase is very critical as there is very less of control over the package in the way it would be used. A set of parameters has to be taken into account which govern this phase. These are mentioned as under.

4.3.1 Pollutants released during usage

For any product packaging, If there are pollutants being released during its usage, it would have a contribution towards its environmental Impact. Pollutants can vary for the medium they pollute, like: air, water, land. They can vary in the severity of pollution and duration of impact. This can be categorized as less or more harmful, having short term or long term impact.

4.3.2 The energy required to operate/ use

Many product packaging accounts for energy consumption during usage. The energy involved in usage may be direct of form the system wherein the package is being used. The requirement of energy in usage of product packaging, would account for the environmental impact.

4.3.3 Energy source for use

In line with parameter 4.2.9, For the energy being accounted for, in the usage of the packaging, The source of energy would also be important. The sources of energy could be, thermal, solar, atomic, hydro, etc. This can probably be ranked for based on their impact on the environment.

4.3.4 Average life of product packaging

Every product packaging would have a life before it stops delivering the intended result or starts deteriorating. If the average life of the product is closer to the final time duration for which the package is designed for, the packaging can be considered as having a lesser impact on the environment. As it meets the end need and has lesser chances of non delivery.

4.3.5 Mean time between failure.

During the usage, it is quite possible that the product package fails or gets damaged. For the package that has failed has not accounted for the job it was intended for and therefore would have an adverse impact on the environment. Measuring the mean time between failures would give an understanding for its replacement and further impact on the environment.

4.4 End Of Life

End of life is the last stage of the product life cycle. This closes the loop of the product package Lifecycle, therefore, would attribute the end result of the packaging, accounting for parameters which can directly be related to environmental nuisance of a product package. This stage would deal with issues like disassembly, recycle, reuse, etc. following would be the parameters of environmental impact assessment in this stage.

4.4.1 Time If done manually

The disassembly of a product package is an unavoidable phase. Every package has to be disassembled before the use of the inside product. Measuring the time required for disassembly of a package manually could evaluate the manual effort required for using the product packaging. A package which involves lesser time would have the lesser manual energy required and could therefore be more environmentally friendly.

4.4.2 Percentage of material recoverable

When the package is discarded and the inside product put to use, The amount of material recovered from a product packaging would be in percentage of the original package. This recovered material could further be reused or recycled. A package which has maximum of material available for reuse or recycle would have benefits for the environment.

4.4.3 The energy required for recovering the materials

After the product package is out of use and the materials being recovered. The recovery process would involve energy for the percentage of material available for reuse or recycle. The amount of energy used for recovery of material is therefore an important parameter and has to be measured.

4.4.4 Energy source of disassembly

In line with parameter 4.2.9 and 4.3.3, for the energy being used in disassembly, Accounting for the source of energy would also be important. The sources of energy could be, thermal, solar, atomic, hydro, etc. This can probably be ranked for different energy sources based on their impact on the environment.

4.4.5 Percentage of materials recyclable

In the process of recycling, some of the portion of the package may get left out. Therefore the complete package is very rarely recycled. The environmental impact of a packaging would depend on the percentage of material that can be recycled. As a general case, more is the percentage of material available for recycling, lesser would be the impact on the environment.

4.4.6 The energy required for recyclability

The process of recycling of package would involve usage of energy. Accounting for the energy required for recycling is therefore important for environmental impact assessment of product packaging. Lesser the energy required for recyclability, lesser would be the impact on the environment.

4.4.7 Energy source for recycling

In line with parameter 4.2.9 and 4.3.3 and 4.4.4. For the energy being used in recycling, concern for the source of energy would also be important. The sources of energy could be, thermal, solar, atomic, hydro, etc. This can probably be ranked for different energy sources based on their impact on the environment. Energy source being renewable would have a good effect on the environment as compared to energy source being non renewable.

4.4.8 Residual Life

Many a times, the packaging material is not sent for recycling and rather has an afterlife or reuse in its present structure to satisfy some alternate need. The reuse of the material can be measured by the residual life of parts of the product packaging. There can also be a case of reuse of complete packaging. Measuring the residual life can affect the environmental impact assessment, and is therefore is a necessity.

4.4.9 Percentage of material to be able to use

For the parts of product packaging being reused. The percentage of reusable material can be measured for its environmental impact. More the material available for reuse, lesser would be the impact on the environment. Measuring the percentage of material to be able to reuse therefore becomes important.

4.4.10 Reassembly

In certain conditions of reuse, some of the components of the packaging can be used to be fitted in an existing package, to give an entire new package itself. Such reuse of these package involves some reassembly as well. Reassembly can also affect the environmental impact of the product packaging and therefore needs attention.

5. Conclusion

The research is intended to arrive at an exhaustive list of parameters which would help in environmental impact assessment of product packaging. This has been achieved in varied phases. First of all a list was prepared as an outcome of brainstorming within a group of experts. This list was further populated in comparison with the available tools and techniques for environmental impact

assessment of product packaging. It was of utmost concern that the list should be exhaustive in nature and none of the issues as related to product packaging be missed out. The final outcome came as a list of 27 parameters taking into concern all the issues which could influence the environmental impact assessment of product packaging. As a further course of study, the authors are interested in finding out the weights of the listed 27 parameters in line with their impact on the environment. These identified parameters along with their weights would support in arriving at a method for environmental impact assessment of product packaging.

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