

Research Paper

Product Design Process in the Context of Sustainable Development: An Approach to Waste Reduction

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Abstract

In this study, the importance of decisions of industrial designers in the primary stage of the design of products in terms of reducing environmental impacts was evaluated. In this descriptive research, the relationship between designers' awareness and design quality in terms of waste reduction considerations was assessed. Then, 56 industrial designers as the research participants filled out the questionnaires. The collected data were analyzed by SPSSWin 23. Statistical analysis of the results based on the Spearman rank test showed that there was a significant relationship between choosing a sustainable approach to design and reducing product waste after its life cycle. Moreover, the level of responsibility of industrial designers for the environment is effective in reducing product waste. Questionnaire analysis showed that designers who cared about the fate of their designed products after the end of the life cycle frequently used sustainable approach. The results showed that designers who took a sustainable approach to design and cared about the fate of the products after the end of their life cycle designed products in such a way that they could be reused. There was also a significant relationship between the choice of a sustainable approach by designers and the use of recycled materials in new products. It seems that more awareness should be raised and further studies should be conducted to improve benefiting of designers' sustainable approaches as well as to raise their awareness about the necessity of observing the sustainable development objectives.

Keywords: Environment, Industrial design, Recycling, Sustainable development, Waste reduction.

1. INTRODUCTION

The environment is negatively affected due to the growing population, the expanding urbanization, and the consequences of consumerism. Thus, a comprehensive collaboration of planners and experts of urban management organizations is required to cope with this group of negative impacts. Furthermore, urbanization and its development aspects involve more energy consumption, environmental pollution, and some paradoxes in terms of human lifestyle and the environment (Yu et al.,

2020). Undoubtedly, the evolution of social and economic conditions is related to the green infrastructural characteristics of societies (Amado et al., 2020). Certainly, different sciences and specialties should help promote the human quality of life based on the concept of sustainability. One of these sciences is industrial design with the goal of catering to the customers' needs, as well as development and productivity requirements. In this regard, industrial designers should commit themselves to apply environmental considerations. Note that in recent years the issue of taking responsibility for the

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future generation to protect the environment, which is the legacy of ancestors and heritage to the posterity, has attracted a great deal of attention, and great attempts have been made in this regard. Designers can play an effective role in this area.

There are various models at a designer's disposal which can be used to realize the environmental objectives. In 1992, the first United Nations conference on environment and development (UNCED), or the Earth's conference was held in Rio de Janeiro. This is the event where the first agenda for environment and development known as Agenda 21 was recognized, composed, and approved. In September 2015, 193 countries of the UN General Assembly approved agenda 2030 entitled "transformation in our world: 2030 sustainable development plan", with 92 paragraphs. Article 59 explains 17 sustainable development goals, and 169 related objectives plus 232 associated indices (URL1), (Sutherland et al., 2016). Sustainable development has been targeted in different areas, among which goal 12 in sustainable development known as "responsible consumption and production" has the use of environmentally friendly methods and the reduction of waste in its agenda. This goal is related to sustainable products, which are very important. A sustainable product should have six characteristics: Customer satisfaction, Dual focus, Lifecycle orientation, Considerable progress, Constant improvement, and Competitive proposals (Belz & Peattie, 2009). Paying attention to environmental rules and regulations for the consequences of discharging urban waste into the environment, especially in developing countries that are facing technological constraints and the inefficiency of experts, would lead to proper waste management and would mitigate adverse environmental impacts. Although design requires a free mind in terms of creativity and mental expression freedom, such freedom should not cause negligence of environmental protection requirements. This is because a designer should design according to social responsibility and ethics. They should also act smartly when selecting materials for their design, and use green and recyclable materials as much as possible (Qingli, 2019). Brongart and Macdonoch (2010), in the lifecycle section of their book called "Cradle-to-Cradle Design", suggest that when preparing any material and product, at the end of the lifecycle, its pieces should be separable, whereby its components should be recycled to the earth after composting or recycled as raw materials. By presenting models related to systems of production that are based on the industrial design concept, new environmentally friendly products can be developed (Masuda, 2001).

The newly emerging designs with environmentally friendly characteristics indicate that consumers accept using environmentally friendly products (Hong et al., 2019). One of the important phases for producing products that cause fewer problems in recycling is that at different stages of design, performance assessment of the product recycling processes should be carefully observed. It helps the proper selection of materials as well as the economic cycle of the product and its development (Grimaud et al., 2017). In an applied and creative project performed innovatively at the faculty of industrial design of fine arts of Partov University, a type of furniture was designed with the help of remnants of wood powder and fabrics of one of the furniture industries, and it was introduced as a piece of environmentally friendly furniture (Costa et al., 2017). Designers have a prominent role in product design, and in some cases, 80% of the environmental impact might be decreased (Karell & Niinimäki, 2020). In addition, low-impact material usage is known as another environment-friendly approach for designers (Sauerwein et al., 2020). Furthermore, the Green design concept is an effective approach to the 2030 sustainable development goals (Chen et al., 2020). The interactive relationship between industrial design and green production decreases the required resources in the design process, which is beneficial for mankind in the long run (Li & Liu, 2016). Increasing the design complexity of different products (e.g., vehicles and various connections) leads to increased impurities as well as the waste of materials in the recycling process of obsolete tools (Soo et al., 2018). Nevertheless, various models have been presented for the products' environmentally oriented design and the reduction of the relevant impacts (Tian et al., 2019). As there is a firm association between industrial designers and employers, making a synergetic approach between industrial designers and industrial sectors' authorities will result in useful outcomes under sustainability umbrella. Of course, there are some available methods (e.g., sustainable design methods and tools (SDMTs)) to help employers to define the related plans (Faludi et al., 2020). Designing products that are presented based on industrial design principles caters to this issue. The aim of this research study is to investigate the role of industrial designers in reducing the waste level and, in turn, lowering environmental risks.

1.1. Industrial Design, Sustainable Design

According to IDSA, "Industrial Design (ID) is the professional practice of designing products, devices, objects, and services used by millions of people around the world every day. Industrial designers typically focus

on the physical appearance, functionality, and manufacturability of a product, though they are often involved in far more during a development cycle. All of this ultimately extends to the overall lasting value and experience a product or service provides for end-users". Industrial design is a strategic process to solve this problem which contributes to innovation and success in business. Furthermore, products, systems, services, and innovative experiences leads to improved life quality (International Council of Societies of industrial design (ICSID).

Sustainable design is the philosophy of designing physical objects as well as creating environment and services in such a way that it would be compatible with ecological sustainability rules, in which the goal of sustainable design is "to completely eliminate adverse environmental impacts through smart and precise design" (McLennan, 2004). Sustainable design is a general reaction to global environmental crises, the rapid development of economic activities and human population, diminishing natural resources, damages to ecosystems, and the loss of biodiversity (Shu-Yang et al., 2004). According to sustainable design issues, life cycle assessment should be considered. LCA is a method for assessing environmental impacts associated with all lifecycle stages of a commercial product, process, or service. For example, with regard to a product, it includes the extraction and the processing of raw materials (cradle), distribution, use, and recycling or final disposal of its constituent materials (grave) (Ilgin & Gupta, 2010).

1.2. Waste Types and Management

Waste or garbage is unwanted or unusable materials. Garbage is indeed any material, which is thrown away after the initial consumption. Wastes are categorized into five groups of Typical, Medical (hospital), Special, Agricultural, and Industrial wastes. Waste management is a process that includes

critical issues such as life cycle assessment, cost-benefit evaluation, and decision making (Kyriakopoulos et al., 2019). The waste management system contains a whole set of proceedings related to managing, treating, disposing, or recycling waste materials (Demirbas, 2011). These activities include collecting, transferring, and disposing of waste as well as supervising the implementation of the rules related to waste management. The main purpose of waste management is to reduce the harmful effects of waste on human health, the environment, and aesthetics. A major part of waste management is related to managing the urban solid wastes that are indeed the wastes produced by houses, industries, and commercial activities (Cheremisinoff, 2003). Furthermore, there are firm associations between waste reduction policies and economics, social, and industrial-based sustainability (Kyriakopoulos et al., 2019). Note that before the design, designers should pay attention to all lifecycle stages of a product (i.e., from the production, transportation, distribution, usage, and termination of the product lifetime to the recycling stage of pieces or reuse of product in another form). An industrial designer can take huge steps in realizing a healthier life and changing the path of life for environmental protection based on the decisions he makes (e.g., creative or innovative decisions or decisions in line with environmental requirements) during the design stage. This is because increasing waste means increasing the risk of human environment loss.

Waste management hierarchy (Fig. 1) is based on the three principles of reduction, reuse, and recycling, classifies the strategies of waste management based on the possibility of minimizing waste production. The waste hierarchy is the cornerstone of most strategies for minimizing waste production. The goal of the wastes hierarchy is to maximize the practical benefits of products and hence produce minimum waste (Albert, 2017).

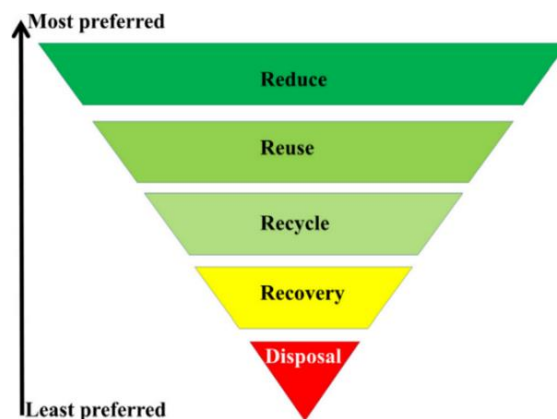


Fig 1. Waste Management Hierarchy (Shumal, M., et.al, 2020)

1.3. Recycling

Recycling is the main element of reducing modern waste, and it is the third component of the waste hierarchy (i.e., reduce, reuse, and recycle) (Lienig & Bruemmer, 2017). Hence, recycling leads to environmental sustainability with the aim of substituting the input raw materials and guiding the waste output from the economic system (Geissdoerfer et al., 2017).

2. MATERIALS AND METHODS

In this cross-sectional study, 56 industrial designers of the Faculty of Architecture, Iran University of Science and Technology (IUST) filled out the online questionnaires. A combination of systematic random sample (based on education affaire information) and voluntary sampling method was used, and the data were analyzed by SPSSWin 23. Compiling the filled-out questionnaires took about two weeks in September 2020. In this study, to figure out the recent research works around the world, the Scopus search engine was chosen and assessed by VosViewer.

3. RESULTS

Statistical analysis of the results based on the Spearman rank test showed that there was a significant

relationship between choosing a sustainable approach to design and reducing product waste after its life cycle. Moreover, the level of responsibility of industrial designers for the environment is effective in reducing product waste. Questionnaire analysis showed that designers who cared about the fate of their designed products after the end of the life cycle frequently used a sustainable approach. The results showed that designers who took a sustainable approach to design and cared about the fate of the products after the end of their life cycle designed products in such a way that they could be reused. There was also a significant relationship between the choice of sustainable approach by designers and the use of recycled materials in new products.

Bibliography in VOS viewer and Scopus search engine shows about 1493 related papers (2015-2021) based on two keywords of “product design” and “sustainable development” (Fig 2). Furthermore, 971 papers were found based on two other keywords of “recycling”, and “ waste reduction” in published research works in 1972-2021, which most of them were reported in 2019 (Fig. 3)

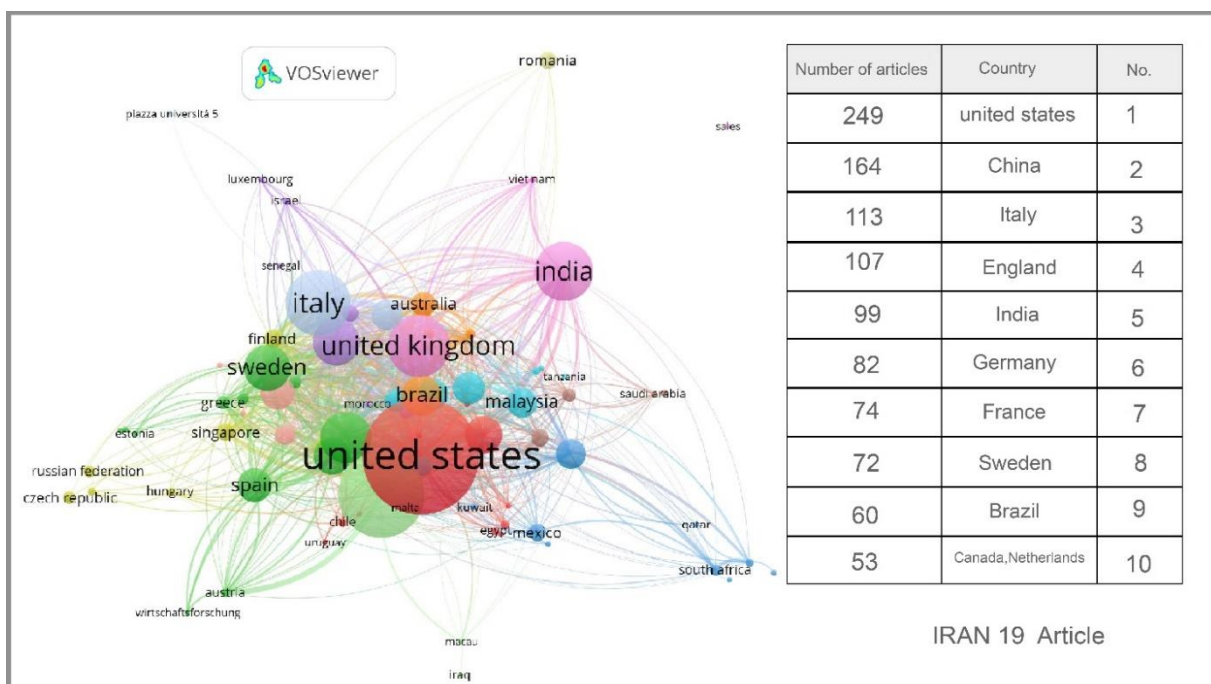


Fig 2. Vosviewer Results

Beyond the above-mentioned findings, some sorts of products were assessed in terms of waste management and the related factors which were

considered by the designer in order to reduce waste (Table 1).

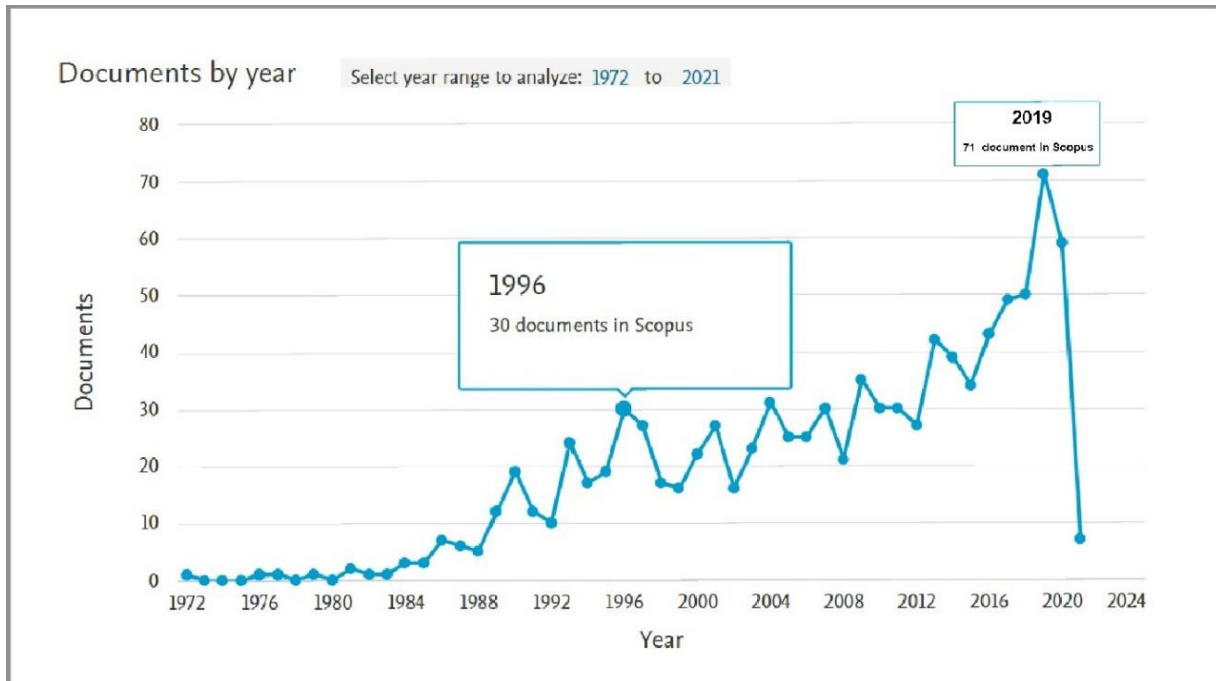









Fig 3. Distribution of Paper Numbers including Keywords of “Recycling”, and “ Waste Reduction”

Table 1 (A). Product Introduction

Product number	description	Example
1	<p>A. Ability to be updated, additional technologies or components to older products</p> <p>B. Ability to make successive repairs</p> <p>Not being repairable means being discarded early and consequently increasing the volume of garbage and waste.</p> <p>C. Use of durable materials</p>	 <p>Source: (Escursell et al., 2021).</p> <p>In Finland, Repack is a reusable packaging bag made of a durable, recyclable and lightweight polymer that has a reasonable cost-saving effect, and Repack suggests that customers should have empty bags. Deliver them through the post office to be reused (Escursell et al., 2021).</p>
2	Reuse disposable products in the new application	 <p>Source:(URL2)</p>

Product number	description	Example
3	<p>Many luxury brands have produced good products by adopting a design strategy for sustainability. For example, a perfume company has designed perfume bottles, which after using its content; customers fill the perfume bottles directly in the retail store. This innovation has saved 2.3 million bottles and boxes each year (Aguirre, 2020).</p>	 <p>A. Package of toilet liquid that is discarded after consumption. B. Refillable packaging many times</p> <p>Source: Authors</p>
4	<p>For product design, if the complexity of the form is not related to the function of the product and has only an aesthetic aspect, it is unnecessary and means using more materials and thus increasing more waste after the end of using the product. functionality doesn't need more complexity. Using materials more than the essential needs to make more waste.</p>	 <p>Source: Universal Principal of Design (Lidwell et al., 2010). TABURET M seat is strong and comfortable, a simple piece of molded wood with no external matter and unnecessary complexity (Lidwell et al., 2010).</p>
5	<p>The designer should aware of the types of connections and use them intelligently for product design can lead to easy separation of parts in a discarded and unusable product and reduce the time remaining in the recycling cycle and separation of various materials, resulting in removing the parts quickly from the waste and returning to the production cycle.</p>	 <p>Source: Authors</p>
6	<p>Less variety of materials and colors leads to ease of recycling</p>	 <p>Source: (URL3)</p>
7	<p>A product should be designed in such a way that the separation of its parts at the recycling stage does not require a complicated process, leading to the rapid exit of the parts from the separation process and entering the next stage of recycling, thus reducing the waiting time for waste when separating.</p>	 <p>Source: Authors</p>

Product number	description	Example
8	<p>Circular economy To use recycled parts in product design not only is economic but also has less waste.</p>	 <p>Source: (URL4) For example, LEGO (2018) announced that it would use bio-derived polyethylene to make its plant elements (organs such as leaves, shrubs, and trees). (URL4)</p>
9	<p>Today, some developed countries use recycled materials to produce some products instead of using raw materials and even some of these countries import waste from other countries and after performing a series of recycling and re-processing stages, benefit the materials for production.</p>	 <p>Source: (URL5) An example of Ford Co. for series A fender is using PE water bottles.</p>
10	<p>Using special techniques and creativity, design can be moved to less use of materials in such a way that function of products is maintained. Also, larger a product, a larger pack, use of more materials, higher cost of transfer and higher use of fuel and energy. For example, IKEA Co. uses flat packs for ease of transfer and lower cost.</p>	 <p>Source: (URL6) An example is the YAMAHA Co. violin in which all additional parts are removed and only necessary parts related to the body of the performer are considered in its design by the designer with special elegance using minimal style (Lidwell et al., 2010).</p>
11	<p>Biodegradable plastic is produced using starch, cellulose, chitosan and protein extracted from reproducible environment friendly biomass. The process of production needs 65% less energy and produces less emission than conventional plastic (Singh & Verma, 2020).</p>	 <p>Source: (URL7)</p>




Product number	description	Example
12	The designer, considering the solution of several needs by one product, prevents the excessive use of materials to produce different products to meet different needs, and thus prevents the production of single-use products.	 <p>Source:(URL8) An example is a product with 3 functions of the chair, table and stool in one.</p>
13	If designers can design products that engage the user's emotions and thus create a deep sense of ownership, they are less likely to be replaced by newer products. Basically, product replacement is delayed with strong emotional bonds (Page, 2014). According to Jonathan Chapman of Carnegie Mellon University, USA, emotionally sustainable design reduces the consumption and waste of natural resources by increasing the resilience of consumer-product relationships (Chapman, 2009)	 <p>Source: (URL9)</p>
14	In order to produce less than one product, a designer can design solutions for group use of a product, thus preventing the production of products that are used on special occasions and / or rarely during a year, for personal use, and as a result, reducing the use of energy and raw materials. Using Product-Service System (PSS) and focusing on selling product performance instead of selling products, an integrated mix of products and services can be achieved, and this competitive service-based strategy leads to environmental sustainability (Salwin & Kraslawski, 2020).	 <p>Source:(URL10) Transportation services by participatory vehicles such as UBER</p>

Table 1(B). Solution

Product number	Solution
1	Enhance the life cycle of a product
2	Reusability for a new user at the end of a product life cycle
3	Design rechargeable packaging for consumer products to prevent early disposal
4	Reduce unnecessary complexity in product design
5	Minimize locks and fittings in the design
6	Limit the use of color and a great variety of materials to use good enough material and color
7	Design product parts for easy separation at the end of the product life
8	Selection of recyclable materials
9	Use recycled materials instead of using raw materials
10	Reduce weight and size of products
11	Bioplastics for packaging design
12	Multiple-use product Vs. single-use product
13	Emotional design
14	Service design

4. DISCUSSION

The concept of sustainable development (SD) that formed in Brundtland's report in the 1970s. It refers to a kind of development in which future generations are considered (Rafieian & Mirzakhali). Furthermore, different aspects of sustainability should be considered in environmental and product design and the related processes (Hessari et al., 2018). The design process includes a complex and problem-based approach in which users' demands should be met (Koleini Mamaghani & Barzin, 2015). In this regard, to boost the sustainable products, some sorts of creative design toward more social health and users' satisfaction should be considered, too (Mohammad Moradi et al., 2013).

Considering our findings, it seems that more awareness should be raised and further studies should be conducted so that designers benefit from sustainable development and enhance their awareness about the necessity of observing sustainable development goals. Based on the results and the collected library data, it can be concluded that a major part of the industrial design-based methods consists of those through which designers can develop green products and would produce less waste. In their paper entitled "sustainable design: the sustainability of classic designs as a stimulus for reducing environmental impacts", JCMoor and Frankearti (2015) investigated the consequences of the premature disposal of products. They presented some solutions to enhance the lifecycle of products and, hence, reduce consumption. The stimulus of this research study was the products known as classic designs which would result in the formation of a strategy for designing products with a relatively longer useful life to reduce adverse environmental impacts (Martins, 2015). Prolonging the lifecycle of a product through upgradability, repair ability, and the use of resistant materials can lead to better products. For example, Ireland managed to significantly reduce the use of plastic bags by imposing some commission fees for using such bags. This led to the prevalence of using an attractive alternative known as "I am not plastic", which is a fabric bag, which was intelligently designed by a British designer, Hindmarch, in 2007. In addition, if designers consider another use for their product through a prospective approach in the smart design stage so that the user would not throw that product away, they can take effective steps for reducing waste. Today, the packaging is one of the important and even indispensable parts of many consumer products. Designing rechargeable packages to prevent early disposal of the package is another method that would help reduce waste. Undoubtedly, reducing inessential

complexities in the design of the products can offer more benefits in addition to the mentioned points. Thus, designers should design the products in a simpler and more practical way as much as possible so that fewer materials would be used for their production. The higher the diversity of materials used in the design of a product is, the harder the recycling will be. Even sometimes because of the high cost of separating this material and different colors, their recycling process would not be economical. Thus, by considering these points in the design, designers can pave the way to facilitate the recycling of their products. Note that one of the most important points which any designer should be familiar with and have comprehensive information about is understanding the characteristics and properties of different materials and new technologies regarding the use of newly emerging Eco-friendly materials. This is because the selection of the type of consumer materials in the fabrication of products directly affects the degree of recycling of those materials after the lifecycle. Based on the results of this study, it can be stated that the impact of selecting a sustainable approach to reducing waste is much higher than the effect of other approaches. Furthermore, based on the frequency table of design approaches in a conducted research study, only 15% of the theses defended at Tehran universities between 2006 and 2013 were conducted within the framework of the sustainable design approach. According to (Sadeghi Naeini, et.al, 2015), there were some different design approaches among final theses of master's students among universities in Tehran between 2006-2013, which indicated that the highest frequencies of the approaches were devoted to cultural design (in 2009 and 2010), comprehensive design (in 2007), ergonomic design (in 2006), sustainable design (in 2012), user-centered design (in 2008), emotional design (in 2008, 2010, and 2011), global design (in 2009 and 2012), behavioral design (in 2012), interactive design (in 2012), user experience-based design (in 2012), health design (in 2008), historical design (in 2006), service design (in 2009, 2006, and 2011), social design (in 2008 and 2013), environmental design (in 2008), and collaborative design (in 2012 and 2013). Considering the results of studies in the mentioned period of time, most of the approaches emphasized cultural, sustainable, service, and environmental designs, respectively.

5. CONCLUSIONS

Today, industrial designers will need pioneering designs in line with technology since this field has a special status considering its wide scope in different

areas and its ability to influence human life improvement. Designers as the first individuals who determine the final destiny of a product at the end of its lifecycle are responsible. Indeed, they are responsible for the consequences of negligence in the primary stages of the product design, either in the selection of materials, connections, or color. Undoubtedly, the application of strategies such as engineering substitution, elimination, and measure can result in suitable outcomes. This research indicated that there is a direct relationship between the awareness of designers about environmental requirements and waste reduction; by selecting proper methods and approaches such as sustainable development, designers can play a significant role in reducing the environmental contamination. To achieve this aim, the application of efficient methodologies and approaches such as service design is important. In fact, service design guides service development processes in an effective way and with minimum energy usage. Combining this group of design approaches with environment-based principles and attitudes focusing on waste management would lead to effective outcomes. Accordingly, it is suggested that those who are interested in environmental protection, conduct further studies to investigate novel approaches in environmental and product design. Undoubtedly, industrial sectors should define some new approaches and make some related changes in their strategies toward sustainability. Here are some examples based on the problems in our country:

- Using envelopes designed with recycled materials to carry products purchased in department stores instead of using plastics.
- Designing cosmetic boxes with biodegradable materials instead of plastic.
- Designing urban furniture with durable materials for long-term use with the least possible damage caused by sabotage in urban environments.
- Designing children's toys from biodegradable materials.
- Designing a variety of consumables such as health products with the ability to refill.

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