

Sustainable Design and Innovation for Office Furniture and Its Implementation

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ABSTRACT

Products such as furniture are a combination of components that together provide the functionality required by the customer. For the designer, the product configuration has special importance. The impetus for new ideas becomes obvious as they will influence the future industrial designers. The objective of this research is to develop a new tool to help designer make a most effective decision making toward sustainable design. At early design decision makings, the design concept selection at the component design level can cause the product to be redesigned or remanufactured. Early design decision makings are essential and have significant impact on sustainable design of furniture products. However, there are still challenges to evaluate a significant sustainable design especially to furniture industry on open plan system. The aim of the research presented in this paper is to address the issues above in an integrated sustainable design.

1. INTRODUCTION

Customer need a good product and they must satisfied its, in order to do that an expert need to ensure nothing important is overlooking, due to the complex product company need to devise area of people involved as a team to develop an idea into a good office furniture i.e open plan system(OPS) . Towards to sustainable design product design are the most important factors to influence that. Lack of information can give an effect to realizing the sustainable design [1]. People always make thing complex, but how to make it simple. According Suh [2] At every design stage there have a hierarchical nature to do it, when that such hierarchical decision making is not utilized the process become more complex . Design is important because it determine at the initial or upstream stage to conclude the final outcome of engineering activities, manufacturing, and the provision of defence needs. The sustainable design describe as a philosophical approach to design that seeks to minimize the quality of the built environment while minimizing or eliminating the negative impact to the environment [3].

Although there have many studies among office furniture have had to overcome these issues. But they still need to educate and raise the level of awareness about sustainability even to manufacture or to customer. Especially the customer expectation due to the environmental performance of furniture and office system is still varied. They need an intermediate people to recommending give specifying needs because customer are not willing pay an extra cost for environmental features or performance [4]. The challenge for designers is how to optimize a design to best meet the needs of today's markets, but before the optimization is complete, designer need to be forces the influence on the design decision shift [5] [6].

For addressing sustainable design issue this paper is organized as follow: in the following section a method will discuss an approach for sustainable design and innovation of office furniture and its implementations. To achieve the objective of sustainable design for office furniture on Open Plan System (OPS), evaluation on these four factors should be carry out in the early design process. The four factors are combining a modular design and reconfigurability, axiomatic design (AD), design structure matrix (DSM) and sustainable design index (SDI). The study highlights a need for tool to assist designer in delivering and embedding sustainable design in their daily design process for open plan system(OPS).

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2. RESEARCH METHODOLOGY

The concept that every designer bring to the innovative level is depend on how they can defined the design problem. They can realized it's until the product need to develop when the furniture design have a problem. To solve that problem they need to broaden a knowledge and how that they think about furniture OPS. Design methods also take a value into account for product design [7]. For industry the sustainable design is like a new concept. Most of the industries related to the Office furniture system still difficult to define the sustainable design to their office furniture system (OPS) [4].

The aim for this design methodology is to present in a clear picture the way to develop a sustainable design index in furniture industry that can be produced and profitable for designer, manufacturer and customer. For this study we have identified sustainable design and furniture as a main subject that need to be addressed. Figure 1, illustrates a conceptual process framework model to run this study; this model included 5 steps as shown which are (i) modularity and reconfigurability, (ii) axiomatic design (AD), (iii) design structure matrix (DSM), (iv) sustainable design index (SDI) and (v) CAD-based implementation. This is a part of ongoing research study.

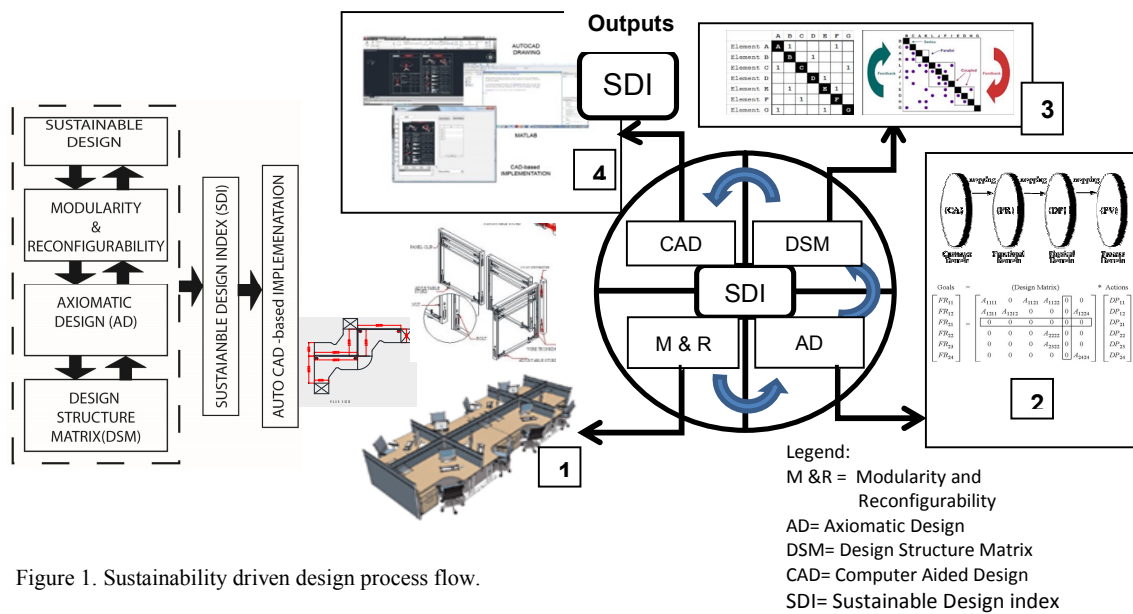


Figure 1. Sustainability driven design process flow.

The components for this study are shown in Figure 2, which provides a model is constructed using several factor assessing office furniture namely open plan system(OPS),toward sustainable design. Sustainable design is generally defined as those products provide environmental, social and economic benefit. This concept of study also indicates the correlation among modularity and reconfigurability, axiomatic design, design structure matrix and sustainable design index.

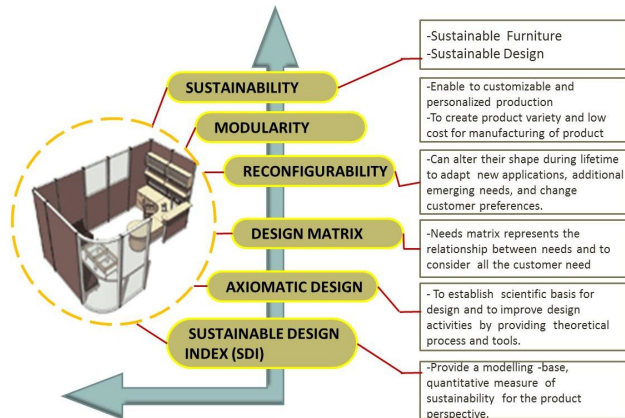


Figure 2. Sustainability driven design process flow.



Figure 3. Example of Open Plan System.

3. SUSTAINABILITY AND FURNITURE DESIGN

Sustainability is generally expressed in terms of Triple Bottom Line (TBL) – people, planet and profit. As mention by Ramani et al [8] the research in the field of information modelling, uncertainty quantification, and the decision making as applied to sustainability will be a key important. Another area of future importance is the seamless integrations of sustainability into a design practices. Due to that, this time to begun and push the furniture industry in Malaysia to convert traditional model business toward more sustainable practices. It also could potentially improve both economic and environmental efficiency of the entire life cycle.

Since Malaysia is today the world's 8th largest producer of furniture, 3rd in Asia and 2nd in the Asian region, furniture design is an important area to be considered for implementing sustainability [9] and [10], when company try to adapt the sustainable issues into their product design practice, they have to develop their own definition about sustainability and ensure the new principle are operational. Designing for sustainability is difficult because a product may have many social, environmental and economic consequence or impacts during its life cycle and these consequence are difficult to predict accurately whilst the product is being designing. For this study we have to look the design process and the basic of problem solving to understand were the sustainable design tool can be used.

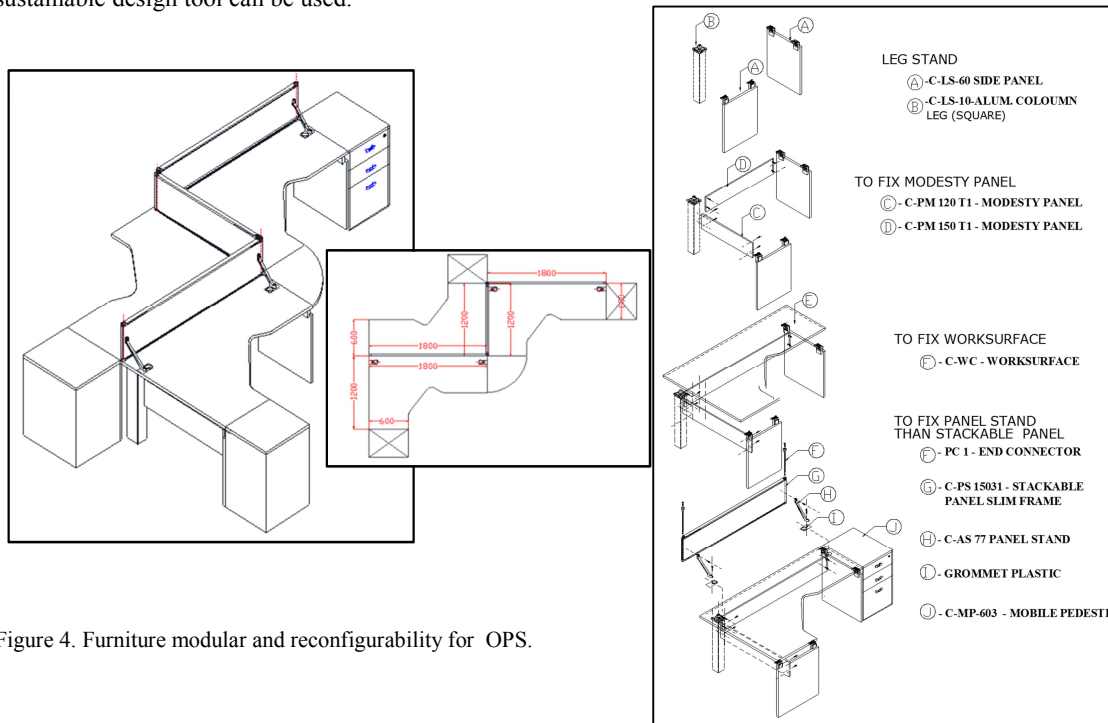


Figure 4. Furniture modular and reconfigurability for OPS.

4. MODELING AND TOOLS FOR SUSTAIABLE DESIGN

Method for evaluating sustainable design was presented, including modularity and reconfigurability, axiomatic design, design structure matrix and sustainable design index. These major components of the sustainable design measurement methodologies are interrelated with each other. A new approach is aimed to overcoming the difficulties of evaluating a data also enable quantitative measurement of sustainable design performance of office furniture (OPS). Greatest implications to the designer are using appropriate design methods and tools, the primary goal is to achieve of the potential product, to reduce the risk in the product development and the total duration time, and to solve the design task. Through an experience the designers can fully utilize their knowledge with the methods and tools to achieve a better product [11]. In this paper a new method is proposed to link the modular and reconfigurability, axiomatic design, design structure matrix approach to define effective and rational modules from the viewpoint of sustainable design index. An (OPS) is used to verify the proposed method and the model are discussed.

4.1 MODULAR DESIGN & RECONFIGURABILITY

The key point for any furniture is innovative, all kind of furniture kept constant upgrade follows the trend and to fulfil the end user's needs. The kinds of furniture such as civil furniture, office furniture, hotel furniture, kitchen furniture, sift furniture, traditional furniture, and teaching furniture [12]. The modular office furniture also can category as table, storage units, pedestal, executive tables, discussion table shows as in figure 3. The 21st century furniture design and innovation will be to wing for the furniture business and enterprise. A designer creates the piece of furniture by manipulating any combination of elements chosen form a vast of design possibilities [27]. Due to that the creativity creating a new product, modular design is increase and become more effective way of communication between products and people in enterprise. The basic furniture modular is created in order to meet the requirements globally; it will fit the end user need with creating their own flexibility creation. Therefor the modularity design furniture is an effective way of innovative especially for open plan system (OPS) furniture. The product can be thought of in both functional and physical terms. The most important characteristic of a product's architecture is its modularity as figure 4. Types of modularity can comprise to three elements which is slot, bus and sectional [13]. The term of modularity has been widely used in different context, ranging from manufacturing to the design of electrical and mechanical products and software, numerous successful cases of launching modular design has been reported in the literature [14]. The modularity is a frequently used as a means to support design for variety. Modularity also refer to the degree to which there can be mixing and matching of components in the product architecture, through replacement of functional components, a modular architecture enable creation of new product variants with little or no time[15].

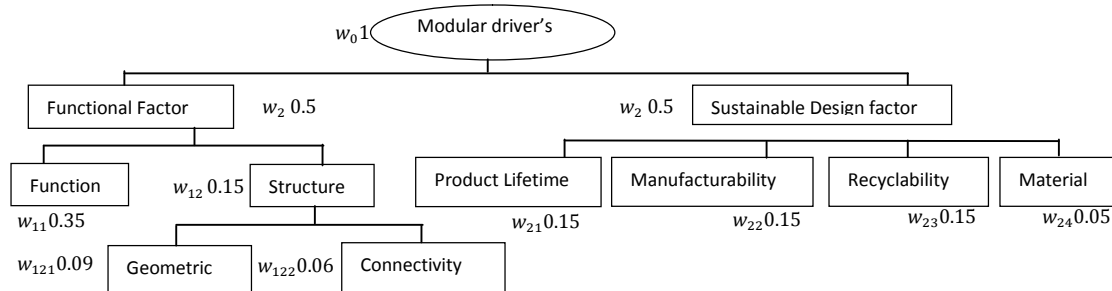


Figure 5. Weight hierarchy of modular drivers.

The concept of reconfiguration has been used is related field including fixed design, assembly design and re configurability system [16], there are a numerous applications for reconfigurable architecture. Reconfiguration allows adding, removing or modifying specific process capabilities, to meet a market demands and to full fill the end user needs [17].

Reconfigurable always command used on open plan system, open office system, the purpose is to separate work space as figure 4. The system may consist of office furniture, panel system, wall panel, system partition system, or a tiling system. The concept and appearance of open office system create a mood some und user such as emotional consideration, especially when standing walking even discussing. This need for additional architectural elements to enhance the feeling or privacy and individuality of the office area, while minimizing the effort to plan, install or modify the overall configurable [18].

4.2 AXIOMATIC DESIGN

To fulfil the customer need for better information helping the designer for improving, such the requirement of customer motivation for making new purchasing which is replacing the functioning product with newer model will be required [8]. In the absence of a criterion for selecting a good design, both designer and management play the important role to establish the decision making. The application of axiom is the answer to the question with applying the both simple axiom which is the Independent Axiom and the Information Axiom [11].

Many study using axiomatic design during the strategic planning that provide the systematic and scientific basis for making the design decision [19], [20], [21], [22] and structure methods of AD & QFD [23]. The axiomatic design matrix including functional requirement (FRs) and Design parameter (DPs), as

shown5+ in Figure 6 [24]. The use of axiomatic design as a concept to integrate functional basis and TRIZ technology, which makes easier to integrate and analyse design requirements, solutions, and design processes in both conceptual design and detail design [24] The relation between the FRs (functional requirements) , DPs (design parameters) and [A] (design matrix) can be represented in an equation of the form [25] and [19] :

$$\mathbf{FR}=[\mathbf{A}]\mathbf{DP}, \quad (1)$$

This equation is called design equation is used to interpret the right set of DPs to satisfy given FRs [2], [25], [26] and [27].

	DP1	DP2	DP3
FR1	X	O	O
FR2	O	X	O
FR3	X	X	X

Figure 6. Design matrix including FRs and DPs.

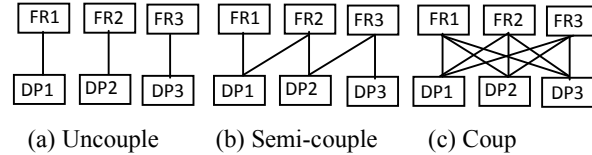


Figure 7. Three coupled types of design.

4.3 DESIGN STRUCTURE MATRIX (DSM)

There is clearly a need for an intuitive and effective visualization of a product and design processes. One approach to solving this problem is to use Design Structure Matrix (DSMs) [28]. At the moment the popular design methods used by designer is Axiomatic design (AD) and design structure matrix (DSM) [21] [27]. By examining the design matrix three level of functional dependency, or coupling, it can be identified as a) Uncouple b) Semi-couple c) Couple as shown in Figure 7, show with and appropriate design method all the complexity can be reduce with using the design methods which is Design Structure Matrix (DSM). A correlation between components of design structure matrix illustrated as Figure 8 (a) and (b) below [29]. To integrate the seven matrixes, weight of modular drives should be identified based on the requirement of product and consumer. The weight hierarchy of modular drivers is presented in figure 5.

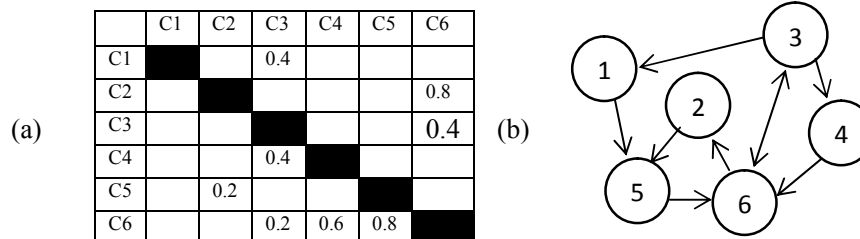


Figure 8. A sample DSM (a) Basic DSM (b) Spaghetti.

4.4 SUSTAINABLE DESIGN INDEX (SDI)

As we move onto detail design we can start to make some more accurate assessment of sustainability. Decision made at this stage is critically important in creating sustainable design for office furniture industry [30]. The generating of sustainable design index (SDI) requires a series of procedures- data normalization, weighting, and score aggregation as show in table 1. Which is the product realizations of the product function and its value is determine from the grade number, 0, 2, 4, 6, and 8. When the (SDI) is used to compare the sustainability performance of multiple similar products, the comparison should base on the same normalization and weighting methods.

Table 1. Standard relationship for two components.

Type of relationship	Interaction	Description
No	0	No relation at all
Weak	2	Lose connection and medium relation
Medium strong	4	Medium connection and medium relation
Strong	6	Medium connection and high relation
Very strong	8	Firm connection and high relation

Throughout the investigation the question was raised which is the criteria from the expert are needed, and then to apply it in order to measure the level of sustainable design in furniture industry (OPS). The methods for this index will be adapted form [30] which is the data collection and analysis will started with industry groups determined, selecting and weighing the indices, all of the information and criteria will gather from the expert through the interview and telephone calls. The limitation to apply of SDI in this study will consider the suitable and the need for this furniture industry on (OPS) only, although there will be much detailed work to be carried out on SDI and related aspects. The total sustainable design index (SDI) is achieved by computing a weighted average of overall mark from the environmental, social, and economic elements. The influencing elements scores are recoded by the designer in each entity of matrix and evaluate the SDI in each matrix. For Sustainable criteria (SC) as table 2, model can be express as follow:

$$SC_{env} = \frac{\sum_{i=1}^n (\omega_i S_i)}{n \sum_{i=1}^n \omega_i} \quad (2)$$

Where the symbol SC_{env} denotes the sustainability criteria, S_i is the impact factor based on a ranking 0-10 for the environmental elements of material, ω_i is the weight of every factors of the material stage. The value of the social (SC_{soc}) and economic (SC_{eco}) elements of the materials can be calculate in the similar procedure.

The methods for SDI are development for this study and look at the areas relevant to the designer's work, and the effectiveness of sustainable design to the office furniture OPS through a data analysis within the process of final calculation. The data collection enquiry is aimed at designer whose expertise being in furniture OPS.

4.5 CALCULATING SUSTAINABLE DESIGN INDEX (SDI)

The three criteria of environmental, social and economic has been collected and calculated the example result as show in Table 3. The three criteria were combined in the sustainable design index (SDI). The weights for the three criteria were derived from the pairwise evaluation matrix as assessed by the design team member. It is calculate for each option by multiply each value by the weight, follow by summing the weights score for all criteria using the weight summation method. The best design option has the highest score in the sustainability design index. The higher sustainability index the better the option. Once the criteria are standardised, they can be incorporated into a decision-making model. The sustainable design index (SDI) model can be expressed as follows

$$SDI = \frac{F_{env} \cdot W + F_{soc} \cdot W + F_{eco} \cdot W}{3} \quad (3)$$

Where the symbol SDI denote as Sustainable design index (SDI) and F_{env} is an environmental F_{soc} is social and F_{eco} is an economic each of this factor will multiply by the weight. The total of score form table 3, example show that the option b is the higher score means design option b is the better option toward sustainable design index. Values of the SDI for each option of design vary between 0 (most unsustainable) and 10 (most sustainable) the umbrella of sustainability assessment tools consist of indicators and indices. Indicators must be simple to measures, most often quantitative that represent of environmental, social and economic. That indicators should simplicity, are quantifiable, allow trend to be determined and tool are continuously measured and calculated [31].

Table 2. Components of sustainable criteria.

Life cycle oriented sustainable design				
Sustainability Criteria	Environment	Beginning of life (BOL)	Middle of life (MOL)	End-of life (EOL)
		Renewable resources	Technology	Reuse
		Non-renewable (durable)	Process	Recycle
		Non-renewable (non-durable)	Energy Used	Remanufacturing
				Redesign
	Economy			Disposal
		Raw material cost	Production Cost	Reuse Cost
		Procurement	Energy Cost	Recycle Cost
				Remanufacturing Cost
	Society			
		Detail design	Transportation Cost	Reuse Cost
		Safety	Worker Health	Recycle
		Conceptual design	Safety	Remanufacturing
		Part manufacturing		Redesign
		Replacement		

Sustainable criteria	(Alternative)					
	Option A		Option B		Option C	
	score	Weight	Score	Weight	Score	Weight
Environment	4.95	0.4	7.5	0.5	8	0.2
Economic	6.35	0.4	8	0.4	7.6	0.4
Social	6.75	0.3	5.55	0.1	4.55	0.3
Sustainable design index(SDI)	2.181		2.501		2.00	

Table 3. Calculating the alternative option for (SDI).

5. CONCLUSIONS

This paper presents the output research ongoing to establish useful tools for designer to aid them in the process of sustainable design. The research has developed method and the type of criteria required of a sustainable design tool in order to make it more appropriate and useful to designer. The combination of sustainable design information and sustainable design tools helping to educate designers to ensure the environmental are addressed at the early stage of product development, resulting in more innovative solution. Sustainability design index is observed to help designer to identify and to help company to integrate the sustainability into their purpose and process. In conclusion a new method was driven for an SDI that quantitatively and objectively describes the important for office furniture. The SDI is composed of modularity and reconfigurability, axiomatic design, design structure matrix and sustainable design index. In future work the algorithm of the SDI method will be implement using CAD-based derive from MATLAB interface GUI for the research purpose.

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