From an Ecodesign Guide to a Sustainable Design Guide: Complementing Social Aspects of Sustainable Product Design Guidelines

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Abstract

Background Designers influence the environment and society because they influence the way most products are made, used, and discarded. Sustainable design guidelines are usually the first and handy method that designers can easily consult and apply to their projects even at an individual level for specific ways of achieving more sustainable design results. Environmental design philosophies have evolved from green design to ecodesign and now to sustainable design. Environmental design's scope of interest has also been expanded from just the environment to the economy and then to society in general. However, I found most current guidelines actually lack social aspects in their strategy list. So, this study aims to suggest a new sustainable design guideline that complements social aspects.

Methods I examined 16 sustainable design approaches for this study and selected four sustainable design guidelines optimized for the industrial design field. Then I reviewed the features of each guideline and conducted a comparison analysis at the specific strategy item level. I identified the guidelines' strengths and weaknesses through the analysis and discovered that most guidelines do not properly cover the social aspects of sustainable design and actually function as ecodesign guides. So I conducted further study on social aspects using three relevant books and extracted topics to suggest a new sustainable design guideline that properly covers social aspects.

Results The new guide evolved from an ecodesign guide to a sustainable design guide by incorporating social design aspects. I also tried to integrate the strengths because I found that each of the four guides has its own strong points. Through the comparative analysis, I extracted commonly suggested, high-priority strategy items. I also tried to minimize the number of items by combining similar or redundant items to keep this integrated guide as essential as possible. Finally, I updated the explanations and examples for each strategy item that were obscure or outdated.

Conclusions Sustainable development is an ongoing unresolved issue requiring long and tortuous efforts by people from all walks of life and the design field is no exception. The role of sustainable design guidelines is crucial but I found that all of the reviewed guides leave room for improvement, especially regarding social aspects. So I tried to craft a better sustainable design guide by taking issues from three renowned social design books so that the revised new guideline can be consulted for thorough sustainable design issues. I hope this study's result will be a convenient guide and an easy introduction to sustainable design for people seeking specific ways to make products more sustainable.

Keywords Sustainable Design, Ecodesign, Green Design, Product Design, Design Guideline, Design Strategy, Social Design

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1. Background of the Study

Ecology, economy, and equity (3E) have been three main issues in sustainable development since the United Nations introduced the Brundtland Report in 1987, and John Elkington suggested the Triple Bottom Line (TBL) in 1994, which considers economic, environmental, and social aspects as three axes of sustainable business activity (Edwards, 2005). Sustainable design inherited this tradition and considers ecological, economic, and social issues as its main topics (B. Y. Kim & Kim, 2010). As a result, sustainable design has become a comprehensive subject that actually covers a large part of contemporary design issues that our generation's designers confront. Industrial designers influence the environment because they suggest the way products are made, used, and discarded. They significantly affect the decisions for selecting materials, production methods, finishes, and packaging methods for most products people use (Cho, 2000).

If designers don't think critically about their role in society, they are likely to serve only commercialism by encouraging endless excessive consumption through their ability to make products more attractive (Whiteley, 1997). If designers are aware of their influence on the environment and of diverse ways of making their design decisions more sustainable, they may be able to contribute to positive change. The role of sustainable design guidelines is important because design practitioners consult the guidelines for basic action strategies to achieve sustainable results for their projects. Design students also learn them as one criterion for their future works. In this study, I reviewed four sustainable design guidelines optimized for the industrial design field and conducted a comparative analysis. From this, I discovered that most guidelines do not properly cover the social aspects of sustainable design. So I conducted further research on social topics through three related books and extracted social items to suggest a new sustainable design guideline that properly covers social aspects.

2. Green Design, Ecodesign, and Sustainable Design

Sustainable design (or design for sustainability) is often confused with similar concepts such as ecodesign or green design, but each term has a different meaning when we take a closer look. "Environmental design philosophies have evolved from green design to ecodesign through to design for sustainability" (Bhamra & Lofthouse, 2007) over the years as "the design community's response to the emergent environmental and social pressures and broader sustainability trends" (Sherwin, 2004). As explained in Table 1, green design was the initial attempt to reduce environmental impacts with methods such as minimizing material or energy use, fostering reuse, and recycling. Its focus, however, was simply the environment. Green design evolved into ecodesign, which is more closely integrated with the overall design process considering practical issues. Ecodesign is a product development strategy aiming to design, produce, and sell environmentally and economically excellent products by considering environmental aspects along with other elements of competition such as cost and quality (Chun, 2009). However, sustainable design inherits the holistic approach of sustainable development, which has taken the position that environmental,

economic, and social issues cannot be dealt with separately since the UN World Commission on Environment and Development published the Brundtland Report (also known as Our Common Future) (Edwards, 2005). Sustainable design takes the same approach as ecodesign regarding environmental and economic issues, but also includes social issues such as equity and ethics.

Table 1 Differentiation of environmental design philosophies

Design Philosophy	Explanation	Related Issue*
Green Design	Focuses on single issues, for example the inclusion of recycled or recyclable plastic, or consideration of energy consumption.	Environment
Ecodesign	Environmental considerations are considered at each stage of the design process.	Economy Environment
Design for Sustainability	Design that considers the environmental and social impact of a product (for example usability, responsible use).	Society Economy Environment

* Related Issue column was added to the table from Bhamra, 2007, p.39

3. Sustainable Design Guidelines

3. 1. Criteria for Guideline Selection

There are numerous approaches for pursuing sustainability from tens of thousands of organizations in various fields and Edwards (2005) explained the decentralized leadership as one of five characteristics of the sustainability movement. He introduced 23 selected principles in his book, and four, including The Hannover Principles and The Sanborn Principles, are directly related to sustainable design. I reviewed 16 sustainable design approaches in total including the four principles from Edwards' book and discovered that those approaches can be classified into three categories. Table 2 lists all the reviewed approaches for this study by category and the terms such as principle, manifesto, guideline and strategy used in this study are derived from these reviewed approaches. The first category includes principles and manifestos that declare the fundamental behavioral criteria or philosophy of individuals or groups. In this category the statements are condensed and the document lengths are very short, usually just 1 or 2 pages. The second category includes guidelines and strategies that suggest lists of specific action items for implementing sustainable design results. Explanations and examples for each item tend to be included, so the document lengths range from several to scores of pages. The third category includes frameworks and processes that explain systematic procedural approaches for achieving sustainable design results, and usually those documents have larger volumes similar to book lengths.

Table 2 The list of sustainable design approaches reviewed for this study

Category	Approaches for Sustainable Design
Principles & Manifestos	The Hannover Principles (McDonough & Braungart, 1992, as cited in Edwards, 2005)
	The Five Principles of Ecological Design (Ryn & Cowan, 1995, as cited in Edwards, 2005)
	The Todds' Principles of Ecological Design (Todd & Todd, 1994, as cited in Edwards, 2005)
	The Sanborn Principles (Donald Aitken Associates, 1994, as cited in Edwards, 2005)
	The New Sustainable Design Manifesto (Greenwood, 2014)
	An Evolving Manifesto for Eco-Pluralistic Design (Fuad-Luke, 2009)
Guidelines & Strategies	Developmental research guideline for sustainable design (J. H. Lee, 2010)
	A Study on the Development of Guideline and Application for Sustainable Design (J. Kim, 2011)*
	A Study on Sustainable Product Design Method in Product Planning (K. A. Lee, 2006)
	The Designer' s Field Guide to Sustainable Design (lunar.com, 2016)*
	ESP Design Strategies (Greenwood, 2012)*
	Okala Ecodesign Strategy Wheel (White, St. Pierre, & Belletire, 2013)*
	Ecodesign Strategy Wheel (Brezet & Van Hemel, 1997)
	Eco-Design Strategies (Fuad-Luke, 2009)
Processes & Frameworks	Aligned for Sustainable Design (IDEO & BSR, 2008)
	Design for Sustainability: A step-by-step approach (UNEP & Delft University of Technology, 2009)
	Life Cycle Assessment: ISO 14040 (ISO, 2006)

* Four selected guidelines for this study

I selected four guidelines for the comparative analysis from all 16 reviewed approaches and used the following selection criteria. First, I tried to choose approaches optimized specifically for industrial design rather than the guides targeted at the engineering or architectural fields. Therefore, I excluded the nominees like The Hannover Principles and The Sanborn Principles because their contents actually concern architecture rather than industrial design. Second, I focused on the second category, guidelines and strategies, in this article because they are usually the first and most handy guides that designers and design students, who are aware of the environmental impacts of their practices and want to know specific ways to achieve more sustainable design results, can easily consult and apply to their projects even at an individual level. Sometimes guidelines and strategies are proposed as parts of bigger processes, but I regarded them as the second category in this article as long as their guidelines can be used separately. Also, I examined if the guide provides proper explanations and examples for detailed analysis. I have found the 16 sustainable design approaches mentioned above during my search of guidelines with these criteria and finally selected four guides that are considered to best match the criteria: The Designer's Field Guide To Sustainable Design by Lunar, ESP Design Strategies by Tom Greenwood, A Guideline for Sustainable Design by Ji-yeon Kim, and the Okala Ecodesign Strategy Wheel by the Okala Team.

3. 2. The Designer's Field Guide to Sustainable Design

One of the world-renowned design agencies, Lunar (founded in 1984), established its internal initiative, Elements, in 2008 "to enliven LUNAR's long-standing charter to use creativity to make a difference for our environment" (lunar.com, 2016). The Elements team introduced The Designer's Field Guide to Sustainable Design to help Lunar designers and engineers create more sustainable products, and also made it available to anyone on Lunar's website. The guide provides 15 strategy items categorized into four topics like "What is it trying to accomplish?", "How is it brought to life?", "How is it used?", and, "Where does it end up?" The

topics are basically arranged in the product life cycle order, spanning from product planning through manufacturing to use and finally, to disposal. It provides detailed explanations and examples for each strategy item. The item numbers in Lunar's guide are much fewer than the other three guidelines, and the simplicity makes this guide easier to access. However, the oversimplified item numbers are not sufficient enough to specify all important topics for sustainable product design. And another overlooked aspect in this guide is that it does not include the social aspect of sustainable design even though its title references sustainable design instead of ecodesign.

Table 3 The Designer's Field Guide to Sustainable Design by Lunar

Category	No.	Strategy Items
A. What is it trying to accomplish?	a1	Question the premise of the design
	a2	Make it less complex
	a3	Make it more useful
B. How is it brought to life?	b1	Reduce material variety
	b2	Avoid toxic or harmful materials and chemicals
	b3	Reduce size and weight
	b4	Optimize manufacturing processes
	b5	Design packaging in parallel with products
C. How is it used?	c1	Design for upgradeability
	c2	Create durable and high quality design
	c3	Design for life after death
D. Where does it end up?	d1	Make it modular
	d2	Use recycled, recyclable, renewable & biodegradable materials
	d3	Minimize fasteners
	d4	Don't use paint

3. 3. ESP Design Strategies

ESP Design Strategies are a set of action items for sustainable design suggested by Tom Greenwood, a British brand consultant with a sustainable product design and engineering background. He started an online review of sustainable design tools, methods, and principles called ESP Design in 2004 under the acronym of Environmentally Sustainable Product Design, and a year later changed the name to Entirely Sustainable Product Design to include broader sustainable design issues. The UK government awarded him the 2007 KTP Business Leader of Tomorrow Award for his commitment to sustainability. He is not currently running the ESP Design website any more since 2013, and the previous website, www.espdesign.org, is now accessible only through the Internet Archive service (Greenwood, 2012). Now he is running another site called Live Wholesome (livewholesome.co.uk), and sharing his thoughts on wholesome living, green technology, and plant-based food. He wrote a blog post titled "The New Sustainable Design Manifesto" on this site and explained why he stopped updating ESP Design. He concluded that "genuine sustainable product design is simply not possible when we are designing for a system that puts financial profit before all other factors, and for a culture that is addicted to ever increasing levels of consumption" (Greenwood, 2014). ESP Design Strategies consist of 44 action items marked with icons representing environmental, social, or financial sustainability. For example, the 29th item, "Reduce Transportation" is marked with three icons because it relates to all three issues. Also, all the strategy items are explained with relatively detailed expatiation in ESP Design Strategies, but it does not provide case examples for each item.

Table 4 ESP Design Strategies

No.	Strategy Items	Related Issue*	No.	Strategy Items	Related Issue*
1	Design the Business System First	Env. / Soc. / Fin.	23	Plan for Continual Improvement	Env. / Fin.
2	Clarify Core Functions	Env. / Soc. / Fin	24	Minimize Leaks	Env. / Soc. / Fin.
3	Select Responsible Suppliers	Env. / Soc. / Fin	25	Minimize Cycling Losses	Env. / Fin.
4	Product Service Systems	Env. / Soc. / Fin	26	Renewable Energy	Env. / Soc.
5	Multi-functionalism	Env.	27	Rechargeable Batteries	Env. / Soc.
6	Modularization	Env. / Soc.	28	Feedback Mechanisms	Env. / Soc. / Fin
7	Minimize Material Variety	Env. / Fin.	29	Reduce Transportation	Env. / Soc. / Fin
8	Weight Reduction	Env.	30	Simplification	Env. / Soc. / Fin
9	Recyclable Materials	Env.	31	Integrate Packaging Design	Env. / Fin.
10	Recycled Materials	Env.	32	Durability	Env. / Soc. / Fin.
11	Biodegradable Materials	Env.	33	Re-Usability	Env. / Fin.
12	Renewable Materials	Env.	34	Remanufacture	Env. / Fin.
13	Minimize Composites	Env. / Soc. / Fin	35	Design for Disassembly	Env.
14	Avoid Hazardous & Toxic Materials / Substances	Env. / Soc. / Fin	36	Maintenance	Env. / Soc. / Fin.
15	Low Embodied Energy Materials	Env. / Fin.	37	Reduce Consumables	Env. / Fin.
16	Minimize Material Contamination	Env.	38	Integrate Disposal Instructions	Env.
17	Identify / Label Materials	Env.	39	Use Waste Products	Env. / Fin.
18	Avoid Glass	Env.	40	Closed Life Cycle Design	Env. / Fin.
19	Look for Synergies	Env. / Soc. / Fin	41	Design Products to be Loveable	Env. / Soc. / Fin
20	Aim for Maximum Efficiency	Env.	42	Rewrite the Brief	Env. / Soc. / Fin
21	Design for Part Load Operation	Env.	43	Start with a Blank Sheet of Paper	Env. / Soc. / Fin
22	Efficient Processes	Env.	44	Change Consumer Behavior	Env. / Soc. / Fin

* Env. / Soc. / Fin. are the abbreviations for environmental, social and financial sustainability

3. 4. A Guideline for Sustainable Design

J. Kim extracted 60 action items for sustainable design from case analysis at the early stage of her study and verified the list through a survey targeting 25 designers and 25 consumers in her Master's thesis (J. Kim, 2011). Then she refined the list and reduced the number of items according to the survey result into 52 items to be used as sustainable design guidelines or a checklist for evaluating sustainable products. Though her study is relatively focused on electric and electronic products, she extracted the items from actual product examples. The most important reason I selected her guide is that I thought her strategies are concrete enough to be used as action items when compared to several other similar studies conducted in South Korea. She also tried to integrate her sustainable design guide into the design process and actually designed an air purifier using her sustainable design process as the final result of her thesis.

The strategy items in this guide are grouped by each item's nature, such as cycle, energy preservation, efficiency, safety, and sociality, while the items in other three guidelines are ungrouped (ESP Design Strategies), or grouped by product life cycle stages (Lunar's guide and Okala Ecodesign Strategy Wheel). Another important difference is that J. Kim's guide tries to earnestly cover social issues as a part of sustainable design while the other three guides are actually ecodesign guides, mainly focusing only on environmental and economic issues. However, when we look closely at the social items, they leave something to be desired. For example, the items belong to the first subcategory E1. User Consideration such as e3.

User Convenience and e4. Understanding User Needs, sound too general to be used as action items. Also it is highly questionable if the items belong to the second subcategory E2. Information are relevant to the social category.

Table 5 Kim's Guideline for Sustainable Design

Factor		Strategy Items	Factor		Strategy Items
A. Cycle	A1. Reuse	a1. Reuse	C. Efficiency	C3. Usability	c6. Durability
		a2. Material Substitutability			c7. Lasting Use
		a3. Upgrade			c8. Interaction
	A2. Recycle	a4. Biodegradable Materials			c9. Expandability
		a5. Recycled / Recyclable Materials		C4. Function	c10. Faithful Basic Functions
	A3. Reduce	a6. Purity of Material			c11. Integrated Functions
		a7. Single Material		D1. Environ-mental Safety	d1. Regulation Compliance
		a8. Minimal Finish			d2. Nontoxic Materials
	A4. Repair	a9. Easy Assembly / Disassembly			d3. Harmful Substance Free
		a10. Easy Maintenance			d4. Pollution Reduction
B. Energy Preser-vation	B1. Material	b1. Durable Materials		D2. User Safety	d5. Safety Consideration
		b2. Nature Revertible Materials			d6. Safe Shape
	B2. Natural Energy	b3. Self Generation Electricity		D3. Clean & Safety	d7. Cleanliness Consideration
		b4. Clean Alternative Energy	E. Sociality	E1. User Conside-ration	e1. Providing User Options
		b5. Storing Natural Energy			e2. Intuitive Usability
	B3. Energy Saving	b6. Transportation Cost Reduction			e3. User Convenience
		b7. Minimal Resources			e4. Understanding User Needs
		b8. Simple Manufacturing Process		E2. Infor-mation	e5. Providing Product Information
		b9. Energy Efficiency			e6. Environment Information
		b10. Optimal Design			e7. Broken Appliance Collection System
	B4. Life Extension	b11. Product Life Extention		E3. Universal	e8. Ergonomic Design
C. Efficiency	C1. Identity	c1. Component Standardization			e9. Equity (Nation / Generation)
		c2. Modularization			e10. Improving Quality of Life
	C2. Reduction	c3. Minimal Cost		E4. Ethics	e11. Considering Developing Countries
		c4. Minimal Quantity & Weight			e12. Use of Local Resources
		c5. Package Integration			e13. Fostering Donation Culture

3. 5. The Okala Ecodesign Strategy Wheel

Philip White, chair of the Industrial Designers Society of America (IDSA) Ecodesign Section, Steve Belletire, and Louise St. Pierre formed the Okala Team in 2001 as a result of the designers' and academics' struggle to understand how to practice and what to teach about ecological design. The team named itself after the Hopi word "Okala" which means "life sustaining energy" and started to develop an ecodesign curriculum for undergraduate industrial design schools. They also started to teach field designers in partnership with the U.S. Environmental Protection Agency the next year. They published "Okala: Learning Ecological Design" in 2004 and have updated their publication at intervals of every two or three years up to the current edition, "Okala Practitioner: Integrating Ecological Design," published in 2013. The authors provide practical information about ecodesign from business

and ethics perspectives, and also present Okala Impact Factors which can be used for quick impact assessment in the Okala Practitioner, besides the Okala Ecodesign Strategy Wheel. The Okala Ecodesign Strategy Wheel successfully converted the original Ecodesign Strategy Wheel (Brezet & Van Hemel, 1997) UNEP published into an industrial designer's field guide. However, some of its 47 action items are actually redundant because they are classified by the product life cycle order. For instance, the items about minimizing energy use (items no. 18, 29) and toxic emissions (22, 32) appear repeatedly in the category C. Manufacturing and E. Use. Another critical limit of the Okala Ecodesign Strategy Wheel is its scope. As it specifies in its title, this guideline focuses on ecodesign and does not properly include social aspects of sustainable design.

Table 6 Okala Ecodesign Strategy Wheel

Category	Strategy Items
A. Innovation	1. Rethink how to provide the benefit
	2. Design flexibility for technological change
	3. Provide product as service
	4. Serve needs provided by associated products
	5. Share among multiple users
	6. Mimic biological systems
	7. Use living organisms in product system
	8. Create opportunity for local supply chain
B. Reduce Material Impacts	9. Avoid materials that damage human or ecological health
	10. Avoid materials that deplete natural resources
	11. Minimize quantity of materials
	12. Use recycled or reclaimed materials
	13. Use renewable resources
	14. Use material from reliable certifiers
	15. Use waste byproducts
C. Manufacturing Innovation	16. Minimize manufacturing waste
	17. Design for production quality control
	18. Minimize energy use in production
	19. Use carbon-neutral or renewable energy sources
	20. Minimize number of production steps
	21. Minimize number of components / materials
	22. Seek to eliminate toxic emissions
D. Reduced Distribution Impacts	23. Reduce product and packaging weight
	24. Reduce Product and packaging volume
	25. Develop reusable packaging systems
	26. Use lowest-impact transport system
	27. Source or use local materials and production
E. Reduced Behavior and Use Impacts	28. Encourage low-consumption user behavior
	29. Reduce energy consumption during use
	30. Reduce material consumption during use
	31. Reduce water consumption during use
	32. Seek to eliminate toxic emissions during use
	33. Design for carbon-neutral or renewable energy
F. System Longevity	34. Design for durability
	35. Design for maintenance and easy repair
	36. Design for Re-use and exchange of products
	37. Create timeless aesthetic
	38. Foster emotional connection to product
G. Transitional Systems	39. Design upgradeable products
	40. Design for second life with different function
	41. Design for reuse of components
	42. Integrate methods for used product collection
H. Optimized End of Life	43. Design for fast manual or automated disassembly
	44. Design recycling business model
	45. Use recyclable non-toxic materials
	46. Provide ability to biodegrade
	47. Design for safe disposal

4. From Ecodesign Guide to Sustainable Design Guide

4. 1. Comparing the Guidelines

Each of the four guides has its own strong points. On the other hand none are perfect, and each leaves some room for improvement when compared with each other. Lunar's guide is essential and easier to remember but its simplicity is also a disadvantage because the guide list is too short to thoroughly cover sustainable design methods. Also it does not include social aspects of sustainable design. The ESP Design guide explains each action item relatively in detail but it does not provide example cases. Only J. Kim's guide covers the social aspects of sustainable design in earnest, while the others actually just focus on ecodesign. Many of J. Kim's social items, however, seem unsuitable for the category or too comprehensive to be used as strategy items. The Okala guide successfully converts the original Ecodesign Strategy Wheel published by UNEP into an industrial designer's field guide, but it also overlooks the social aspects of sustainable design. Table 4 summarizes these key features of the four guides for easy comparison at a glance. In the case of the Number of Society Items, the seventh comparison standard of the table, the financial, environmental and social relevance overlaps in the ESP Design guide, unlike the other guides that classified the specific items to be included in a specific group. So the classification criterion has been reviewed on an equal basis with the rest of the guides, and the detailed information on the two items of the ESP Design guide categorized as the society group can be found in section 4.4 Extraction of Sustainable Design Strategies.

Table 7 Guideline Comparison

	Lunar	ESP Design	J. Kim	Okala
Year	2008~	2004~2013	2011	2001~
Media	Lunar Website	ESP Design Website (Archived)	Thesis (Master)	Book (Latest edition 2014) & Okala Website
Grouping Criteria	4 Groups by Product Life Cycle (Circular)	Environmental, Financial, Social (Overlapping)	5 Groups by Item Attributes	8 Groups by Product Life Cycle (Circular)
Origin	Not Explained	Not Explained	Case Study	EcoDesign Strategy Wheel (Brezet & Van Hemel, 1997)
Number of Items	15	44	52	47
Number of Society Items*	0	2	9	3
Explanation Level for Each Item	Detailed	Detailed	Brief	Brief
Examples for Each Item	All Items	Few Items	Some Items	All Items

* Society item details can be found in the section 4.4.

4. 2. Making up for Social Aspects

Environmental problems are closely related to social issues and we can find that viewpoint's origin in the sentence "many problems of resource depletion and environmental stress arise from disparities in economic and political power," explained in the Brundtland Report's Equity and the Common Interest section (World Commission On Environment and

Development, 1990). Environmental design philosophies have evolved from green design to ecodesign to sustainable design to keep pace with the times, as we discussed earlier. However, the three guides except J. Kim's guide are actually ecodesign guidelines, and even J. Kim's social items leave room for scrutiny before taking them as strategy items for sustainable design as I explained in chapter three. So I tried to study the social aspects of sustainable design further using three social design books. I summarized their major topics in Table 8 and as a result, I categorized the topics into six groups.

Table 8 The major social design topics from the three selected books and J. Kim's guide

Topic Category	Design for the Real World (Papanek, 1985)	Design for Society (Whiteley, 1997)	Social Design (Park, Oh, & Cho, 2015)	J. Kim's Guide
1. Design to relieve consumerism	– Consumerism design – Throwaway society – Kleenex culture – Planned obsolescence	– Consumerism design – Overconsumption – Throwaway culture – Style obsolescence	– Consumerism design – Materialism	
2. Design with responsibility	– Design for people's 'needs' instead of 'wants'	– Responsible design – Ethical consuming	– Interest in social issues	
3. Stimulate community			– Local economy – Community oriented – CPTED*	e12. Use of Local Resources
4. Consider equitable use	– The handicapped – Senior citizen – Pregnant woman	– The handicapped – Feminist perspectives	– The handicapped – Design for equity	e1. User option e9. Equity c8, e2, e3, e5, e8**
5. Consider underprivileged People & Fields	– People in the 3rd World – Underprivileged field	– The underprivileged – Appropriate technology	– The underprivileged – People in the 3rd World – Appropriate technology	e11. Developing Countries
6. Minimize environmental impact	– Environmental pollution – Ecology – Dense population	– Destruction of the environment – Limited resource – Green consumption	– Environmental pollution – Ecosystem first – Upcycling	A. Cycle B. Energy Preservation C. Efficiency D. Safety

* Crime Prevention Through Environmental Design

** c8, e2, e3, e5, e8 items are also related with intuitive and ergonomic design issues

4. 3. Making a New Comprehensive Guideline

I aimed to complement the guidelines by adding social design topics that were overlooked or treated as subordinate issues in the previously examined guidelines, so that the integrated guide can be used as a sustainable design guideline beyond the role as ecodesign guides. I also tried to integrate the previously examined four guidelines by extracting commonly suggested strategy items to make it easier for field designers and design students to consult specific sustainable design methods. The augmented guide basically inherits the product life cycle order as grouping criteria for the strategy items from the Okala guide because I determined that the classification method has been refined since Brezet & Van Hemel's Ecodesign Strategy Wheel. I also located the newly added Society group between the Innovation and the Material groups because social topics need to be considered at the planning stage of design process. The grouping and arrangement results of the final guideline items, item descriptions and case examples can be found in detail in the section 4.5 Sustainable Design Strategies, and the criteria from which each of the detailed items are derived are as follows. Basically, I selected strategy items when more than two guides suggest them or when I see them as equally important to other selected items if they are suggested in just one guide. I tried to minimize the number of items by integrating similar items when they appear repeatedly due to the product life cycle classification method. Section 4.4, Extraction of Sustainable Design

Strategies, explains how strategy items overlap among the guidelines, how similar items are integrated, how social items are complemented, and how the final sustainable design strategies were extracted. I selected item titles from existing items when I found the proper title to represent the integrated items; otherwise I made new titles for the integrated items. I also integrated five topic categories extracted from three social design books as strategy items in the Society category of the new guide.

4. 4. Extraction of Sustainable Design Strategies

CATEGORY	EXTRACTED STRATEGIES	RELATED ITEMS FROM EXISTING GUIDES	Design for the Real World (Papanek, 1985) / Design for Society (Whitbey, 1987) / Social Design (Park, Oh & Cho, 2015)
INNOVATION 1	I1. Question the premise of the design	LUNAR **a1. Question the premise of the design** / ESPD 1. Design the Business System First, 42. Rewrite the Brief, 43. Start with a Blank Sheet of Paper / OKALA a1. Rethink how to provide the benefit	
	I2. Share among multiple users	ESPD 4. Product Service Systems / OKALA **a5. Share among multiple users,** a3. Provide product as service	
	I3. Minimize energy consumption in production and during use	ESPD 24. Minimise Energy Leaks / J. KIM b9. Energy Efficiency / OKALA **c3. Minimize energy use in production**, e2. Reduce energy consumption **during use**	
	I4. Consider carbon-neutral or renewable energy	ESPD 26. Renewable Energy, / J. KIM b3. Self Generation Electricity, b4. Clean Alternative Energy, b5. Storing Natural Energy / OKALA c4. Use **carbon-neutral or renewable energy** sources, e6. Design for carbon-neutral or renewable energy	
	I5. Provide information related with sustainability	ESPD 28. Feedback Mechanisms / J. KIM e6. Environment Information Delivery	
	I6. Mimic or use living organisms	OKALA a6. Mimic biological systems, a7. Use living organisms in product system	
SOCIETY 2	S1. Encourage low-consumption user behavior	ESPD 44. Change Consumer Behaviour / OKALA **e1. Encourage low-consumption user behavior**	1. Design to relieve consumerism
	S2. Design responsibly with responsible partners	ESPD 3. Select Responsible Suppliers / OKALA b6. Use material from reliable certifiers	**2. Design with responsibility**
	S3. Stimulate community	J.KIM e12. Use of Local Resources / OKALA a8. Create opportunity for local supply chain	**3. Stimulate community**
	S4. Consider inclusive design	J. KIM e1. Providing User Options, e8. Ergonomic Design e9. Equity (Nation, Generation)	4. Consider equitable use
	S5. Make it intuitive	J. KIM c8. Interaction, e2. **Intuitive** Usability, e3. User Convenience, e5. Providing Product Information	
	S6. Consider underprivileged people	J. KIM e11. Considering Developing Countries	**5. Consider underprivileged people & fields**
MATERIAL 3	M1. Reduce material use	J. KIM b7. Minimal Resources, c4. Minimal Quantity & Weight / OKALA b3. Minimize quantity of materials	
	M2. Minimize material variety	LUNAR b1. Reduce material variety / ESPD **7. Minimise Material Variety** / J. KIM a6. Purity of Material, a7. Single Material	
	M3. Use low embodied energy materials	ESPD **15. Low Embodied Energy Materials**	
	M4. Use recycled or recyclable materials	LUNAR d2. Use recycled, recyclable, renewable & biodegradable materials / ESPD 9. Recyclable Materials, 10. Recycled Materials / J. KIM **a5. Recycled & Recyclable Materials** / OKALA b4. Use recycled or reclaimed materials, h3. Use recyclable non-toxic materials	
	M5. Use renewable materials	LUNAR d2. Use recycled, recyclable, renewable & biodegradable materials / ESPD **12. Renewable Materials** / OKALA b2. Avoid materials that deplete natural resources, b5. Use renewable resources	
	M6. Use biodegradable materials	LUNAR d2. Use recycled, recyclable, renewable & biodegradable materials / ESPD **11. Biodegradable Materials** / J. KIM **a4. Biodegradable Materials**, b2. Nature Revertible Materials / OKALA h4. Provide ability to biodegrade	
	M7. Avoid hazardous & toxic materials / substances	LUNAR b2. Avoid toxic or harmful mat. & chemicals / ESPD **14. Avoid Hazardous & Toxic Materials, Substances** / J. KIM d2. Nontoxic Materials, d3. Harmful Substance Free / OKALA b1. Avoid materials that damage human or ecological health, c7. Seek to eliminate toxic emissions, e5. Seek to eliminate toxic emissions during use	
	M8. Minimize composites or contaminative finish	LUNAR d4. Don't use paint / ESPD 13. Minimise Composites, 16. Minimise Material Contamination / J. KIM a8. Minimal Finish	
PRODUCTION 4	P1. Make it less complex	LUNAR **a2. Make it less complex** / ESPD 30. Simplification / J. KIM b10. Optimal Design / OKALA c6. Minimize number of components/materials	
	P2. Make it more useful	LUNAR **a3. Make it more useful** / ESPD 5. Multi-functionalism / J. KIM c11. Integrated Functions / OKALA a4. Serve needs provided by associated products	
	P3. Optimize manufacturing process	LUNAR **b4. Optimize manufacturing process** / ESPD 22. Efficient Processes / J. KIM b8. Simple Manufacturing Process / OKALA c1. Minimize manufacturing waste, c5. Minimize number of production steps	
TRANSPOR -TATION 5	T1. Reduce transportation	ESPD **29. Reduce Transportation** / OKALA d4. Use lowest-impact transport system, d5. Source or use local materials and production	
	T2. Reduce size & weight	LUNAR **b3. Reduce size and weight** / ESPD 8. Weight Reduction / J. KIM b6. Transportation Cost Reduction / OKALA d1. Reduce product and packaging weight, d2. Reduce Product and packaging volume	
	T3. Design packaging in parallel with products	LUNAR **b5. Design packaging in parallel with products** / ESPD 31. Integrate Packaging Design / J. KIM c5. Package Integration	
USE 6	U1. Create proper and durable designs	LUNAR c2. Create durable & high quality designs / ESPD 32. Durability / J. KIM b1. Durable Materials, b11. Product Life Extention, c6. Durability, c10. Faithful Basic Functions / OKALA f1. Design for durability	
	U2. Foster emotional connection to products	ESPD 41. Design Products to be Loveable / OKALA **f2. Foster emotional connection to product**	
	U3. Create timeless aesthetic	OKALA **f5. Create timeless aesthetic**	
	U4. Reduce consumables	ESPD **37. Reduce Consumables** / OKALA e3. Reduce material consumption during use, e4. Reduce water consumption during use	
	U5. Design for maintenance and easy repair	ESPD 34. Remanufacture, 36. Maintenance / J. KIM a2. Material Substitutability, a10. Easy Maintenance / OKALA **f3. Design for maintenance and easy repair**	
	U6. Consider upgradeability	LUNAR c1. Design for upgradeability / ESPD 23. Plan for Continual Improvement / J. KIM a3. Upgrade, c9. Expandability / OKALA a2. Design flexibility for technological change, g1. Design upgradeable products	
	U7. Make it modular	LUNAR **d1. Make it modular** / ESPD 6. Modularisation / J. KIM c2. Modularization	
	U8. Design for reuse	LUNAR c3. Design for life after death / ESPD 33. Re-Usability / J. KIM a1. Reuse, c7. Continuous Use, c1. Component Standardization / OKALA d3. Develop reusable packaging systems, **f4. Design for reuse** and exchange of products, g2. Design for second life with different function, **g3. Design for reuse** of components	
DISPOSAL 7	D1. Design for disassembly	LUNAR d3. Minimize fasteners / ESPD **35. Design for Disassembly** / J. KIM a9. Easy Assembly & Disassembly / OKALA h1. Design for fast manual or automated disassembly	
	D2. Integrate disposal instructions and label materials	ESPD **17. Identify/Label Materials, 38. Integrate Disposal Instructions** / OKALA h6. Design for safe disposal	
	D3. Integrate methods for used product collection	J. KIM e7. Broken Appliance Collection System / OKALA h2. Design recycling business model, **h5. Integrate methods for used product collection**	
	D4. Add design on wastes	ESPD 39. Use Waste Products / OKALA b7. Use waste byproducts	

Excluded Items
(Reson of exclusion in brackets)

ESPD 2. Clarify Core Functions (too general), 18. Avoid Glass (controversial), 19. Look for Synergies (too general), 20. Aim for Maximum Efficiency (too general), 21. Design for Part Load Operation (peripheral), 25. Minimise Cycling Losses (peripheral), 27. Rechargeable Batteries (peripheral), 40. Closed Life Cycle Design (too comprehensive) **J. KIM** c3. Minimal Cost (too general), d1. Regulation Compliance (too comprehensive), d4. Pollution Reduction (too comprehensive), d5. Safety Consideration (too general), d6. Safe Shape (too general), d7. Cleanliness Consideration (too general), e4. Understanding User Needs (too general), e10. Improving Quality of Life (too comprehensive), e13. Fostering Donation Culture (peripheral) **OKALA** c2. Design for production quality control (peripheral)

4. 5. Sustainable Design Strategies

1. INNOVATION

I1. Question the premise of the design
I2. Share among multiple users
I3. Minimize energy consumption in production and use
I4. Consider carbon-neutral or renewable energy
I5. Provide information related with sustainability
I6. Mimic or use living organisms

7. DISPOSAL

D1. Design for disassembly
D2. Integrate disposal instructions and label materials
D3. Integrate methods for used product collection
D4. Add design on wastes

2. SOCIETY

S1. Encourage low-consumption user behavior
S2. Design responsibly with responsible partners
S3. Stimulate community
S4. Consider inclusive design
S5. Make it intuitive
S6. Consider underprivileged people

6. USE

U1. Create proper and durable designs
U2. Foster emotional connection to products
U3. Create timeless aesthetic
U4. Reduce consumables
U5. Design for maintenance and easy repair
U6. Consider upgradeability
U7. Make it modular
U8. Design for reuse

3. MATERIAL

M1. Reduce material use
M2. Minimize material variety
M3. Use low embodied energy materials
M4. Use recycled or recyclable materials
M5. Use renewable materials
M6. Use biodegradable materials
M7. Avoid hazardous & toxic materials, substances
M8. Minimize composites or contaminative finish

5. TRANSPORTATION

T1. Reduce transportation
T2. Reduce size & weight
T3. Design packaging in parallel with products

4. PRODUCTION

P1. Make it less complex
P2. Make it more useful
P3. Optimize manufacturing process

4. 5. 1. Innovation

Origin:(L)=Lunar / (E)=ESPD / (K)=J. Kim / (O)=Okala

I1. "Question the premise of the design" (L)

Check the possibility of "dematerialization" (Brezet & Van Hemel, 1997). Think about an entirely new approach in providing the benefit you are aiming(O). Challenge the project brief if it is fundamentally unsustainable(E).

Example: "Instead of heating an entire building, heat only the air around people"(O). / Digital book distribution system.

I2. "Share among multiple users" (O)

Consider joint ownership especially when the product is used from time to time and stays idle most of the time.

Example: Cooperatives for sharing hand and power tools(O). / Car sharing services.

I3. "Minimize energy consumption in production" and use (O)

Design energy efficient products and minimize energy leaks in the systems such as heating, cooling, water, gas and standby energy(E). Consider embodied energy when you select materials and minimize energy consumption in production.

Example: Nest, smart thermostat that learns using patterns and optimizes energy consumption (nest.com, 2016)

I4. Consider "carbon-neutral or renewable energy" (E)

Design products using carbon-neutral or renewable energy and also try to use carbon-neutral or renewable energy for production.

Example: Solar-powered water heating system(O) / Motion or kinetic energy chargers that generate electric power from everyday movements.

I5. Provide information related with sustainability

Providing sustainability information can encourage users' interest and participation(K). Feedback mechanism on energy consumption can improve users' behavior(E).

Example: Realtime fuel efficiency feedback while driving.

I6. Mimic or use living organisms (O)

Nature is perfectly sustainable in itself. Refer to how living organisms achieve their goals they are aiming. You can even include living organisms as a part of your design.

Example: Turbine blades mimicking the efficiency of whale fins(O). / Water purification using water plants(O).

4. 5. 2. Society

S1. "Encourage low-consumption user behavior" (O)

Instead of encouraging endless consumerism, invite people to behave in more sustainable way. Provide information about sustainable consumption to convince people or present chances they can participate in.

Example: Knit kit from Save the Children campaign (Park, Oh, & Cho, 2015).

S2. Design responsibly with responsible partners

Encourage ethical consumption. Also beware of the method for raw material extraction because it affects significantly the overall environmental impact of the end product. Certified suppliers ensure sustainable collection of resources.

Example: FSC (Forest Stewardship Council) certification ensures that old growth forests are not destroyed(O).

S3. Stimulate community

Consider using local materials, suppliers and manufacturers(K). It reduces environmental impact from transportation and stimulates local economy as well.

Example: "If an aluminum smelter is located nearby, design products from recycled aluminum"(O).

S4. Consider inclusive design

Design products that can be used comfortably by anyone regardless of the user's age, gender, physical and cognitive ability. Consider ergonomic aspects for all the users.

Example: Lever type door handles are easier to use than Knob type for the people who have weak grasping power. (ncsu.edu, 1997)

S5. Make it intuitive

Design products to accord with users' expectation and intuition. It is desirable that designed results should be easy enough to be used without any preliminary knowledge or experience.

Example: Easy IKEA manuals explained just with simple drawings without linguistic description.

S6. Consider underprivileged people

Design for people with low consumption power or people in developing countries because usually it is difficult for them to enjoy benefits from design.

Example: paraSITE Inflatable Shelter for homeless people (moma.org, 1997) / LifeStraw designed to filter drinking water (lifestraw.com, 2016)

4. 5. 3. Material

M1. Reduce material use

Reduction is the most effective way to relieve environmental impact, reuse is the second best and recycle should be considered after the previous 2 methods(Chapman, 2005). Minimizing material use reduces impacts on all aspects of product lifecycle such as raw material collection, production, distribution and disposal.

Example: "Structural analysis software can identify where to remove unnecessary material"(O).

M2. "Minimize material variety" (E)

Reduced material variety makes recycling process "easier, more efficient and more profitable" at the end of the product's life(L). Single material products do not even require disassembly process for recycling.

Example: "San Francisco based Green Toys makes children's toys entirely out of recycled milk jugs" (L) even without use of any glue, metal screws and spray paint for easier recycling.

M3. Use "low embodied energy materials" (E)

"Some materials are far more energy intensive than others" for their production(E). So understanding the embodied energy of materials is important to estimate the environmental impact of products.

Example: Aluminum is more than 7 times energy intensive than steel according to the Inventory of Carbon and Energy (circularecology.com, 2016).

M4. Use recycled or recyclable materials (L,E,K,O)

Recycling can reduce raw material demand and landfill. Also material recycling usually requires much less energy than producing materials from raw materials.

Example: Emeco's 111 Navy Chair is made from 111 recycled plastic bottles in collaboration with Coca-Cola.

M5. Use "renewable materials" (L,E,O)

Minimize using materials made from fossil fuel or other depleting resources and use renewable materials such as plant-based materials and biopolymers.

Example: "Linen, made from flax, consumes less fossil fuel than nylon"(O). Polylactic acid (PLA) plastic made from corn starch.

M6. Use "biodegradable materials" (L,E,K)

Choosing materials that can go back to nature quickly in landfill reduces environmental impact(K). Usually renewable materials are also biodegradable as well.

Example: "Mobile phone made of corn starch bioplastic"(K). Packaging buffer made of paper instead of Styrofoam.

M7. "Avoid hazardous & toxic materials, substances" (E)

Avoid materials containing RoHS restricted substances (lead, mercury, cadmium etc.), VOCs (formaldehyde etc.) and endocrine-disrupting chemicals (bisphenol A etc.)(L,E,O).

Example: Avoid making baby bottles with polycarbonate which contains bisphenol A(L). Avoid making toys with PVC which contains lead and cadmium.

M8. Minimize composites and contaminative finish

Avoid contaminative finishes and "take advantage of the natural beauty of materials"(L). Contaminants such as colorings, UV stabilizers, fire retardants, surface treatments and labels hinder recycling or causes degradation of material quality during recycling(L,E). Composites such as fiber reinforced polymers are also hard to recycle(E).

Example: Minimize application of painting and labeling(L,E,K).

4. 5. 4. Production

P1. "Make it less complex" (L)

Simple design reduces material use and manufacturing process(L). Usually it also means less material variety and more capability to recycle(L). Simple products are less likely to go wrong during use and easier to maintain as well.

Example: IKEA Benjamin stool(L). / Simply structured wall mount type CD player designed by Naoto Fukasawa.

P2. "Make it more useful" (L)

Multipurpose products reduce the needs of buying each product separately(L). Accordingly, they reduce comsumption and also increase convenience(L).

Example: Smartphones can be used also as cameras, MP3 players, personal organizer, alarm clocks etc(E).

P3. "Optimize manufacturing process" (L)

"Manufacturing process should be considered throughout the design process, so that it can be manufactured using efficient methods"(E). Material and energy consumption tend to decrease when production processes are optimized.

Example: Making body wash is simpler and less energy consuming than making bar soap(O).

4. 5. 5. Transportation

T1. "Reduce Transportation" (E)

Minimize distances among resources, production and distribution. Energy consumption and greenhouse gas emission for transportation throughout the product life cycle significantly affects the products' overall impact.

Example: Glass bottles are more sustainable than plastic bottles from the material aspect but long distance transportation may turn the result around because glass bottles are much heavier.

T2. "Reduce size and weight" (L)

Transportation energy will be saved if products are lighter(O). Also, more products can be transported in the same capacity if packaged products are smaller(O).

Example: Puma's Clever Little Bag reduced the size of its conventional shoes package (fuseproject.com, 2016).

T3. "Design packaging in parallel with products" (L)

You can find more fundamental solutions of reducing packaging materials or volumes if you consider it from the beginning of design process.

Example: "Products can be designed to be disassembled for shipping, or to nest during shipping"(O).

4. 5. 6. Use

U1. Create proper & durable designs

Properly working high quality products can transcend the throw away culture. Also, design durable products to be used for long time. Making products last longer physically and emotionally is one of the most fundamental ways for sustainable design.

Example: CNC machined unibody Macbooks are physically and emotionally durable.

U2. "Foster emotional connection to products" (O)

People tend to care for and use products longer when they have emotional attachment to the products. Instill care for users, stories or philosophy to your products and try to design something lovable which builds a bond between users and products.

Example: "A toy that requires assembly by parent and child together acquires meaning"(O).

U3. "Create timeless aesthetic" (O)

Avoid transient fashions and defy style obsolescence. Try to create aesthetic which can be appreciated for long time.

Example: Dieter Rams' 606 shelving system has been produced and used for more than 50 years and the timeless aesthetic is one major reason of its lasting success (vitsoe.com, 2016).

U4. "Reduce consumables" (E)

Many products require consumables during their lives(E). So it will be helpful for reducing environmental impacts if you can "minimize the quantity of consumables used over the lifetime of the product"(E).

Example: Dyson vacuum cleaners that do not require paper dust bags.

U5. "Design for maintenance and easy repair" (O)

Maintenance is vital in maintaining performance and increasing the lifespan of products(E). People can use products longer if they can easily maintain and repair their products.

Example: Fairphone 2 is designed for easy maintenance so that people can even replace broken LCD panels by themselves. (fairphone.com, 2016)

U6. Consider upgradability

Especially electronic products become obsolete quickly due to fast technological advancement, so partial upgradability can extend the products' lifespan(L).

Example: Standardized computer components enable convenient upgrade / Phonebloks, modular smartphone which can be upgraded partially and easily by users (phonebloks.com, 2016).

U7. "Make it modular" (L)

"Modularization allows customized products to be created from a set of standard modules, products to be altered or upgraded to meet the users changing needs, and for products to be easily repaired"(E).

Example: Acer Revo Build modular PC (acer.com, 2017) / USM Modular Shelving System can be expanded or transformed along with the users' lifecycle (usm.com, 2016).

U8. "Design for reuse" (O)

"A product can be used in a new application, extending the useful life of the material"(O). Reuse has less environmental impacts than recycling, and the portion of recycling or waste disposal can be reduced if products (or parts of the products) are reusable.

Example: "A jam jar can become a drinking glass after use"(O). / Standardized car components can be reused for remanufacturing.

4. 5. 7. Disposal

D1. "Design for disassembly" (E)

Products need to be disassembled until the constituent parts become single material parts for recycling. Easy disassembly fosters recycling by making the process more efficient and profitable. Easy to disassemble products tend to be easy to repair.

Example: Herman Miller's Mirra chair is designed for easy disassembly and 98% of the components are recyclable.

D2. "Integrate disposal instructions and label materials" (E)

Identify or label materials because it is "difficult or impossible to distinguish from others without clear identification"(L). "If products are to be treated properly at end of life then the user must know what to do with it when it reaches the end of its life"(L).

Example: Compact fluorescent light bulbs should be disposed carefully because they contain mercury gas(O).

D3. "Integrate methods for used product collection" (O)

Consider the way you can integrate collection methods after use to increase recycling rate(K).

Example: The recycling rate of single use cameras is higher than 80% because they are collected at DPE stores after use for printing. / Dell & HP have recycling programs for PCs and related products.

D4. Add design on wastes

Reusable materials are thrown away just because the cost of reusing process is higher than the expected result value. Design ideas can convert wastes into valuable goods through upcycling.

Example: Freitag bags made of used truck covers, bike tires and seat belts (freitag.ch, 2016) / Piet Hein Eek scrapwood furniture collection (pietheineek.nl, 2016)

4. 6. Exemplifications of Successful Sustainable Product Design

In the section 4.5 Sustainable Design Strategies, individual design examples for each strategy item have been presented in order to introduce as many cases as possible that best feature each item. However, for real products that accomplish sustainable design successfully, it is often true that many of the strategy items are met at the same time. In this section, I will explain the practical value of the sustainable design strategies presented through this study by looking at the examples of two successful sustainable product designs in which the strategy items are actually applied in combination to become sustainable products. Green Toys Inc., which makes eco-friendly toys, was founded in San Francisco's Bay area in 2007 and currently sells products in more than 80 countries, including the US, through retailers such as Amazon, Whole Foods, Pottery Barn and Nordstrom. According to Forbes, over 10 years after its establishment, now it is considered as a leading brand in the US preschool toy market(Choi, 2015). Green Toys' products are basically made of pure high-density polyethylene (HDPE)

recycled from milk jug (M4. Use recycled or recyclable materials) without using any screw, glue, or paint so that there is no need to disassemble them when recycling (M2. Minimize material variety / M8. Minimize composites or contaminative finish / P1. Make it less complex). As of March 2017, more than 47 million milk jugs have been recycled so far according to the company's homepage (greentoys.com). Since they only use the recycled food packaging container, their material does not contain harmful substances such as bisphenol A or phthalate (M7. Avoid hazardous & toxic materials, substances). The packaging of the product is also made to a minimum size with recycled paper printed with soy ink (T2. Reduce size & weight). Green Toys stimulates local economy (S3. Stimulate community) and reduces greenhouse gas emissions for transportation compared to many other companies that manufacture in China because their headquarter, plastic recyclers, product manufacturers, packaging companies, and warehouses are all within five mile distance (T1. Reduce transportation). In terms of aesthetics, Green Toys adopts a relatively classic design direction, so their toys can be used for a long time without style obsolescence (U3. Create timeless aesthetic). Also, their products can be cleaned in a dishwasher so they are easy to maintain (U5. Design for maintenance and easy repair).

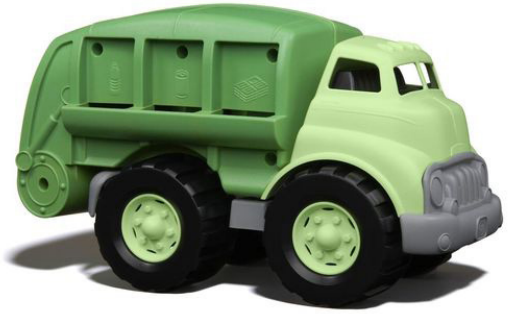

Figure 1 Recycling Truck by Green Toys (www.greentoys.com)

The second example of a sustainable product design is the 606 Shelving System designed by Dieter Rams and built by Vitsoe, which has been sold for nearly 60 years since 1960. When we take a look at Dieter Rams' well-known 10 principles for good design, we can understand that the principles like "9. Good design is environmentally friendly" and "7. Good design is long-lasting" refer directly to sustainability, and most of the remaining principles are also largely related to the sustainable design strategy items reviewed in this study. In particular, the 606 Shelving System is one of the most representative products that reflect his design philosophy. 606 Shelving System consists of E-Tracks (a thin strip-shaped wall mounts), the shelf modules made of folded metal sheets and connecting pins, and basically the use of materials is extremely efficient in this system compared to other shelving designs because it uses walls as the frame of the shelving structure (M1. Reduce material use). 606 System can be easily expanded or modified according to the user's changing situations thanks to its modular structure consists of the components such as various shelves of four depths and two widths, sloping shelves inclined at two angles to accommodate magazines, hanging rails for hangers, cabinets, drawers, and even tables (U6. Consider upgradeability / U7. Make it modular / P2. Make it more useful). Users can easily replace only the problematic part when it is broken (U5. Design for maintenance and easy repair) or they can reuse it in parts (U8. Design for reuse). Also, it is easy to recycle because basic modules such as E-Tracks, shelves, and pins are made of single material (aluminum or steel) just

except for some modules like cabinets (M2. Minimize material variety / M4. Use recycled or recyclable materials / D1. Design for disassembly). The 606 system was designed using an essential design language and the product's aesthetic completeness is so great that it has been more than 50 years since the product was designed, and is still a success story of a typical timeless design that is still loved and steadily sold by users without a sense of outdated feeling (U3. Create timeless aesthetic). The designs of each modular component are simple, complete and robust, so they minimize the possibility of trouble (P1. Make it less complex / U1. Create proper and durable designs). If the various sustainable design strategies covered in this study are taken on board and can be applied in combination as we have seen through the examples of Green Toys and the 606 Shelving System, the result of this study can be used as a useful guideline to set the design direction for making more sustainable products in actual design projects.

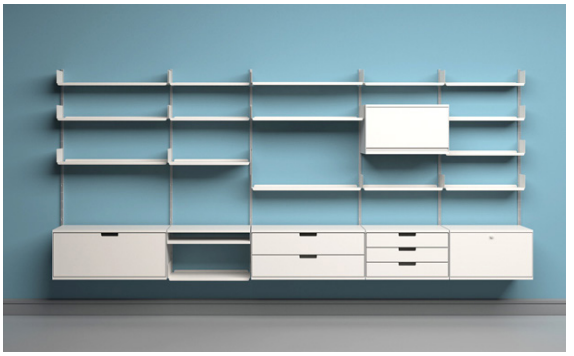

Figure 2 606 Shelving System (www.vitsoe.com)

5. Conclusion

At the end of 2015, leaders from 195 countries in the Paris Agreement agreed to keep global temperatures from rising more than 2˚C, with an ideal target of keeping the temperature rise below 1.5˚C , to prevent the global climate catastrophe, and it was reported as the most important climate change agreement in history by Time magazine (Worland, 2015). Sustainability may sound like a worn-out or insensitive topic to some people because it has been debated for several decades. It is still, however, an ongoing unresolved issue requiring long and tortuous efforts by people from all walks of life including designers without a doubt.

There are various sustainable design principles, manifestos, guidelines, and strategies that many organizations and researchers present due to the decentralized nature of sustainability movements. This study introduced and compared the four selected guidelines which field designers and design students can conveniently access and consult. I identified each guide's strengths and the weaknesses and also extracted commonly important issues through a comparative analysis of item details. Through the analysis, I realized that three of the four reviewed guidelines are actually ecodesign guidelines that do not properly cover social aspects of sustainable design. Therefore, I tried to strengthen the point by taking issues from three renowned social design books, so that the new integrated guideline can be consulted for thorough sustainable design issues.

Additional research on the social aspects could give a more comprehensive perspective for clarifying and categorizing related strategy items. I also tried to complement the explanations and examples of strategy items when the current ones are considered obscure or outdated. I hope this study results can function as a convenient guide and an easy introduction to sustainable design for people who want to know specific ways to make things more sustainable. This study focuses on just sustainable design guidelines and the qualitative aspects of sustainable design, so further study on how designers can conveniently apply quantitative approach such as Life Cycle Assessment for achieving more sustainable results in their practices is required in the future.

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