



**UNIVERSITI PUTRA MALAYSIA**

***DEVELOPMENT OF INFINITE QUALITATIVE MODEL FRAMEWORK  
FOR CONSUMER PRODUCT AESTHETIC DESIGN***

**MOHD QADAFIE BIN IBRAHIM**

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**DEVELOPMENT OF INFINITE QUALITATIVE MODEL FRAMEWORK  
FOR CONSUMER PRODUCT AESTHETIC DESIGN**

By

**MOHD QADAFIE BIN IBRAHIM**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

**November 2021**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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**November 2021**

**Chairman : Associate Professor Fairuz Izzuddin bin Romli, PhD**  
**Faculty : Engineering**

Most engineering design processes today are more focused on functional aspects of product design and do not take aesthetic elements into account. Therefore, they are often difficult to use, unattractive, and/or do not solve the intended problems. As for the designers, they are not well-equipped to properly include aesthetic considerations during their design process, even though the advantages are widely acknowledged. This study proposes an Infinite Qualitative Method (IQM) that effectively combines together theories from multiple disciplines such as social sciences, mechanical engineering design, industrial design and marketing management. The need for the new design framework is more pronounced for small manufacturing companies due to limited resources and also a lack of design skills among their small workforces. In fact, this research study is motivated by discussions and suggestions by the owners of two small companies producing consumer products within the local manufacturing industry in Malaysia.

The IQM framework consists of two main components: product design and product development. The product design process includes an exploratory phase comprised of three stages: vision, ideation, and 3D conceptual. As for aesthetics, it is fully embedded within these stages by using established aesthetic design tools. Conversely, for the product development process, it explains the progress from multiple disciplines that have been adapted to ensure an efficient development process for the product. Ultimately, both of these components are interlinked with each other at a point in the framework where the product design component provides a theoretical design foundation for various stages of progress before engineering, manufacturing, and marketing teams take in-charge. The validation of the IQM design framework is achieved through triangulation analysis of results from a conducted survey, controlled experiment, and full-scale case study. IQM design framework adapts the best combination of design tools and methods with a novel approach that can potentially lead to a much better-quality product design. The study's significant finding is that this design method will provide a simple, easy, yet

comprehensive way for design engineers to create well-designed products. IQM addresses the lack of proper aesthetic considerations in current product design methods.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PEMBANGUNAN RANGKA KERJA MODEL KUALITATIF INFINITI  
UNTUK REKA BENTUK ESTATIKA PRODUK PENGGUNA**

Oleh

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Kebanyakan rekabentuk produk kejuruteraan sekarang lebih memfokuskan kepada fungsi justeru mengabaikan elemen estatika. Natijahnya, banyak produk di pasaran yang sukar digunakan, tidak menarik dan juga tidak menyelesaikan masalah sebagaimana diinginkan. Situasi ini memerlukan satu rangka-kerja rekabentuk baru yang dapat membantu pereka-bentuk dan jurutera mengimbangi ciri-ciri fungsi dan estetika sesuatu produk, yang juga menggabungkan multi-disiplin seperti sosial sains, rekabentuk kejuruteraan mekanikal, rekabentuk industri serta pengurusan pemasaran. Perlu ditekankan, rangka-kerja ini ditujukan kepada syarikat pembuatan kecil yang selalunya mempunyai sumber yang terhad dengan tenaga kerja yang sedikit serta kurang kemahiran. Ingin ditegaskan, kajian ini adalah hasil sumbang-saran dan cadangan dua pemilik syarikat kecil yang mengeluarkan produk untuk konsumer dalam sektor pembuatan di Malaysia.

Rangka-kerja baru ini, Infinitive Qualitative Method (IQM) terbahagi kepada dua; rekabentuk produk dan pembangunan produk. Bagi rekabentuk produk, kitarannya mengandungi tiga fasa; visi, ideasi dan konseptual 3D. Bagi elemen estatik, ianya disebatikan ke dalam semua fasa ini melalui penggunaan kaedah dan alatan khusus estetika yang terbukti efektif. Manakala pembangunan produk memperincikan perkembangan pelbagai disiplin bagi memastikan proses yang efisien. Natijahnya, kedua komponen berkait pada satu titik di mana rekabentuk produk menjadi rujukan asas kepada pasukan pemasaran dan pasukan pembangunan kejuruteraan. Validasi rangka-kerja IQM mengguna-pakai analisis 'triangulasi' secara tinjauan, eksperimen terkawal dan kajian kes penuh. Rangka-kerja kemudiannya dimuktamadkan berdasarkan dapatan dan input prosedur validasi ini. Keseluruhannya, kajian ini menyerlah potensi penggunaan dan manfaat rangka-kerja IQM yang baru ini. Ianya menekankan supaya pertimbangan lebih diberikan kepada nilai estetika berbanding kaedah rekabentuk sedia-ada. Juga, penggunaan kaedah IQM sangat mudah tetapi menyeluruh dalam membantu jurutera rekabentuk membangunkan produk yang sempurna. Hasil menggunakan

rangka-kerja IQM terbukti lebih baik berbanding pendekatan konvensional yang diamalkan sekarang.



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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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## Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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## LIST OF ABBREVIATIONS

2D	Two Dimensions
3D	Three Dimensions
BAH	Booz, Allen and Hamilton
CAD	Computer-Aided-Design
CAE	Computer-Aided Engineering
ID	Industrial Design
IDE	Industrial Design Engineering
IQM	Infinite Qualitative Method
KE	Kansei Engineering
ME	Mechanical Engineering
NPD	New Product Development
PC	Personality Characteristics
PDD	Product Design and Development
PDE	Product Design Engineering
QF	Qualities of Form
R&D	Research and Development
SD	Semantic Differential
SVP	Social Values and Positions
UI	Usability and Interaction
UPM	Universiti Putra Malaysia
VR	Virtual Reality

## CHAPTER 1

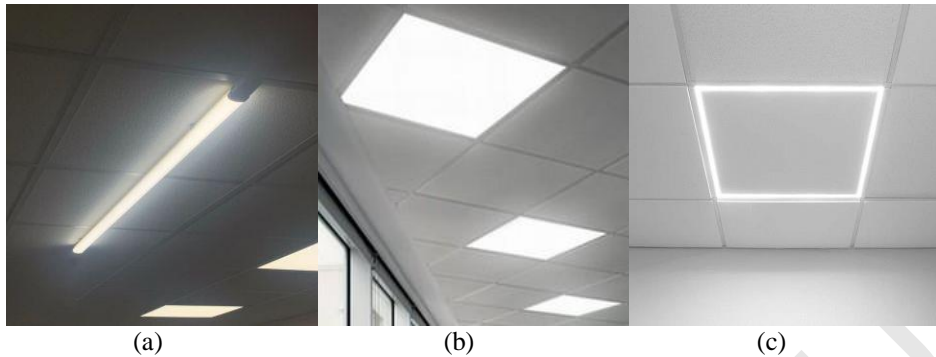
### INTRODUCTION

*All men are designers. All that we do, almost all the time, is design, for design is basic to all human activities. The planning and the patterning of any act toward a desired, foreseeable end constitute the design process. Any attempt to separate design, to make it a thing-by-itself, works counter to the fact, design is the primary underlying matrix of life.*

(Papanek, 1984)

#### 1.1 Overview

Product design is a combination of attributes of the artefact, comprising of the distinct properties of form (i.e., aesthetics) and functions (i.e. capabilities) of the tangible goods (Luchs & Swan, 2011). As indicated by Veryzer (1995), in order to ensure a product's market success, conceptualization of design that acknowledges both its aesthetics and functional components need to be adopted. In short, the aesthetics elements of products are prominently determined by their design characteristics including colour and shape, which can affect the aesthetic assessment of various cognitive and affective processes. Monö (1997) has described aesthetics as a study that investigates the influence of the physical 'produkt gestalt' or configuration on the human sensation, covering all fields of design including architecture, product design, visual communication design, interface design and animation. In a more commercial context, product appearance is recognised as a crucial factor in the success of a product (Bloch, 1995; Hertenstein et al., 2010). Meanwhile, product functionality corresponds to the design capabilities to perform what it has been intended for. The purchase of products by consumers is often made based on their expectation of the product's performance in meeting their goals (Chitturi et al., 2008), thus a resultant negative post-consumption emotion may occur when there are any perceived discrepancies between expected and actual performance of the products (Chaudhuri, 2006). Overall, it can be taken that product designs with great quality will meet the needs and expectations of the consumers, as well as other quality dimensions including performance and aesthetics (Ambarwati, 2020). As observed in Figure 1.1, all of the ceiling light designs shown are able to function as they are intended but the level of their appeals are obviously different depending on their level of incorporated aesthetics design elements.



**Figure 1.1 : Different light designs with similar functionality**

Generally, any new products that are introduced into the market have evolved through the sequence of typical development stages: beginning with the initial product concept or idea that is then refined, evaluated, developed, tested and eventually launched into the market (Booz et al., 1982). These activities are often comprised under the so-called New Product Development (NPD) process at the product company, which might differ between industries and companies as it is adopted to their specific resources and needs. NPD essentially covers the entire product development lifecycle, starting from market analysis up until the final product launch. One of the main stages of NPD is the Product Design and Development (PDD) process that consists of all designing activities, which takes place with the establishment of the product design team. This is the stage where the look and feel of the product are practically created to suit with established customer needs. Some of the common phases of PDD process include ideation, feasibility study, preliminary design, testing and product launch.

Recently, along with the advancement in the design software and hardware as well as design techniques, development of the integrated design process known as Industrial Design Engineering (IDE) has gained growing interest. In general, IDE can be seen as a multidisciplinary field of practice addressing the entire industrial innovation process that covers all activities leading to the adoption of a new product in the market (Diehl & Christiaans, 2003). It primarily integrates the disciplines of mechanical engineering design (ME) and industrial design (ID), which drives the product designing process to be accomplished on the basis of integrated interests of the users, industry, society and the environment. The inclusion of industrial design elements offers crucial visual and tactile features that can have a positive aggregate impact on both sales as well as total consumer experience over the product's lifespan (Abdullah, 2015). Additionally, the industrial design elements can be appropriately implemented to many other industries (Ulrich & Eppinger, 2016). The integration of industrial design elements into product development process has already become indispensable in recent times and it has been acknowledged as one of the important strategic tools for product development at the moment. Furthermore, the availability of several latest technologies has also helped to attract substantial attention to IDE, which include cloud computing, pen stylus-based workstation and also productivity devices like Microsoft Surface, iPad Pro, Oculus and Vive VR goggles that effectively assist real-time design and virtual prototyping. Many

techniques and approaches are currently being developed and improved with the use of these technologies to increase productivity and efficiency in the design process.

## 1.2 Problem Statement

It can be observed that the current market environment is becoming more competitive as many variations of similar products are made available to the customers. With such high competition, many new products have failed to find their market success. In fact, it has been stated that for every seven new product ideas, about four of them will enter development, one and a half will be launched, and only one will succeed in the market (Bhuiyan, 2011). Moreover, it has also been implied that most new developed products do not even make it to the market and those that make it are still facing a high failure rate of between 25 to 45 percent (R. Cooper, 2011). Many of these product failures can be related to their improper design. One of the determinant factors for product's market success is customer acceptance, and a main factor of the failure is the disability of the product design to induce good impression to potential customers. This situation is highly believed to be caused by the lack of consideration for aesthetics during the product design and development process since it is hardly taken as a major contributor to the sales proposition (Marina; Candi & Gemser, 2010).

As previously indicated, a high-quality product carries both aesthetic and functional properties that satisfy the customer needs (Salem et al., 2020). Nevertheless, making a balanced design decision for these two aspects during the product development is not exactly an easy task for designers or engineers. Currently, the focus of typical product development process involving innovation management is inclined towards functional values that concern more on the practical benefits that the product's performance can offer to customers (Goto et al., 2019). This is supported by M. Candi & Saemundsson (2011), who stated that the design of engineering products has been more concerned with the objective functional characteristics and the utility of the offerings instead of subjective characteristics such as ergonomics, look and feel that are more prominently considered in industrial design. With greater emphasis on functional properties during development process of many engineering products, this can potentially lead to market failure if their aesthetic properties are not appropriately considered. Aesthetic design is viewed as one of the key factors in marketing of a product since it highly influences customers' purchase intention (Afzali & Ahmed, 2016). However, according to Blijlevens et al. (2017), most products in the markets are often difficult to use, unattractive and/or do not exactly solve the intended problems.

While a good engineering product design should be balanced in terms of its form and function, this is difficult to be achieved especially in small manufacturing companies because of their limited resources and also lack of design skills (Berends et al., 2011). In addition, it is also observed that small manufacturers mostly conduct their product development process in ad hoc, unplanned and unstructured manner, and rarely adopt systematic design procedures (Scozzi et al., 2005). Unlike big product manufacturing firms that have the capability to outsource their product development tasks to external designers, it is vital for small product manufacturers to optimize the use of their limited

resources to produce good quality product designs for their market competitiveness. It is apparent that such situation urgently calls for systematic and structured approaches to their design process. In view of this, there have been numerous studies that propose design framework to facilitate product designers and engineers in small manufacturing companies including (Cederfeldt & Elgh, 2005; Gherardini et al., 2017; Lovett et al., 2000). Nonetheless, while these design frameworks mostly capture the essences of systematic engineering product design and development process, they are still lacking in guiding the focus on balancing the functional and aesthetic properties of the new product. This is identified as an ongoing research gap that needs to be addressed, which acts as the main driving motivation for this thesis research study.

It should be noted that this thesis work is also heavily revolved around actual real-life scenarios that are faced by two identified small companies within local manufacturing industry in Malaysia. The provided cooperation from these two companies has allowed the development of proposed new design framework in this study to be better aligned and relevant to actual situation in the industry. In fact, the issues or problems presented by the two companies are the actual triggers for this research work. The first company, which is a small carpentry and furniture company, has proper manufacturing capability but with very limited design workforce capacity of only one senior draftsman. Based on their shared views, their business acumen in the market is heavily impacted by this limitation. Without any available funding to increase the number of designers, they are looking for means of empowering their current draftsman in new product development. The issue is not so much on the functionalities of their furniture products but more on the incorporation of good design aesthetics to make their products more appealing and competitive in the market. Meanwhile, the second company that has collaborated in this research study is a micro-enterprise that produces laundry detergents. Since the scale of their operation is relatively small, they are unable to externally outsource the design works for their detergent bottles.



**Figure 1.2 : Research collaboration visits at the companies**

Subsequently, the owner takes upon himself to undergo few graphic design courses to design their own bottles. It is known that the detergent bottle design can have a great influence in providing good impressions and attracting market interests from the customers, thus the company is in need of a simple method or framework that can guide them in producing bottle designs that are balanced in terms of functionality and aesthetics. Figure 1.2 shows the pictures taken during the visits made to the companies. All in all, for both cases, it seems that a structured design module with a low learning curve will be greatly beneficial for these two companies.

With the overall realization on the ongoing issues with current design frameworks and also the needs of small companies in improving their product design and development process, the primary aim of this thesis work is to explore the possibility of improving the product aesthetic elements by integrating them during the conceptual design phase. Conceptual design stage is the most suitable time to incorporate the aesthetic elements into the product since this is when an intensive reflection of its essential characteristics is done. It is evident that the functional factor alone cannot provide a complete product resolution. However, product aesthetics is multi-dimensional and in order to properly consider it in the design process, an apt comprehension of art and psychology is also needed. Therefore, the new proposed design framework in this thesis work should also include these components in addition to the typical science and engineering methods.

### **1.3 Research Objectives**

As discussed in the previous sections, there are some identified deficiencies in most of available new product design and development frameworks, particularly in regard to the integration of aesthetic elements. The progressive hype of “Industry 4.0” is seen to initiate some new and radical product design approaches among industry players. On the practitioners’ side, there are demands for the product designs to be more appealing to the customers. Consequently, the incorporation of ID has become rather a must from the start of the product design process, which can present a problem for manufacturing companies with small or limited design team members, particularly those without ID professional. To aptly address this challenge, a new design framework that empowers product engineers to fully integrate and optimize the ID elements when designing new products without relying on ID specialists is required. In other words, with the focus on small product companies and manufacturers, there is a need for new product design framework that can effectively aid designers or engineers in properly balancing both functional and aesthetic elements for the product design. This new design framework can be derived through curation, implementation and improvement of available design tools and techniques.

Taking everything into account, this research work is primarily focused on developing a new improved product design framework that is effectively tailored for application by small scale product companies. In corroboration with this work intent, the following research objectives that are essential to support its achievement have been set up:

- 1) To establish the lack of aesthetic elements awareness and implementation in NPD process.
- 2) To develop an improved product design framework through integration of IDE for product design and development process.
- 3) To validate and demonstrate the application of the proposed design framework in actual product design case study.

It should be noted that the new proposed product design framework from this study is named as Infinitive Qualitative Method (IQM).

#### **1.4 Research Questions**

In line with the established research objectives, several research questions are derived to facilitate and guide the gathering of necessary data, especially while developing the suitable methodology for this study. The formulated research questions are listed as follows:

- a) What are essential elements or steps in product design and development process?
- b) What are the available methodologies, tools and technologies that can be applied to ease the product design and development process?
- c) What are the essential characteristics or measurements to simplify the design and development process for non-complicated products in small scale companies?
- d) How can the creative product design process be structured in such a way that a non-creative person can consistently meet the desired expectations?
- e) How to appropriately construct and develop a new product design and development framework?
- f) What are the essential qualitative or quantitative measurements that can be used to evaluate the effectiveness of the proposed framework?
- g) How to properly demonstrate the effectiveness of the new proposed design framework?

#### **1.5 Research Scope and Limitations**

The main basis of this research is the realization that balanced functional and aesthetic design elements are highly influential to the market success of the product. The work done is aimed to develop a new proposed design framework that can facilitate product designers and engineers to produce good quality product designs. For this development of the new design framework, the research work is tailored to the following scope that also corresponds to the limitations of this study:



- a) The new design framework to be developed in this study primarily focuses on the major steps involved during the product designing phase. With regards to the initial development of the product architecture, only a limited part of the subject is covered and examined in this research. The emphasis is placed on the sequences of ideation, built-up characteristics and the inspiration for new interpretations (micro level). Although the design framework essentially encompasses the whole NPD ecosystem, the work done is emphasized more on having a structured method to aid the product designers and engineers in producing good quality designs of their products. No consideration is paid to other subjects of concern in typical framework development studies such as sustainability and optimisation, product creation and engineering, as well as the structure of the design team and human culture (meso level).
- b) The proposed IQM design framework is principally tailored to the design and development of consumer products, which design features and aesthetics play an important role as the selling factor. Additionally, within this category of products, the developed framework is also highly focused on non-complicated products with total number of components between two to 20, which narrows down its direct applications. Nevertheless, the proposed design framework can still possibly be applied for other types of products with some adjustments, if necessary, particularly in terms of the design methods and tools used in its steps.
- c) The suggested application of tools, methods and technology within the steps of the proposed design framework in this research work are highly dictated by the tailoring to the focused product design cases at hand. It is emphasized mainly on the design work at the level of the specific design projects and only slightly touches on the possible wider use of this approach, especially in other settings and cultural diversity. However, the suggested tools, methods and technology used in this study can be alternatively replaced with other suitable ones depending on the preferences and applications, as long as they are in line with the appropriate intents of each corresponding step of the design framework where they are applied. Such exploration of tools, methods and technology is practically beyond the bounds of this study due to the emphasis only on the selected design cases at hand.
- d) The demonstration on the effectiveness of the proposed design framework is based on the identified actual design cases and primarily focused on improved quality of the output product designs. Although there are other expected benefits from the use of the proposed design framework, they are not the main highlights in this research work. This essentially means that the evaluation of other potential effects from the use of the proposed design framework apart from the resultant quality of the product designs is not covered in this study.

## **1.6 Significance of the Study**

In general, this study is an example of applied, inter-disciplinary research that employs qualitative and quantitative data collection and analysis. The major contribution is the development, specification and evaluation of a new framework comprising of process flow, tools, models, measures and a design method. It is grounded on a generic product

design framework, established tools and extends to the utilisation of latest technology in computer-aided-design (CAD) and virtual reality (VR) technology. The validation of the proposed design framework, which is called the Infinite Qualitative Method (IQM), is conducted using the triangulation method for verification of its relevancy and efficiency.

At the core, this contribution stems from revisiting the “form and function” as a basic philosophy of designing products. By adapting well-established methods and tools into the proposed design framework, it can help empower product engineers to explore new design solutions while still remain within their professional experiences. Through this way, the product is developed based on existing design theories with the integration of new paradigm in a novel way. Ultimately, a structured and effective process (including models, measures and methods) for the identification and selection of design options is developed and assessed. This is critical both in reality and theory as it ensures that the time and energy likely to be needed to carry out such an analysis are not inefficient.

On the whole, the expected contributions from this study are summarized as follow:

- a) The proposed IQM design framework is developed to be seamlessly simple to integrate into the current NPD framework. Furthermore, it is an easy-to-use method since it uses already well-established tools and techniques within its steps while its highly structured and familiar tools approach will guide users easily at any level of design stage and take into account any consideration that need to be addressed.
- b) The application of IQM can facilitate small design teams to develop high quality product designs with character and personality, particularly through the incorporation of aesthetic elements that are normally ignored by product engineers.
- c) In addition, the proposed IQM framework can also be used by managers and marketers as a method for consumer study and reference point between teams. For example, the IQM may be used to compare the preferences of certain features, measure the effect of the different shortcomings and also to classify the budget and length of the project.

This research study is primarily undertaken with engineering design students in a team of two to five members and working on a less complex and simple product design. It is anticipated that such knowledge and experience are extended as they become design engineers upon their graduation, which is the current common career progression. This working structure is ideally suited for products with similar production method and defined features such as soft drink bottles, bathroom fittings including water faucets and sinks, and also other small consumer products. In addition, another target group for the proposed IQM are the amateur designers and hobbyists, where this design framework is expected to help them to clearly understand their design problems and offer structured solutions in order to create their own products. Last but not least, the resultant simple design process also benefits the companies and accountants to track the progress and budget of the project.

## 1.7 Thesis Organization

Overall structure for this thesis documentation can be briefly described as follows. The first chapter is primarily meant to build the case for the relevancy of this research study by explaining the driving motivation. Once this is established, the research objectives and the research questions to support their achievement are formulated. The research questions act as the guide for literature review process and the findings are reported in following Chapter 2. Using the knowledge obtained from the literatures, the research methodology for this study are planned and presented in Chapter 3. In the meantime, Chapter 4 is dedicated to present construction details of the new proposed IQM product design framework and findings from its validation and demonstration process. Finally, this thesis concludes with Chapter 5 that discusses the conclusion of the results and findings from this research study, which contains the assessment on the achievement of the research objectives and suggested future work.

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