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A Modular Framework for Green Product Design

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Abstract: A modular framework for green product design has been presented in this paper. Contemporary industry is beginning to realize the negative impact that they have on the environment in terms of greenhouse gas emissions, destruction of natural habitats, hazardous waste emissions, etc. It is imperative that products be designed in such a way as to enable effective disposal at the end of their useful lives. However, this cannot be done at the expense of product functionality. Thus, environment friendly product disposal is an additional 'X' that must be incorporated into the DfX algorithm in order to address the pressing need of sustainable product development.

This paper presents the framework of just such an approach. The approach incorporates interactive design modules that prompt the designer to select and choose from a variety of design alternatives in order to enable sustainable product design. The three end of life options (recycle, reuse and remanufacture) are also included in the framework so as to provide a range of functional and economic categorizations. Thus, it would result in an entire suite of product designs that have similar end goals, but are quite different in terms of material selection, functionality, product architecture, product disposal options etc.

Keywords: end of life options, green design, modular product design

1. Introduction

Widespread diffusion of consumer goods and shortening of product lifecycles has led to an unprecedented number of used products being discarded. For example, every family in the USA is expected to own a computer by 2005. In 1991, Carnegie Mellon University estimated that by this time, some 150 million obsolete PCs, *none with readily recoverable materials*, will require more than 8 million cubic meters of land fill space at a cost of around US$400 million (Lee *et al*, 2001). However, the number of potential landfill sites for non-hazardous solid wastes has seen an exponential decrease. In the United States alone, landfill sites have diminished from18, 000 in 1985 to 9,000 in 1989. According to a recent study, the United states had lost more than 70% of its landfill sites by 1997 (Zhang *et al*, 1997) with landfills in many states reaching their permitted capacities at an alarming rate.

End-of-life products contain extensive amounts of reusable material which is too expensive to dispose of, retrieval of which would be beneficial to the manufacturer as well as the environment. The gravity of the situation has prompted increasing governmental pressure on manufacturers in the form of various environmental legislations which have been drafted to obligate industry to continue assuming responsibility for their products even after their useful life. Products will be expected to derive minimal energy and resources from the environment and *discharge minimal amount of wastes during and after their life cycles*. For example, the German policy on combating waste from end of life vehicles requires car manufacturers to take back end of life vehicles free of charge from the last owner in order to enable material recycling. Unrecyclable material is required to be disposed of without causing any harm to the environment or to human health (Choi Athelstan, 1994). In order to minimize environmental impact of mass produced consumer products, it is essential to design products from that perspective.

This paper presents a framework to enable green product design. By definition, a green product is one which puts minimal stress on nature resources (the environment). The framework utilizes a modular design approach. This approach was chosen to enable flexibility in accommodating several design objectives, some of which may be mutually conflicting in nature.

2. Method

2.1 Design

A 'green product' design necessarily needs to take into account the following factors:

- Functionality: A product that is unable to perform its intended function is bound to fail no matter how environmentally friendly it may be. Thus, functionality is the overarching requirement of any product design.

- Consideration of End of life (EOL) options: From the perspective of green product design, consideration of EOL options is of paramount importance. There are five main EOL options: Repair, refurbishing, remanufacturing, cannibalization and recycling. Table 1 presents the main differences between each of these options. Environmental concerns in designing for the environment are depicted in figure 1. Design for Environment includes different product development activities, such as appropriate material selection, usability analysis for environmental friendliness, designing for energy efficiency, adoption of environmental friendly manufacturing methods, designing for end-of-life, improvement in packaging, and removal of toxic materials during manufacturing purposes. The design for environment module categorizes the end–of–life objectives of a product into 6 different categories and lists the factors that affect the design process with environmental considerations in mind. Table 2 depicts the modular incorporation with respect to a specific EOL strategy.

- Consideration of effort requirements to take apart and reassemble a product (Disassembly, reassembly and maintenance): This is important from the point of view of disassembly (in order to repair and /or dispose of an EOL product) and reassembly (in order to maintain a product that had suffered a breakdown).Tables 3 and 4 depict that maintenance procedures and related design attributes essential to successful product development in those particular categories. The structure of the maintenance module is depicted in figure 2.

  Each of the aforementioned factors will be incorporated in to the green design module which will then interact with the user through an interface. The structure will enable the user to design the final product based on specific environmental constraints and design objectives.

Table 1: End of Life (EOL) Options related to product disposal

Options	Objective	Level of Disassembly	Result
Repair	Restore working Condition	Product level (Limited Disassembly and fixing).	Some parts repaired.
Refurbishing	Improve Quality level (though not like new)	Module Level (Some Technological upgrading).	Some Modules repaired /replaced.
Remanufacturing	Restore Quality level as new	Part level.	Used and new parts in new products.
Cannibalization	Limited recovery	Selective disassembly and inspection of potentially reusable parts	Parts reused and /or recycled/disposed of
Recycling	Reuse materials only.	Material Level.	Materials used in new products.

Table 2: Design considerations with respect to EOL strategies in Green product design.

EOL Strategy	**Modular Incorporation**
Reuse	Maintainability, Assembly / Disassembly
Service	Maintainability , Assembly/ Disassembly, Functionality, Usability
Remanufacture	Disassembly, Materials
Recycling with Disassembly	Disassembly, Materials
Recycling without Disassembly	Materials
Disposal	Materials

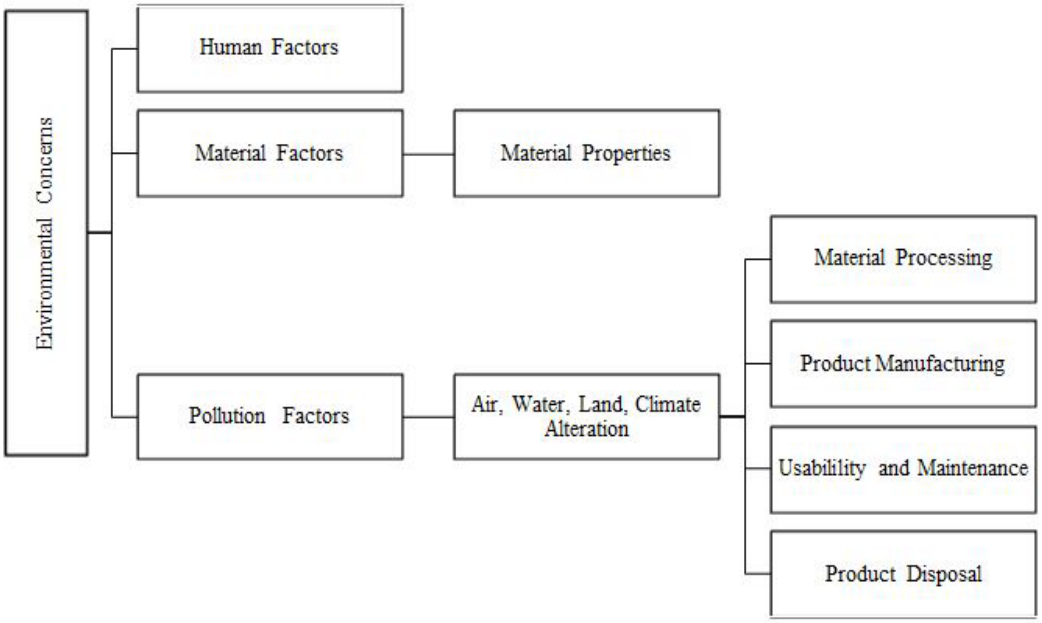

Figure 1: Environmental concerns in designing for the environment.

Table 3: Maintenance procedures and design factors affecting them

Process	**Factors**
Cleaning	Material Properties, Human Factors
Lubrication	Friction, Surface Roughness, Interference, Motion
Machining	Surface Roughness, Weight, Material Properties, Geometry
Replacement	Tool Factors, Human Factors

Table 4: Design attributes affecting ease of pre-maintenance procedures

Design Attribute	**Design Functions**	**Sub factors**
Preparation/Cleansing	Mechanical Cleaning Machine Cleaning Liquid Cleaning	Material Property, Hazards
Disassembly	Factors from disassembly module	

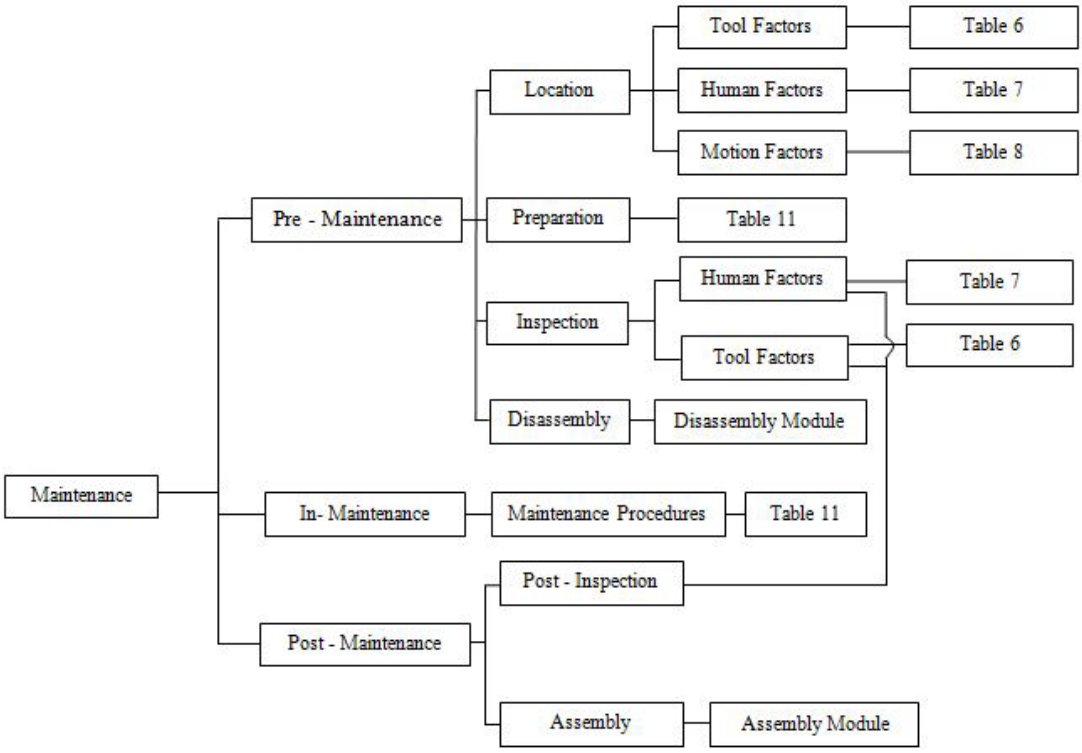

Figure 2: Structure of the maintenance module

The modular structure will be a part of a system will operate as an extension to an existing CAD package. This will enable part of the information can be extracted directly from the CAD model. The system interacts with the designer through an interactive questionnaire to obtain this information. An example of the questionnaire is depicted in table 5.

Table 5: Interactive questionnaire used by the 'green design' module to interact with the user.

Interactive Questions/Directions for using Intelligent Systems	System Direction
Do you wish to modify product design to enhance environment friendliness	Y/N
Please specify the component you wish to modify	1/2/3/4/5/6
Please specify the Nature of the component	Direct to component classification list
Please specify the EOL attributes of the component	Direct to EOL attribute list
Please specify the Material requirements of the component	Direct to material property list
Please specify the Force-Motion attributes of the component	Direct to force-motion attribute list
Please specify the Disassembly attributes of the component	Direct to disassembly attribute list
Please specify the assembly attributes of the component	Direct to assembly attribute list

The module will be an interactive functioning unit with the capacity to store information based on the designer's CAD model and designer interaction, use them as a data handle to correlate design rules and recommendations from a central database, and suggest design modifications and improvements to the designer.

3. Conclusion

This paper presented a brief overview of the structure of a 'green product design' strategy based on modular product design. The contents of the modules were discussed and the mode of interaction with the user was also elucidated. This is in

addition to the basic functionality module which is fundamental to any interactive product design system. The interactive nature of the modules facilitates creation of multiple designs that can then be optimized based on other parameters such as assembly, cost, quality etc.

4. References

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