

DEVELOPMENT OF A FRAMEWORK FOR
SUSTAINABLE PRODUCT DESIGN

BY

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ABSTRACT

In line with the significant shift of the global manufacturing practice towards a more sustainable direction, a myriad of frameworks and design tools were developed to provide support to the designers during the product design process. The main goals of the frameworks and tools, ideally, are to incorporate beneficial attributes into a product based on the interests of three pillars of sustainability, namely social, economy and environment. Nevertheless, the literatures studied revealed that most of the frameworks and tools do not cover the sustainability dimensions holistically and simultaneously as an integral part of the design strategy. Besides that, it was found that the product design practices in manufacturing barely integrate the principles and values of Islam commercially, despite Islam being a holistic religion and is applicable in any area of life.

The primary goal of this study is to develop a design tool that could work effectively in the design process to consider a more holistic horizon of sustainability based on an Islamic perspective. As a foundation, a framework of Sustainable Product Design was developed by integrating the elementary elements derived from *Maqasid Shari'ah* and Islamic values pertaining to the sustainability concept and product design into the conventional framework. Subsequently, based on the integrated framework, the ideal product attributes were derived which represent the product's quality dimensions from Islamic perspective. Finally, a new design tool named the ENRICH Tool was successfully developed, comprising six processes, namely Eliminate, Nourish, Readapt, Infuse, Create and Harmonise. The tool works as a cyclical process and can be easily integrated into the typical design process. The design tool was applied in three case studies of design projects, involving different products namely a domestic food waste recycler, a walking aid (simulation approach) and a chapter in a Physics textbook (non-technical product). Based on the Quality Index (QI) comparisons, the results for Case Studies One and Two showed an improvement in designs, respectively, by around 35% (compared to the concept design) and 11% (compared to the final design of DFSS). In Case Study Three, 80% of the 24 questionnaires on the perceptions of the end users on the developed integrated Physics chapter recorded high mean scores of 4.0 and above. The results, therefore, reflect the viability of the ENRICH Tool in the case studies and prove its effectiveness in improving the quality, values and sustainability attributes of the products.

The integrated Sustainable Product Design framework and the ENRICH Tool, which were developed based on the Islamic perspective, could offer alternatives in the design strategy for sustainable product development. The ENRICH Tool could support the industrial product designers effectively in developing a more sustainable product. As a result, it would benefit stakeholders which include the consumers, manufacturing players, government agencies, tax payers as well as the environment, either directly or indirectly. In addition, this attempt could inspire academics and researchers to expand the study on the incorporation of Islamic approach in manufacturing practices particularly in industrial product design. Nevertheless, this endeavour is still at the infancy stage, therefore, further works need to be carried out to improve the developed integrated framework and design tool.

خلاصة البحث

مواكبة التحولات الكبيرة العالمية التي تحدث في مجال التصنيع، والتي تنتج أنماط وأساليب أكثر شمولية واستدامة، طُوِّرَ عددٌ غير قليل من أدوات التصميم لدعم المصممين في عملية تصميم المنتج وفق معايير الجودة. تتمثل الأهداف الرئيسية للأدوات على نحوٍ مثاليٍّ في دمج الركائز الثلاثة للاستدامة، أي الاجتماعية، الاقتصادية والبيئية في منتجٍ طوال دورة حياته بالكامل عن طريق التصميم. مع ذلك، أظهرت المنشورات الأدبية التي تمّ دراستها أن معظم الأدوات لا تغطّي جميع أبعاد الاستدامة بشكلٍ شاملٍ ومتزامنٍ كجزء متكاملٍ من استراتيجية التصميم. إلى جانب ذلك، تبين أن ممارسة تصميم المنتج في التصنيع تكاد أن تدمج مبادئ وقيم الإسلام تجارياً على الرغم من حقيقة أن الإسلام معروفٌ أنه دينٌ شاملٌ وقابلٌ للتطبيق في أيِّ مجالٍ من مجالات الحياة.

الهدف الأساسي من هذه الدراسة هو تطوير أداة تصميم يمكن أن تعمل بفعالية في عملية التصميم مع اعتبار النظر في أفق أكثر شمولية للاستدامة من المنظور الإسلامي. تم تطوير إطار للتصميم المستدام للمنتجات أساساً من خلال ربط التكامل بين العناصر الأولية المستمدة من مقاصد الشريعة والقيم الإسلامية المتعلقة بمفهوم الاستدامة وأتموج تصميم المنتج في الإطار التقليدي المعروف. ومن خلال ذلك، وبناءً على الإطار المتكامل، تم اشتقاق خصوصيات المنتج المثالي الذي يمثل أبعاد جودة المنتج من المنظور الإسلامي. إثر هذا العمل تمكن الباحث من تطوير أداة تصميم جديدة تسمى اختصاراً باللغة الإنجليزية ENRICH، وهي أداة تقوم على ست وظائف وهي: الحذف أو التخلص، وتنمية، وإعادة التكيف، والإدراج والإحداث والتنسيق. تعمل الأداة كإجراء دوري يمكن إدراجه بسهولة في عملية التصميم النموذجية.

تم تطبيق هذه أداة في ثلاث مشاريع التصميم تشمل منتجات مختلفة وهي إعادة استخدام نفايات الغذائية المنزلية، والمشاية أو الآلة المساعدة على الحركة (طريقة المحاكاة) وفصل في كتاب الفيزياء (المنتج غير الفني). بناءً على مقارنات مؤشر الجودة (QI)، أظهرت نتائج دراسة الحالة الأولى والثانية تحسناً في التصميمات، على التوالي، بحوالي 35٪ (مقارنة بتصميم المفهومي) و 11٪ (مقارنة بالتصميم النهائي DFSS). في دراسة الحالة الثالثة، سجل 80٪ من الاستبيانات الـ 24 حول تصورات المستخدمين النهائيين في الفصل الفيزيائي المتكامل المتطور درجات المتوسط الحسابي بلغت 4.0 وأكثر. وبالتالي، فإن النتائج تعكس مدى صلاحية أداة ENRICH في دراسات الحالة وإثبات فعاليتها في تحسين جودة المنتجات وقيمتها واستدامتها.

يمكن لأداة ENRICH التي طُوِّرت على أساس المنظور الإسلامي أن تقدّم بديلاً في استراتيجية التصميم الخاصة بتطوير المنتج المستدام. كما بُرهن في الدراسة أنّ الأداة تعمل بفاعلية في دمج مصالح الاستدامة بشكلٍ كليٍّ خلال دورة حياة المنتج وبالتالي ضمان منافسةٍ جيّدةٍ مع أدوات التصميم الأخرى الراسخة. يمكن أن تدعم أداة ENRICH مصممي المنتجات الصناعية بفعالية في تطوير منتجٍ أكثر استدامة. وبحكم هذه الخاصية تكون هذه الأداة وسيلة ستفيد العديد من الأطراف بداية من أصحاب المصلحة المعيّنين بشكلٍ مباشرٍ أو غير مباشرٍ وعموم المستهلكين، والجهات الفاعلة في التصنيع، والوكالات الحكومية، ودفعي الضرائب إضافةً إلى تقليل من عوامل تلوث البيئة. كما يمكن لهذه المحاولة أن تلهم الأكاديميين والباحثين لتوسيع مجال الدراسة حول تبني المنهج الإسلامي ومعاييرهِ في ممارسات التصنيع وتحديدًا في تصميم المنتجات الصناعية. لكن مع ذلك، يجب أن نقر أن هذا المشروع لا يزال في مراحله الأولى يحتاج إلى المزيد من العمل لتحسين وتطوير هذه الأداة وتطبيقها.

APPROVAL PAGE

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Saidi bin Zain

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Date : 9th March 2020

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LIST OF ABBREVIATIONS

DFA	Design for Assembly
DFE	Design for Environment
DFM	Design for Manufacturing
DFSS	Design for Six Sigma
DFX	Design for X
DfRem	Design for Remanufacture
D4S	Design for Sustainability
ELV	End of Life of Vehicles
EMS	Environmental Management System
FMEA	Failure Mode and Element Analysis
KE	Kansei Engineering
KPI	Key Performance Indicators
LCA	Life Cycle Assessment
PSQF	Product System Quality Function
QFD	Quality Function Deployment
QD	Quality Diagraph
QI	Quality Index
RDM	Robust Design Methodology
RE	Reverse Engineering
RoHS	Restriction of Hazardous Substances directive
TRIZ	Tool for Inventive Product Solution
VE	Value Engineering
WEEE	Waste Electric and Electronic Equipment

LIST OF SYMBOLS

kg	kilogram
kWH/day	kilowatt hours per day
V	Voltan
°C	degree Celsius
rpm	rotation per minutes

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

In manufacturing, the product design stage is where most aspects, criteria, parameters and constraints are taken into account. The aim is to produce the best design specification out of available resources, financial budget and time constraint in the company as well as external requirements such as government policies and regulations. In other words, most of critical decisions about a product are made in the design stage. By executing the right strategy and effective methods, successful new or improved products could be produced. These can eventually be translated into increase in customers, sales, profits and market share. On the contrary, mistakes and weaknesses in the design stage may produce more product defects in the production stage and result in poor quality products in the market that can lead to a decrease in customer satisfaction and loyalty. This, as a result, will contribute to a significant increase in wastes and financial losses that eventually reduces the competitive edge of the company. Moreover, other consequences such as adverse social and environmental impacts may also be generated.

In order to support manufacturers especially the design teams to execute an effective strategy and make the right decisions in product development, a number of design tools are normally employed. The function of a design tool, basically, is to ease in the efforts of enhancing the quality attributes of a product, for instance, its performance, reliability and safety as well as to save associated costs by reducing overdesign, lead time, materials and wastes. Incidentally, most of the design tools are

developed based on certain interpretations of quality and specific design goals aimed to incorporate the quality characteristics into a product by means of design.

1.1.1 The Impact of Manufacturing Activities Globally

Globally, the manufacturing sector continues to massively grow and contribute to the social well-being and economic expansion of many countries. Just about every day, a variety of new products from various sectors such as automotive, electrical and electronics, home appliances, telecommunication, textile, food, education and so on are introduced into the market. The products have immensely benefited people in their daily lives by improving the way they move, communicate, learn, work and do business. The never-ending demands and expectations of people due to continuous increase in population and technology advancement, therefore, generate evergreen product-oriented business, locally and internationally.

Nevertheless, due to people's ignorance, uncontrolled and ineffective manufacturing activities have contributed many adverse impacts unto society and the economy, and particularly to the environment. For instance, unreliable products may have failed, causing accidents, injuries or death, while the high volume of waste which were generated during production now requires millions of dollars for safe disposal. The adverse impact of manufacturing on the environment, meanwhile, has been noticeably neglected for decades. The massive depletion of natural resources, increase in global warming, climatic changes and pollutions are great examples on how inefficient manufacturing activities may threaten our lives and the balance of the ecosystem. The growing global problems reflect the weaknesses of the frameworks and strategies designed by stakeholders and players in the implementation of Sustainable Manufacturing in terms of their comprehensiveness and effectiveness.

1.1.2 The Trend of Product Design and Design Tool

Product design involves either development of an entirely new product or improvement of an existing product that offers new or additional benefits to the customers. Effective product design strategy is essential for manufacturers in striving to keep up with the changes and trends in the marketplace to ensure their future successes. In this regard, enhancement in quality is an inevitable objective in product design. In other words, product design and quality are interrelated and inseparable. In fact, product design and design tools have been evolving along with the change in how quality was defined and interpreted in manufacturing.

In the 1990s, Sustainable Manufacturing has been introduced in order to cope with the environmental impacts due to excessive manufacturing activities (Ocampo & Ocampo, 2015). In this regard, another requirement related to the environment has been put into enormous attention in product design. As a result, various design tools such as Ecodesign and Design for Environment (DfE) have been established and introduced into the industry. However, from the sustainability and holistic perspective, most design tools do not integrate sustainability benefits comprehensively and optimally into a product throughout its entire lifecycle. This deficiency in the design process, as a result, contributes significantly to the adverse impact of manufacturing on the social, economic and environmental levels.

1.1.3 The Need to Infuse Islamic Perspective in Manufacturing Practice and Product Design

Islam is a comprehensive, universal, flexible and ever relevant religion. Even though Islam was introduced through Prophet Muhammad S.A.W. more than 1400 years ago, the principles, guidance and values of Islam continue to be adapted in various sectors